

The Development of Cerebral Oxygenation in Premature Infants

by

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Dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor of Philosophy in
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ABSTRACT

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Abstract

In this dissertation, 24 premature infants were enrolled who were born less than 32 weeks gestational age over a 1 year time period from October 2010 to 2011. The goals were to longitudinally measure cerebral oxygen saturation, evaluate how environmental variables controlled by nursing- positioning and noise- affect cerebral oxygen saturations, and examine the relationship between cerebral oxygen saturation and two currently measured vital signs.

Using general linear mixed models, the developmental trajectory of cerebral oxygen saturation values in premature infants began in the high 70s during the first 2 days of life and then significantly decreased into the mid-60s over several weeks during hospitalization in a neonatal intensive care unit (NICU). The trajectory of cerebral oxygen saturation during the first week of life in those infants who developed an IVH did not significantly differ from those infants without IVH. At this time, use of cerebral oxygen saturation to identify those infants at risk for IVH during the first week of life cannot be supported, but cerebral oxygen saturation monitoring could potentially monitor the severity of the impact of IVH later during hospitalization as those infants with an IVH had significantly lower cerebral oxygen saturation values after the third week of life. In this case, cerebral oxygen saturation might help to understand the long-term degree of neurological damage.

Heart rate and peripheral oxygenation were chosen as the two physiologic variables to compare to cerebral oxygen saturation. Average cerebral oxygen saturation was lower with higher heart rate and higher with higher peripheral oxygenation. Peripheral oxygenation that is already routinely measured in premature infants appears

to not provide an accurate measure of the changes in cerebral oxygen saturation as cerebral oxygen saturation was shown to be a better measure of oxygen in the brain. Cerebral oxygen saturation monitoring is highly suggested for those infants who are at risk for neurological damage such as infants with hypoxic-ischemic encephalopathy or seizures since peripheral oxygenation does not appear to be an appropriate proxy for cerebral oxygenation.

Finally, sound and positioning were chosen to represent two frequently encountered components of the neonatal intensive care environment that might influence infant cerebral oxygen saturation. A peak in sound from the ambient sound level was only 5 decibels and found to not significantly affect cerebral oxygen saturation values. A neutral position considered the gold standard— supine, head midline—was compared to five other positions widely used by NICU nurses. However, results showed positions with a turned head did not significantly change cerebral oxygen saturation from the neutral position. Yet, differences in cerebral oxygen saturation were found between two lateral positions (left lateral, 0° head elevation and right lateral, head elevated 15°) with an elevated head measuring lower cerebral oxygen saturation levels.

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1. Introduction

Every year approximately 500,000 infants are born prematurely in the United States (Hamilton, Martin, & Ventura, 2009) with health care costs exceeding \$500 million (Chan et al., 2001). Advances in technology have increased premature infants' chances of survival and subsequent discharge from the hospital to home. However, many infants go home with neurological deficits related to prematurity that may be preventable (Donohue & Graham, 2007; Maitre et al., 2009). As compared to their full-term counterparts, premature infants are at increased risk for neurological complications due to the immaturity of their nervous system (Bracewell & Marlow, 2002; Fawke, 2007; Hack et al., 2005; Saigal & Doyle, 2008).

In addition, premature infants are exposed to external stimuli in the neonatal intensive care unit (NICU) such as loud noises and frequent tactile stimulation that would not normally occur in the quiet, liquid intrauterine environment. Exposure to these stimuli also affects neurological development and as a consequence, neurological complications such as motor impairments, learning disabilities, and neurosensory damage can occur (Anderson & Doyle, 2008; Bracewell & Marlow, 2002; Donohue & Graham, 2007). Prevention of complications and altered neurological development could promote neurodevelopment comparable to the full-term infant.

To detect and prevent neurological complications, physiologic changes in the premature infants' nervous system in relation to the intensive care environment must be identified. However, monitoring the nervous system of premature infants for these physiologic changes is not standard of care. The nervous system of premature infants is only monitored when suspected damage such as seizure activity has occurred.

Cerebral oxygen saturation is a potential biomarker of the premature infant's developing nervous system; it can be monitored using cerebral oximetry. Cerebral oximetry measures cerebral oxygen saturation as the oxygen content within the specific area of the monitored brain, the quantity of which is based on the amount of blood delivered to the brain. Cerebral blood flow, controlled by the autonomic nervous system, increases as a premature infant develops (Inder & Volpe, 2004), but how cerebral oxygen saturation values change over time is unknown. Cerebral oximetry would provide a noninvasive, continuous method to monitor nervous system development. Thus, it is preferred over invasive methods that continuously measure cerebral blood flow. Longitudinal measurements of cerebral oxygen saturation in premature infants are needed to provide the basis for preventing neurological complications as the infants mature in the neonatal intensive care unit (NICU).

Circulation influences cerebral oxygen saturation by controlling blood flow. Impaired circulation commonly occurs in premature infants. Common vital signs, heart rate and peripheral oxygenation, may indicate cerebral blood flow and the brain's receipt of oxygen-rich blood (Seidel, Ball, Dains, & Benedict, 2003a, 2003b). However, the degree to which these vital signs are associated with cerebral oxygen saturation is unknown. For example, crying can reduce oxygenation of the blood (Hansen & Okken, 1979; Martin, Okken, & Rubin, 1979) by disrupting respirations and causing apnea. Heart rate could affect the amount of oxygen delivered to the brain (Pichler, Schmolzer, Muller, & Urlesberger, 2001). Cerebral oxygen saturation may be a more sensitive indicator of reduced blood flow to the brain than heart rate and peripheral oxygenation,

which are currently used clinically. As a result, a new vital sign, cerebral oxygen saturation, requires examination in comparison to currently measured vital signs.

Environmental factors may also affect cerebral oxygen saturation in premature infants (Bremmer, Byers, & Kiehl, 2003). Positioning of the infant and noise are two unavoidable aspects of the neonatal intensive care environment. Positioning is a nursing intervention used to promote skin integrity and encourage proper body alignment (Carrier, 2004). Yet, particular head and body positions may restrict blood flow disrupting oxygen transport to the brain (Cowan & Thoresen, 1985; Pamphlett, Raisanen, & Kum-Jew, 1999; Watson, 1974). Loud sounds in the neonatal intensive care unit may disturb sleep-wake states and decrease cerebral oxygen saturation by disrupting respirations, especially in infants with respiratory compromise (Als et al., 1986). Whether position changes or high sound levels affect cerebral oxygen saturation in premature infants is currently unknown. To effectively use cerebral oximetry, more must be known about the effects of these nursing and environmental factors (Watzman et al., 2000) on cerebral oxygen saturation in premature infants.

Premature infants' neurodevelopment is more vulnerable to alterations than that of full-term infants because of an immature nervous system and early exposure to the neonatal intensive care environment (Blackburn, 1998). Cerebral oxygen saturation may be a sensitive measure to detect and prevent neurodevelopmental complications. To provide optimal care for premature infants, nurses need to understand how physiologic factors and nursing care affect cerebral oxygen saturation. The purpose of this dissertation was threefold: to examine the development of cerebral oxygen saturation in premature infants, to determine how infant position and sound levels affect

cerebral oxygenation saturation, and to explore the relationship between physiologic vital signs and cerebral oxygen saturation.

1.2 Theoretical Framework: Probabilistic Epigenesis

This study was guided by the theory of probabilistic epigenesis (PE), a developmental systems theory that was developed over the 40-year career of Gilbert Gottlieb, PhD. According to developmental systems theories, a person is a dynamic, complex being continuously interacting with the world (Magnusson & Cairns, 1996). Prior to the theory of PE, however, developmental theories suggested that genetics was the sole foundation from which gene expression (e.g., changes in behaviors) occurred within species (Gottlieb, 2000) and that change was predetermined or unidirectional. However, through his mallard and wood duck experiments, Dr. Gottlieb recognized relationships previously thought to be unidirectional were in fact bidirectional (Gottlieb, 2000), with development of gene expressions influenced through interactions with an individual's environment.

To understand the theory, its name must be defined. Probabilistic, unlike predetermined, is based on probability, the chance or likelihood of something being true (Merriam-Webster, 2010). Epigenesis is the change in gene expression by the internal and external environment without a change in gene arrangement (Mississippi State University, 2007). Consequently, probabilistic epigenesis describes the likelihood that genes will change expression due to the interplay between a person and his or her environment.

According to probabilistic epigenesis, each individual develops over time through unique exposures to, and in combination with four hierarchical values of the

internal and external environment (Gottlieb, 1999): genes, physiologic maturation, behavior, and environment. Even though distinct developmental relationships emerge from these varied combinations between the four values (Lickliter, 2008), similar developmental outcomes can still be attained by a process called equifinality (Gottlieb, 2002a). In other words, similar human development can be achieved through varied pathways in spite of an initial circumstance such as a disease process. The goal is to optimize interactions between these four values that will promote normal development.

Genes, physiologic maturation, and behavior are individual characteristics that make-up the person as a whole (i.e., internal environment), which interact with each other and the external environment during development. Development occurs over time through vertical (e.g., gene-physiologic maturation) or horizontal (e.g., gene-gene) interplay between conceptual values. The current state of each of the four values can potentiate future outcomes and each conceptual value can enhance or inhibit further maturation. For example, a cardiac defect will inhibit the natural course of heart maturation (physiologic-physiologic) and also limit the amount of energy the infant can expend interacting with his or her environment (physiologic-environment). In addition, genes act upon the body's nervous system through behavioral changes so that the infant can learn and grow through experiences in the world. At the same time, changes in the external environment will impose changes in behavior that will effect physiologic maturation and gene expression because of the bidirectional relationships defined in the model. For example, an apneic episode in a premature infant (behavior) could be related to a medical record chart dropped one minute ago (noise in the external environment). This apneic episode (behavior) could continue to bradycardia (physiologic development)

and hypoxia in the brain resulting in decreased cerebral oxygen saturation (physiologic development). Overall, probabilistic epigenesis is a holistic theory for explaining developmental outcomes that arise from the interactions between the internal and external environment.

Probabilistic epigenesis is an ideal theory to guide this study for two main reasons. First, infants who are full-term are exclusively exposed to the uterine environment during the preterm period unlike premature infants who spend a portion of their gestational development in a neonatal intensive care unit. Differences in environmental experiences between premature and full-term infants may in part elicit the development of uniquely different health outcomes. Because the environment is identified as an integral component in probabilistic epigenesis, understanding the environmental influence of the neonatal intensive care unit is necessary to learn the environmental impact responsible for premature infant morbidity and mortality.

Secondly, the earlier an infant is born, the more vulnerable the developmental course (Purves et al., 2008b). At no other time during human development can the structure and function of organ systems be more influenced than during the initial formation of the organ systems themselves, which normally occurs in utero. While all basic anatomical structures are in place by the time an infant is prematurely born, the nervous system continues to develop extensively throughout infancy. Therefore, this theory emphasizes the significance of internal and external environments on future developmental outcomes during important developmental periods in premature infants. Exploring relationships between the infant and the environment during these periods of vulnerability will expand current knowledge about the principles underlying risks of

prematurity. Once vulnerable moments and significant environmental assaults are identified, future steps to improve or change developmental trajectories can be examined.

For this study, probabilistic epigenesis was used to discover and explain existing relationships of the internal environments of premature infants (e.g., physiologic maturation) and between premature infants and their external environment. New knowledge developed extends what is currently known about developmental processes in premature infants. Since genes are slow to change over time and behavior changes are limited in their connection with changes cerebral oxygenation, the proposed study will focus on two of the four hierarchical values: physiologic maturation and environment. Figure 1 depicts the guiding framework for this study, with variables organized based upon the theory of probabilistic epigenesis. The lowest value of the model, physiologic maturation, will be assessed using longitudinal measurements of cerebral oxygen saturation, heart rate, and peripheral oxygenation.

Cerebral blood flow is known to stabilize and mature during a premature infant's development (Inder & Volpe, 2004). Cerebral oxygen saturation can serve as a proxy for cerebral blood flow (Caicedo et al., 2011). It is hypothesized that fluctuations in cerebral blood flow are a result of immature regulation of cerebral blood flow that places premature infants at risk for intraventricular hemorrhages (Inder & Volpe, 2004) (IVH, depicted in Figure 1). In this study, cerebral oxygen saturation patterns of premature infants with and without intraventricular hemorrhage were compared to examine potential differences in the trajectory of cerebral oxygen saturation during their hospital stay.

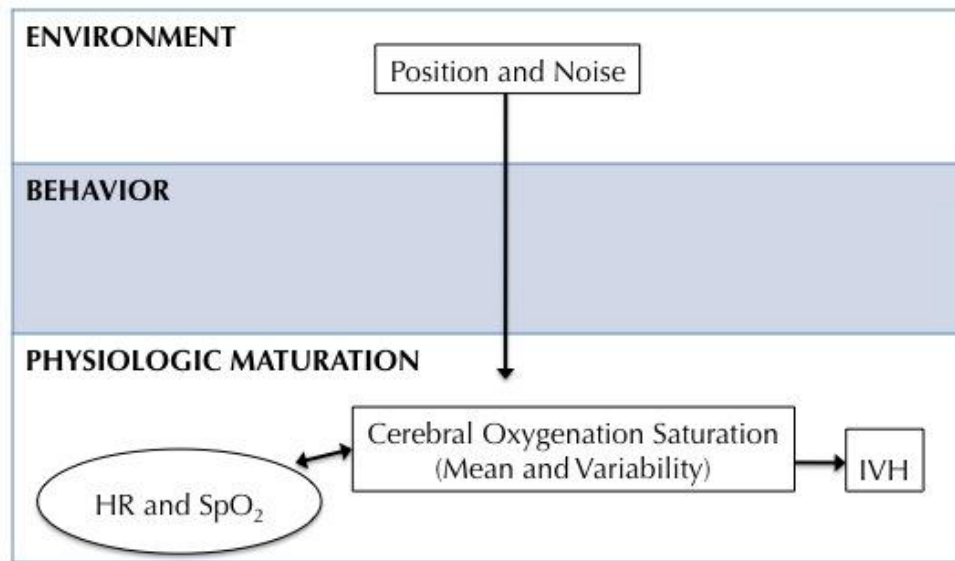


Figure 1. Development of Cerebral Oxygen Saturation

Cerebral oxygen saturation may be influenced by the maturation of vital signs (e.g. heart rate and peripheral oxygenation) (Gleason & Back, 2005). During the last trimester, premature infants must mature in a neonatal intensive care environment that is different from the dark, liquid uterine environment with rhythmic activity that is normally experienced by full-term infants (Bremmer et al., 2003). Because premature infants have immature organ systems, the NICU environment may over stimulate their nervous system and cause changes in heart rate and peripheral oxygenation such as apnea and bradycardia that could alter cerebral oxygen saturation. Therefore, examining the relationship of cerebral oxygen saturation with heart rate and peripheral oxygenation will help discover how these physiologic variables change together over time.

Exposure to external environmental stimuli at unexpected times may disrupt or facilitate sensory development (Gottlieb, 2002c). One environmental stimulus to which

premature infants must adapt is the loud noise in the neonatal intensive care unit. Loud noises result in an initial increased heart rate followed by a decrease in heart rate, respiratory rate, and eventually peripheral oxygenation (Bremmer et al., 2003; Catlett & Holditch-Davis, 1990). Premature infants cared for in the neonatal intensive care unit must also adapt to having their position changed by the nurse every 3 to 4 hours. Cerebral blood flow, as measured by cerebral oxygen saturation, may be affected by noise and positioning in the intensive care environment, which may be reflected in cerebral oxygen saturation values and without intervention, eventually modify premature infants' neurodevelopment.

Detection of altered cerebral oxygen saturation may also help to identify subtle, abnormal neurological activity. For example, altered cerebral blood flow and oxygenation are thought to result in IVH (Inder & Volpe, 2004). Therefore, early detection of unusual cerebral oxygen saturation patterns may allow the clinician to intervene before it is too late to prevent permanent neural damage. Longitudinal cerebral oxygen saturation values, particularly in the first week of life, are needed to analyze whether an association exists between cerebral oxygen saturation patterns and IVH.

1.2.1 Physiologic Maturation

This study examined the physiologic maturation of cerebral oxygen saturation and its relationship over time with heart rate and peripheral oxygenation. Physiologic maturation controlled by the nervous system is the first hierarchical value of probabilistic epigenesis based on the model in Figure 1. The nervous system begins to develop by the third week of gestation and it continues to mature for many years after

birth (Volpe, 2008). The nervous system is a complex network of structures that uses chemical and electrical signals to connect the body to the brain (Sugarman, 2002) and these networks allow the body internally to communicate between organs, tissues, and cells, and externally to interact with the environment. The earliest age at which an infant can live in the extrauterine environment is approximately 22 to 24 weeks gestation (MacDonald, 2002). By this gestational age, a primitive brain and spinal cord have developed from the neural tube and the brain contains all of the neurons it will ever contain (Volpe, 2008). While all basic structures are in place by early gestation (22-24 weeks), organization and myelination of the nervous system continues extensively throughout infancy (Volpe, 2008).

The organizational development of the nervous system includes processes that result in the construction of neural pathways that connect the brain and body (Volpe, 2008) beginning at approximately 5 months gestation. During this time, synapses attach to subplate neurons, dendrites branch out, formation of receptor sites for neurotransmitters begins, and selective neuronal apoptosis are four main processes (Volpe, 2008). Insults to the brain during this time period place a premature infant at risk for altered neuronal connections throughout the entire nervous system, which can lead to seizure activity, mental retardation, and impaired body movements and atypical behaviors (Volpe, 2008). For example, neurotransmitters allow neurons to communicate with each other. Neurons receive inhibitory, excitatory, or modulatory signals, but if the pathway to differentiate the neurons is altered, the neurotransmitter signal will deviate from the intended message (Sanes, Reh, & Harris, 2006). Therefore,

organization of the neuronal connections and pathways is vulnerable to alterations due to changes in the internal and external environment for infants born early.

The last major stage of nervous system development is myelination. Myelin is the fatty material deposited on axons that increases speed of conductivity (Guyton & Hall, 2006). Myelination begins during the second trimester (Kinney, Brody, Kloman, & Gilles, 1988), at a time when premature infants are cared for in the neonatal intensive care unit, and ends in adulthood. Stimuli present in the neonatal intensive care environment and the potential for added physiologic stress from illness may alter the myelination process for premature infants compared to this process unfolding in utero for full-term infants. Irregular myelination throughout the brain may cause atypical neurological processes exhibited in infant behaviors and later as learning disabilities. In particular, infants diagnosed with periventricular leukomalacia have lost oligodendrocytes in cerebral white matter, which results in uneven areas of myelinated brain tissue (Volpe, 2008). Whether or not other illnesses associated with prematurity impair myelination of the developing nervous system is unknown; however, due to the time frame of its development, myelination is potentially vulnerable to disruption in premature infants.

1.2.1.1 Cerebral blood flow and cerebral oxygenation. One dimension of physiologic maturation, cerebral blood flow (CBF), is regulated to maintain circulation. Autoregulation is the ability to maintain cerebral blood flow despite changes in cerebral perfusion pressure (Chillon & Baumbach, 2002); cerebral vessels constrict when cerebral perfusion pressure rises and dilate when cerebral perfusion pressure decrease (Kontos et al., 1978). When premature infants have the ability to autoregulate, however, is not

clear (Boylan, Young, Panerai, Rennie, & Evans, 2000; Lou, Lassen, & Friis-Hansen, 1979; Munro, Walker, & Barfield, 2004; Soul et al., 2007; Tyszczuk, Meek, Elwell, & Wyatt, 1998; Wong et al., 2008). Absence of autoregulation is hypothesized to be the cause for most cerebral damage in premature infants (Calvert et al., 1988; Jorch & Jorch, 1987), in particular intraventricular hemorrhage (IVH). No real-time measure exists to identify infants with impaired autoregulation of cerebral blood flow. However, cerebral oxygen saturation, as a proxy to monitor cerebral blood flow, may serve as a viable measure to noninvasively screen for impairment in autoregulation assuming other factors such as temperature and hemoglobin levels remain constant.

1.2.1.1.1 Development of cerebral blood flow and oxygenation. As infants grow and develop, cerebral blood flow increases (Kehrer et al., 2005; Meek, Tyszczuk, Elwell, & Wyatt, 1998; Tsuji, Saul, Plessis, et al., 2000; Volpe, 2001a). At birth, all infants transition to inhaling oxygen into the lungs and transporting the oxygen by a beating heart to the entire body because the placenta is no longer attached. Decreased pulmonary pressure allows the lungs to inflate and increased systemic pressure results from increased blood flow (Cifuentes & Carlo, 2007). Once the placenta is removed from circulation, an infant must maintain temperature and meet metabolic demands that require two to three times as much oxygen than in utero (Avery, 1974). Because cerebral blood flow supplies the brain with oxygen and nutrients, cerebral oxygen saturation is considered an appropriate surrogate of cerebral blood flow as long as adequate oxygen can reach the circulation.

Research has shown that cerebral blood flow decreases for approximately the first 2 hours after birth and then remains stable at this low flow for the next 24 hours,

though for unknown reasons (Cooke, Rolfe, & Howat, 1979). After the first day of life, cerebral blood flow gradually increases inconsistently over time, possibly due to postnatal growth, increased blood pressure, blood viscosity, or oxygenation (Volpe, 2001a). The fluctuations in cerebral blood flow during the first week of life places a premature infant at risk for IVH (Inder & Volpe, 2004). Cerebral blood flow increases oxygen delivery to meet higher oxygen demands. Patent ductus arteriosus (Kurtis, Rosenkrantz, & Zalneraitis, 1995), respiratory distress requiring respiratory support (Cooke et al., 1979), or infection can also affect cerebral blood flow (Perlman & Volpe, 1985). As a result, cerebral oxygen saturation values may continue to change after the first week of life as premature infants continue to stabilize. Thus, cerebral oxygen saturation values need to be examined longitudinally to capture the development of cerebral oxygen saturation as premature infants mature.

1.2.1.1.2 Measurement of cerebral blood flow and cerebral oxygen

saturation. Actual cerebral blood flow is difficult to measure in premature infants because the most accurate measurement methods including single-photon emission computed tomography, positron emission tomography, and radionuclide angiography (Ashwal & Serna-Fonseca, 2006), require radioactive material that is not recommended for use in infants (Perlman, 2004). Doppler ultrasound and near-infrared spectroscopy are non-invasive, indirect measures of cerebral blood flow in infants (Perlman, 2004). However, Doppler ultrasound focuses on provider selected cerebral arteries or veins to measure cerebral blood flow (Inder & Volpe, 2004) and it requires an ultrasound technician at the bedside to gather data that must then be interpreted by a radiologist

(Phillips Electronics, 2007). In addition, studies utilizing Doppler ultrasound do not provide guidance for continuous clinical decision-making.

A cerebral oximeter, using near-infrared spectroscopy, measures cerebral oxygen saturation without requiring personnel continuously at the bedside (Perlman, 2004; Watzman et al., 2000). An oximeter probe is attached to the infant's head and sends light at specific wavelengths through the scalp and skull (Perlman, 2004). The light wavelengths sent and received by the probe provides information to determine the amount of oxygenated (HbO₂) and deoxygenated (Hb) hemoglobin in the brain (Inder & Volpe, 2004). From these two numbers, a cerebral oxygen saturation percentage is calculated and displayed on the monitor screen. The amount of blood flow the brain receives is suggested by the oxygen saturation. The advantages of using a cerebral oximeter include providing noninvasive, continuous, real-time data to the clinician at the bedside for immediate care decisions and immediate observation of the effects of interventions. Currently, neonatal intensive care nurseries across the country have begun to introduce cerebral oximeters to measure cerebral oxygen saturation values. Although there has been an explosion of research with premature infants using near-infrared spectroscopy (Grant, Franzini, Wild, Eede, & Walker, 2005; Lemmers, Toet, van Schelven, & van Bel, 2006; Petrova et al., 2009; Sorensen & Greisen, 2009), only two recent studies, one using a non-commercially available cerebral oximeter and the other with a commercial cerebral oximeter, provide longitudinal, normative values for cerebral oxygen saturation values in premature infants (McNeill, Gatenby, McElroy, & Engelhardt, 2011; Roche-Labarbe et al., 2012). Therefore, additional research to

establish developmental trajectories of cerebral oxygen saturation using other cerebral oximeters in premature infants is needed.

To date, only six studies have measured cerebral blood flow in premature infants after the first week of life (Bode & Wais, 1988; Greisen, Hellstrom-Vestas, Lou, Rosen, & Svenningsen, 1985; Kehrer et al., 2005; Younkin, Delivoria-Papadopoulos, Reivich, Jaggi, & Obrist, 1988; Younkin, Reivich, Jaggi, Obrist, & Delivoria-Papadopoulos, 1987). Four studies used either xenon clearance or Doppler ultrasound, but xenon clearance and Doppler ultrasound measurements are not equivalent to near-infrared spectroscopy measurement of cerebral oxygen saturation. Two studies used near-infrared spectroscopy to indirectly measure cerebral blood flow. The first study converted raw cerebral oxygen saturation data into cerebral blood flow (mL/min), rather than cerebral oxygen saturation percentages (Kehrer et al., 2005). In the second study, while cerebral oxygen saturation measures were preserved, three probe locations were averaged and only one cerebral oxygen saturation value was reported (Roche-Labarbe et al., 2010), which is problematic since cerebral oxygen saturations have been shown to differ between the left and right frontal cortex (Lemmers & van Bel, 2009). While the measurements used in five of six cerebral blood flow studies differ from cerebral oxygen saturation values, they are similar to cerebral oxygen saturation. The assumption is that measurable oxygen in the brain requires blood flow to deliver oxygen and therefore, cerebral oxygen saturation patterns should reflect results found using other measurement techniques. Since near-infrared technology provides noninvasive and real-time measurements, the proposed research using this technology

would provide developmental trajectories of cerebral oxygen saturation values in premature infants for clinical use.

Currently, neonatal providers rely on non-specific measurements of peripheral oxygen saturation and mean arterial pressure to indicate adequate cerebral perfusion in premature infants. Cerebral oxygen saturation measurements would provide a more direct assessment of the percentage of oxygen in the brain and, in the future, may have predictive ability to identify infants at-risk for cerebral damage.

1.2.1.1.2.1 Cerebral oximetry. Cerebral oximeters obtain continuous, noninvasive cerebral oxygen saturation values (Toet & Lemmers, 2009). A cerebral oximeter set-up consists of an oximeter probe attached to a monitor cable that is connected to a cerebral oximeter monitor. In general, most cerebral oximeters can support up to four oximeter probes with respective monitor cables. Oximeter probes can be placed on the head, usually the forehead, or in some cases, somatic locations (Somanetics Corporation, 2009). The oximeter probe includes a fiber optic light source and light detector(s) (Brazy & Vander-Vliet, 1989). Depending on the cerebral oximeter, fiber optic strands release either LASER (light amplification by stimulated emission of radiation) (CAS Medical Systems, 2008) or LED (light emitting diodes) light (Somanetics Corporation, 2009). Emitted light wavelengths are sent from the light source penetrating the skull and cerebrum and the light detector(s) receives the light not absorbed during the light pathway through the skull and cerebrum. The amount of oxygen present in the brain is suggested by the percentage of oxygen displayed on the monitor screen.

Cerebral oximeters calculate cerebral oxygen saturation using near-infrared spectroscopy (NIRS) technology based on a modified light absorbent theory called the

Beer-Lambert Law. According to the Beer-Lambert Law, an amount of a substance or compound, in this case oxygen, can be determined by how much light the substance absorbs (Owen-Reece, Smith, Elwell, & Goldstone, 1999). In theory, a light source will decrease in intensity when an absorbing substance mediates the light source pathway and the more light absorbed by a substance, the more a substance is present (Schubert & Leyba, 2008).

The Beer-Lambert Law is necessary to understand the principle behind a cerebral oximeter. The Beer-Lambert equation takes into account the products of the light pathway distance, oxygenated and deoxygenated hemoglobin, tissue oxygen concentrations (cytochrome aa₃), and extinction coefficients to determine the final transmitted light intensity (Brazy & Vander-Vliet, 1989; Owen-Reece et al., 1999; Schubert & Leyba, 2008). The Beer-Lambert Law is represented in the following equation (Owen-Reece et al., 1999; Vacchiano, 2009):

$$\text{Light intensity} = (\text{Incidental light}) e^{-DCE}$$

Where: D = Light pathway distance

C = Oxygenated Hgb or Deoxygenated Hgb or Tissue Oxygen

E = Extinction coefficient

Light emitted from locations other than the light source can influence light intensity received by an oximeter. Therefore, incidental light is taken into account in this equation to reduce error from unwanted light sources (Owen-Reece et al., 1999). The length the light travels from the light source to the light detector(s) determines the light pathway distance. This value is fixed based on the cerebral oximeter probe size and manufacturer.

Oxygen can be bound or unbound to hemoglobin, also known as oxygenated hemoglobin and deoxygenated hemoglobin respectively, with each hemoglobin type absorbing different light wavelength amounts (Owen-Reece et al., 1999). Oxygenated and deoxygenated hemoglobin found in vessels and tissue oxygen concentrations, reflecting cellular oxygenation, are thought to comprise all sources of oxygen in the brain (Toet & Lemmers, 2009). These values are unknown and must be calculated along with weighted algorithm values for arterial, venous, and capillary oxygen (Benni et al., 2005; Ito et al., 2001) to acquire cerebral oxygen saturation values. Extinction coefficients are predetermined light absorption amounts that are unique to each substance depending on the emitted light wavelength (Owen-Reece et al., 1999; Vacchiano, 2009). Light wavelengths within the near infrared light spectrum (650 to 900 nm) are the only light wavelengths strong enough to go through skull bone and capture the presence of cerebral tissue oxygenation (Owen-Reece et al., 1999). Additionally, oxygenated hemoglobin, deoxygenated hemoglobin, and tissue oxygenation (cytochrome aa₃) are the only substances in the brain with the capacity to change light absorption when oxygenation values change (Jobsis, 1977). Lastly, proprietary formulas calculate the differences between light absorbed by oxygenated hemoglobin, deoxygenated hemoglobin, and tissue oxygen to display a percentage of cerebral oxygen present in that particular cerebral light source pathway. These equations divide the amount of oxygenated hemoglobin by the total hemoglobin (deoxygenated hemoglobin plus oxygenated hemoglobin) to calculate a percentage of cerebral oxygen saturation (Owen-Reece et al., 1999).

1.2.1.1.2.2 Reliability and validity of cerebral oximetry. There are two cerebral oximeters available on the market for use in the infant population, the INVOS® System by Somanetics® Corporation (Somanetics Corporation, 2009) and the FORE-SIGHT® Cerebral Oximeter by CAS Medical Systems (CAS Medical Systems, 2008). Cerebral oxygen saturation measured by the INVOS is abbreviated as rSO₂ and when measured by the FORE-SIGHT™ it is SctO₂. To ensure these cerebral oximeters provide accurate and precise cerebral oxygen saturation values that reflect cerebral oxygenation, each type of cerebral oximeter must go through rigorous reliability and validity testing (DeVon et al., 2007).

Cerebral oxygen saturation, measured by a cerebral oximeter, is considered a proxy for cerebral blood flow and blood flow or perfusion of the brain at any given time is comprised of 70% venous and 30% arterial blood (Benni et al., 2005). Therefore, proportion of oxygen content in the brain should closely resemble these ratios. The cerebral oximeter calculates the percentage of oxygen in the brain that mimics the proportion of blood flowing to and from the brain (cerebral oxygenation = 0.7 [venous source] x 0.3 [arterial source]) (MacLeod, Ikeda, Keifer, Moretti, & Ames, 2006). If cerebral blood flow increases then presumably cerebral oxygen saturation would increase assuming an adequate supply of oxygen is circulating in the blood volume.

Validity is how well an instrument measures what it was intended to measure (Waltz, Strickland, & Lenz, 2005b). Cerebral oximeters are intentionally noninvasive instruments; however, in order to validate this instrument, a comparison with blood values is required so that it is known whether or not cerebral oxygen saturation reflects similar oxygen quantities in the blood. Due to the mixed-vascular nature (MacLeod et

al., 2006) of cerebral oxygen saturation (Benni et al., 2005; Ito et al., 2001), cerebral oxygen saturation validation must incorporate blood samples from both arteries and veins. Blood samples from a radial artery (SaO₂) or peripheral oxygenation (SpO₂) and a jugular bulb vessel in healthy adults during intentionally induced hypoxic episodes represents the typical method used in multiple studies to achieve this mixed-vascular sampling (MacLeod et al., 2006; MacLeod, Ikeda, Moretti, Keifer, & Grocott, 2005; Pollard et al., 1996; Yoshitani, Kawaguchi, Tatsumi, Kitaguchi, & Furuya, 2002). FORE-SIGHT™ Cerebral Oximeter validation articles demonstrate strong correlations between blood sampling and peripheral oxygenation with cerebral oxygen saturation values during induced hypoxic episodes (MacLeod et al., 2006; MacLeod et al., 2005). Likewise, 12 healthy adult volunteers were compared to an additional 10 healthy adult volunteers using the INVOS. In this study, cerebral oxygen saturation values and mixed-vascular sampling were highly related ($r^2 = 0.794-0.992$) (Pollard et al., 1996). Studies conclude that the FORE-SIGHT™ Cerebral Oximeter and the INVOS® are valid cerebral oximeters in healthy adults.

While cerebral oximeters have been shown to be valid in the adult population, use in the neonatal population requires new studies to validate or determine accuracy of cerebral oxygen saturation values (Waltz et al., 2005b). Validation studies in neonates used the proximal internal jugular vein catheter that is accessed for each infant on ECMO (extracorporeal membrane oxygenation) (Rais-Bahrami, Rivera, & Short, 2006). In studies using the FORE-SIGHT™ Cerebral Oximeter, jugular vein oxygenation (SjvO₂), peripheral oxygenation (SpO₂), and cerebral oxygen saturation (SctO₂), values were simultaneously obtained for each ECMO infant. Methods included weighted

oxygenation values at 70% venous and 30% arterial blood mix for validation. Neonatal validation studies exhibit less accuracy ($\pm 5.1\%$ SctO₂) than adult validation studies ($\pm 3.7\%$ SctO₂) (MacLeod et al., 2006; MacLeod et al., 2005) using the FORE-SIGHT™ Cerebral Oximeter. The authors attribute these findings to possible jugular vein catheter placement occlusions and unstable mixed-vascular ratios related to unregulated hemodynamics (Rais-Bahrami et al., 2006). Findings remain within one standard deviation from the mean and as a result, the FORE-SIGHT™ Cerebral Oximeter is considered a valid instrument in the neonatal population. Validation studies in infants using the INVOS® are not available.

An instrument is considered reliable if it can repeatedly measure or reproduce results for a specific construct (Waltz, Strickland, & Lenz, 2005a). The Bland-Altman plot, the gold standard for physiological tests, occurs as the main method to analyze the precision or reliability of cerebral oximeters (Pollard et al., 1996; Yoshitani et al., 2002). Two studies used the Bland-Altman plot with the first study comparing cerebral oxygen saturation values to mixed-vascular saturation in the INVOS® (Pollard et al., 1996). Multiple blood samples were obtained from 12 healthy adults. Findings suggest a close relationship between the INVOS® cerebral oxygen saturation and the mixed-vascular saturation from the radial artery and jugular venous bulb blood sampling. This study suggests that in adults the INVOS® is a reliable instrument to produce cerebral oxygen saturation values.

Yet, in a second article, the INVOS® is compared to another NIRS device not available in the United States, the NIRO 300 (Yoshitani et al., 2002). Cerebral oxygen

saturation values were synchronized between the two machines but in Bland-Altman results showed that the machines were not calculating cerebral oxygen saturation values similarly. This study questions the precision and reliability of the INVOS® or NIRO 300, yet proprietary formulas for each machine could explain these findings (Yoshitani et al., 2002). Furthermore, cerebral oxygen saturation values might only be reliable when compared within and not between cerebral oximeter machines. Articles that tested reliability in the FORE-SIGHT™ Cerebral Oximeter were not found.

In summary, cerebral oximeters measure cerebral oxygen saturation in a noninvasive manner, based upon the Beer-Lambert Law. A small number of studies demonstrated validity and reliability in the two cerebral oximeters available for the premature infant population. A cerebral oximeter may show value at the bedside for the high-risk premature infant population in the neonatal intensive care unit by providing real-time changes in cerebral oxygen saturation values that may one day be used to improve premature infant health outcomes.

1.2.1.2 Heart rate. Heart rate is a common vital sign used to assess circulation. Heart rate is controlled by the autonomic nervous system (Gournay, Drouin, & Roze, 2002) and influences cardiac output (Lott, 2007) and blood flow to the brain. Cardiac output is the product of heart rate and stroke volume, yet infants are unable to accommodate larger volumes of blood to increase stroke volume. Consequently, heart rate is the only effective means to increase or decrease cardiac output (Lagercrantz, Hanson, Evrard, & Rodeck, 2002). Therefore, assessing the relationship between heart rate and cerebral oxygen saturation is important.

The normal range for heart rate in premature infants is 120-160 beats per minute (Vargo, 2003). Variations in heart rate occur due to age and illness severity. Studies show that premature infants' nervous systems lag in maturation compared to those full-term infants (Clairambault, Curzi-Dascalova, Kauffmann, Medigue, & Leffler, 1992; De Rogalski Landrot et al., 2007; Eiselt et al., 1993; Longin, Gerstner, Schaible, Lenz, & Konig, 2006; Mazursky, Birkett, Bedell, Ben-Haim, & Segar, 1998; Patural et al., 2008) and infants with respiratory distress syndrome (RDS) have even further delays in the maturation of the autonomic system that controls heart rate (Fox, 1983). Premature infant heart rates increase with age, peaking between 4 and 10 weeks postnatal age (Katona & Egbert, 1978; Katona, Frasz, & Egbert, 1980). Compared to full-term infants, premature infant heart rates are higher and remain higher even after they reach full-term post-menstrual age (PMA) (Gournay et al., 2002; Katona & Egbert, 1978; Katona et al., 1980). In this study, gestational and postnatal age were used as covariates since heart rate is age dependent.

1.2.1.3 Peripheral oxygenation. A normal heart rate and respiratory rate do not guarantee adequate oxygen content in the blood to supply tissues and cells. Peripheral oxygenation is the measure of oxygenation in the body. Pulse oximeters routinely used in the neonatal intensive care unit are a low cost method (Mower, Sachs, Nicklin, & Baraff, 1997) used by nurses to measure peripheral oxygenation (Jubran, 1999) since it is difficult to consistently visually assess hypoxemia, even by experienced clinicians (Mower, Sachs, Nicklin, Safa, & Baraff, 1995). Nonetheless, pulse oximetry recognizes low peripheral oxygen values prior to a caregiver's visual assessment, which improves the chances for expedited care decisions when peripheral oxygenation is low.

Peripheral oxygenation and cerebral oxygen saturation are measured in similar ways, but the mathematical computations of each are different. A pulse oximeter probe is attached to an appendage such as a finger, toe, or foot and connects to a pulse oximeter monitor that displays the percentage of peripheral oxygenation at the probe site. A pulse oximeter uses one infrared light wave to detect deoxygenated hemoglobin and a visible light in the red spectrum to detect oxygenated hemoglobin (Jubran, 1999). Pulsatile and non-pulsatile oxygenated and deoxygenated hemoglobin are then compared in what is called the ratio of the ratios (Severinghaus, 2007) to reflect a percentage of peripheral oxygenation on the monitor screen.

Although peripheral oxygenation is a helpful fifth vital sign, alone it is not accurate for detecting infants at risk for fluctuations in blood flow, specifically cerebral blood flow. When perfusion at the pulse oximeter probe site is decreased, light wave signals are compromised, limiting the ability of the probe to calculate the ratio of ratios. For some premature infants, fluctuations in blood flow are due to the nervous system's inability to regulate blood flow, placing them at risk for neurodevelopmental complications. Discrepancies in blood flow between the periphery and brain are not clearly understood, but cerebral oxygen saturation values would be more accurate than peripheral oxygenation values to monitor fluctuations in cerebral blood flow, as cerebral oxygen saturation measurements are not dependent upon pulsatile flow. Therefore, measurement of cerebral oxygen saturation should be a more specific and accurate measurement of cerebral blood flow than peripheral oxygenation measurements in premature infants.

1.2.2 Environment

The external environment is the last concept value from the probabilistic epigenesis theory to be examined in this study. The external environment is the physical, social, and cultural context (Gottlieb, 2002b) surrounding the premature infant. Sound and positioning were chosen for this study to represent two frequently encountered components of the neonatal intensive care environment that are also proposed to influence infant cerebral oxygen saturation.

1.2.2.1 Environmental sound. Sound is an environmental component of the neonatal intensive care unit and the hospital at large. In the hospital setting, technology and personnel create considerable levels of sound (Cmiel, Karr, Gasser, Oliphant, & Neveau, 2004; Kahn et al., 1998; Long, Lucey, & Philip, 1980; United States Environmental Protection Agency, 1974). Hospitals are institutions where patients pursue a transition from illness to an improved health status; however, unusual sounds and loud noises inhibit patient recovery and proper development (Bartick, Thai, Schmidt, Altaye, & Solet, 2010). A concern with hospital noise is not new and, in fact, Florence Nightingale (1860) in her *Notes on Nursing* emphasized the importance of nursing's role in creating a quiet environment for patients to heal. As noise values remain a problem still today, considering noise as a barrier to infant development and overall health is important.

Sound travels through air as energy and is perceived by the brain via the ear (Berube, 1995). Sound intensity can be measured in decibels using a sound-value meter or noise dosimeter. Most sound values are reported as an average (L_{eq}) over a certain length of time or the highest obtained sound level called peak sound (L_{peak}) (Beranek,

1988). To provide examples of sound values, a whisper measures 20 decibels, heavy traffic measures 80 decibels, and a gunshot is 140 decibels (Cmiel et al., 2004). Noise is characterized as an unwanted sound (Kryter, 1985) or an annoyance that can vary considerably from person to person depending on their sensitivity to noise (Weinstein, 1978), age (Lukas, 1976) and hearing ability (Griffin, 1992). Although the presence or absence of sound is objective, the presence or absence of noise is subjective and more difficult to assess. Thus, to be more objective, studies have assigned a decibel value of 60 decibels to mark the threshold between acceptable sound and noise (Baker, 1984; Bentley, Murphy, & Dudley, 1977). However, pre-set decibel values may not be predictive of altered development in infants.

Noise or sound can affect a premature infant's development (American Academy of Pediatrics Committee on Environmental Health, 1997). The ability to hear is highly related to brain development and function since hearing is processed by the primary auditory cortex located on the bilateral temporal lobes of the brain (Purves et al., 2008a; Werner, 2004). Myelination of the cerebral cortex is not mature until full-term age, which leaves premature infants vulnerable to experience environmental sound values with a less developed nervous system (Johnson, 2001). Sound values exceeding 45 decibels affected premature infants by interrupting sleep-wake states (Surethiran et al., 2003; Thomas & Uran, 2007). Additionally, as sound values increase, premature infant oxygen consumption (Thomas & Uran, 2007) and cardiac function increase (Surethiran et al., 2003), resulting in decreased oxygen saturation, increased respiratory rate, and either elevated or decreased heart rate (Bremmer et al., 2003; Surethiran et al., 2003). Previous studies, however, have not examined the relationship between sound levels

and cerebral oxygen saturation. This proposed study examined how sound levels in the neonatal intensive care environment affect values of cerebral oxygen saturation.

Neonatal intensive care units have attempted to reduce the ambient noise over the last few decades; however, high sound levels continue to be a problem (Brandon, Ryan, & Barnes, 2007; Philbin, Robertson, & Hall, 1999; Thomas & Uran, 2007). The United States Environmental Protection Agency (EPA) (1974) suggested daytime hospital noise should range from 40 to 45 decibels and during the night, hospitals should strive for 35 decibels. Recently proposed sound values suggest NICUs should not exceed an average of 45 decibels with sound value peaks no greater than 65 decibels (Committee to Establish Recommended Standards for Newborn ICU Design, 2007). Unfortunately, in many cases noise levels exceed both noise level recommendations. The average neonatal intensive care unit measured 47 to 50 decibels with peaks over 100 decibels (American Academy of Pediatrics Committee on Environmental Health, 1997; Bremmer et al., 2003; Thomas & Uran, 2007); yet average ambient sound levels in the home are 40 decibels (American Academy of Pediatrics Committee on Environmental Health, 1997). Recent sound levels, gathered from the chosen facility for this study ranged from 47 to 67 Leq with peak values as high as 111 decibels. This setting exceeded recommended sound values, which provided an opportunity to assess the relationship between sound and cerebral oxygen saturation.

1.2.2.2 Infant position. In addition to sound, positioning is another facet of care in the neonatal intensive care environment. Few guidelines exist to advise nurses on how to best position infants. Developmental care practices include positioning techniques that promote flexion, symmetry, and hand to mouth activity (Als et al., 1994; Carrier, 2004).

Infants are typically repositioned every 3 to 4 hours at a time when other care activities such as physical assessments, diaper changes, and feedings occur to reduce the amount stimulation to the infant. In general, neonatal nurses are educated regarding these position techniques, but not on how to select a position that will support optimal physiologic stability. Knowing the effect of position on cerebral oxygen saturation may lead to the development of more specific guidelines in the future for positioning premature infants to maximize cerebral oxygen saturation and reduce potential cerebral damage caused by hypoxic episodes. Table 1 shows 14 different position options available to neonatal nurses for positioning premature infants. The list of positions includes multiple head positions within three main body positions, supine, lateral, and prone. Nurses do not use a lowered head or trendelenburg position because these positions are thought to increase cerebral blood flow leading to an increased intracranial pressure in the brain resulting in risk for damaging fragile cerebral vasculature.

Table 1. Positioning Choices for Neonatal Nurses

Supine Position	Lateral Position	Prone Position
Head midline	Left lateral	Head turned to the right
Head midline and elevated 15°	Left lateral and head elevated 15°	Head turned to the right and elevated 15°
Head turned to the right	Right lateral	Head turned to the left
Head turned to the right and elevated 15°	Right lateral and head elevated 15°	Head turned to the left and elevated 15°
Head turned to the left		
Head turned to the left and elevated 15°		

Few studies have examined infant position and cerebral oxygen saturation. Infant position may decrease cerebral oxygen saturation because body or head positions can slow, change flow patterns, or halt blood flow from crimped blood vessels (Cowan &

Thoresen, 1985; Pamphlett et al., 1999; Watson, 1974). Two studies found that prone positioning decreased cerebral blood flow when the head was turned to either the left or right side (Eichler et al., 2001; Vogelberg, Taut-Sack, Friebe, Maier, & Rupprecht, 2004). The first study examined 23 premature infants less than 1800 grams and born less than 34 weeks gestation at three time points: 3-5 days, 7-10 days, and 1 month (Eichler et al., 2001). Using Doppler ultrasound, there was no difference in cerebral blood flow velocity between the supine and prone position at 3 to 5 days or from 7 to 10 days; however, significantly higher cerebral blood flow was observed in the supine position at one month of age (Eichler et al., 2001). These findings may be due to cerebral blood flow being less affected by positioning as the infant ages (Pichler, Urlesberger, Schmolzer, & Muller, 2004). Similar to cerebral blood flow, cerebral oxygen saturation was lower in a prone versus supine position (Wong et al., 2011). Yet, cerebral oxygen saturation decreased in both positions over time. Referring back to Poiseuille's law, blood flow is dependent upon vessel diameter. As an infant matures, vascular diameter enlarges (Pichler, Schmolzer, et al., 2001), allowing for the volume of blood transported to the brain to increase. Therefore, an older infant placed supine will have greater cerebral blood flow than at younger ages. As a result, larger difference in cerebral blood flow were found when comparing other positions such as the prone position that may occlude cerebral blood flow.

The second study, a case study, involved an infant born at 29-weeks gestation (Vogelberg et al., 2004). After 6 weeks in intensive care, the infant developed frequent episodes of bradycardia and desaturations, primarily in the prone position. Doppler ultrasound showed lower flow through the right and left vertebral arteries when the

infant was placed in the prone position, leading to decreased oxygen saturation and heart rate. Findings from these two studies suggest that the prone position decreases cerebral blood flow, and premature infants should not be placed prone.

Descriptions of the effects of positioning on cerebral blood flow have not been consistent. In two other studies, supine position was related to decreased cerebral blood flow. Supine position with head midline was compared to a prone position with the head to the left in 15 stable premature infants born at 27-37 weeks gestation; all diagnosed with apnea of prematurity (Pichler, Schmolzer, et al., 2001). During apneic episodes, near-infrared spectroscopy showed that cerebral oxygen saturation dramatically decreased in the supine position. When placed in the prone position, infants' apneic episodes subsided and cerebral oxygen saturation decreased. A decrease in blood flow to the brain due to a turned head was not found in this study. Rather, this study suggested that the supine position may be detrimental to cerebral oxygen saturation and the prone position may be beneficial in infants diagnosed with apnea of prematurity.

Similarly, another study compared head position to the left or right and midline in 14 infants of 33-37 weeks gestational age (Emery & Peabody, 1983). All infants were in a supine position; 8 were asphyxiated and 6 were non-asphyxiated. Infants with a head position to the left or right showed a decrease in cerebral blood flow compared to infants with a midline head position. Nevertheless, the difference in cerebral blood flow in the turned head positions (left or right) was not significant once the head was elevated 30°. An elevated head, also known as tilting, can cause a decrease in cerebral blood flow (Pichler, van Boetzelar, Muller, & Urlesberger, 2001). That is, as the head moves from horizontal to an incline, gravity pulls blood away from the head. According

to this study, supine, midline head position was just as successful at delivering blood flow to the brain as a turned head while supine if the head was elevated. However, other studies showed that infants had decreased (Pichler et al., 2004) or no change in cerebral blood flow or oxygenation when infants were tilted (Ancora et al., 2010; Pellicer, Gaya, Madero, Quero, & Cabanas, 2002).

Overall, the findings from these studies do not provide clear guidance for optimal positioning. Some studies indicated that the prone position might be harmful to premature infants, while other studies found that the prone position may be beneficial. Yet others suggested that the supine position with the head elevated could positively affect cerebral blood flow. Furthermore, certain studies supported a turned head position for effective cerebral blood flow and other studies found a turned head to be unsafe. The contradictory findings of these studies prohibit drawing any definitive conclusions about the best position in which to place premature infants to promote optimal cerebral blood flow and oxygenation. In addition, studies examined only one or two positions and methods to measure cerebral blood flow varied, resulting in a difficult challenge in comparing findings. Multiple positions examined within the same study using the same measure will help clarify position choices based on cerebral blood flow. Accordingly, this study examined the effects of six different positions measuring cerebral oxygen saturation using a cerebral oximetry only.

1.3 Summary

This study longitudinally measured cerebral oxygen saturation in premature infants born less than 32 weeks gestational age at Duke University Hospital neonatal intensive care unit. In addition, the effects of positioning and sound on cerebral oxygen

saturation were examined along with exploring the relationships between traditional vital signs (heart rate and pulse oximetry) and cerebral oxygen saturation. This study provided foundational knowledge for how cerebral oxygen saturation develops during the course of a premature infant's hospital stay and assists to determine if this physiologic biomarker can be used as a preventative measure to decrease neurological damage in this high-risk population in the future.

1.4 Specific Aims and Research Questions

The overall goal for this study was to understand how cerebral oxygen saturation develops in the premature infant, taking into consideration its relationship to other physiological measures, within the context of the neonatal intensive care environment. A preliminary study was conducted on nine stable intensive care infants to assess the effect of five different positions on cerebral oxygen saturation. Results from this preliminary study are presented in chapter 2. In chapters 3 through 5, this dissertation study addressed five specific aims. The specific aims and research questions were:

Chapter 3

Aim 1. Establish developmental trajectories of cerebral oxygen saturation in premature infants born less than 32 weeks gestational age, from the first 48 hours of life through hospital discharge or 40 weeks post-menstrual age.

Aim 2. Examine how the developmental trajectories of cerebral oxygen saturation change between infants with and without an intraventricular hemorrhage diagnosis.

Research questions:

1. What are the developmental trajectories of cerebral oxygen saturation in premature infants born less than 32 weeks gestational age?
2. How does an intraventricular hemorrhage diagnosis change the developmental trajectory of cerebral oxygen saturation in premature infants born less than 32 weeks gestational age?

Chapter 4

Aim 3. Assess the effects of environmental sound on cerebral oxygen saturation.

Aim 4. Evaluate how various infant positions effect cerebral oxygen saturation.

Research questions:

1. How do peak sound levels effect cerebral oxygen saturation in premature infants born less than 32 weeks gestational age?
2. What positions significantly change cerebral oxygen saturation in premature infants born less than 32 weeks gestational age?

Chapter 5

Aim 5. Investigate the relationships between cerebral oxygen saturation and heart rate and peripheral oxygenation.

Research questions:

1. What are the relationships between cerebral oxygen saturation and heart rate and peripheral oxygenation in individual premature infants born less than 32 weeks gestational age over time?
2. What are the relationships between cerebral oxygen saturation and heart rate and peripheral oxygenation across infants over time covarying for caffeine use, probe location, and gestational age at birth?

2. Cerebral Oxygen Saturation and Infant Position In Stable NICU

Infants

Infants in the neonatal intensive care unit (NICU) are completely dependent on nurses for care. Repositioning is one care task that nurses perform for infants every 3 to 4 hours and each position change may result in an alteration in cerebral blood flow (Cowan & Thoresen, 1985; Pamphlett et al., 1999; Watson, 1974). Specific head or body positions may compress or occlude cerebral vasculature, possibly contributing to brain damage in premature infants (Inder & Volpe, 2004). Therefore, identification of changes in cerebral blood flow related to various infant positions would assist NICU clinicians in determining the best positions to maintain stable infants' cerebral blood flow and reduce brain damage.

Cerebral oxygen saturation monitoring may be a useful method to indirectly measure cerebral blood flow in various positions. Cerebral oxygen saturation, measured by a cerebral oximeter, is the amount of oxygen present in arteries and veins of the brain (Bruns, Norwood, Bosworth, & Hill, 2009). Although cerebral oximetry is becoming more commonplace in NICUs, cerebral oxygen saturation monitoring is not currently standard of care. Most information about cerebral oximetry is available from adult (Belzberg et al., 2007; Colombo et al., 2008; Rubio et al., 2008; Vohra, Modi, & Ohri, 2009) and animal studies (Klaessens, Hopman, Liem, van Os, & Thijssen, 2005; Sakata, Grinberg, Grinberg, Springett, & Swartz, 2005). Only in the last few years have commercial cerebral oximeter probes been manufactured small enough for infant heads. Therefore, previous studies examining at cerebral oxygen saturation in NICU infants

have been limited in number and initially focused on infants with cardiac problems (Brazy, Lewis, Mitnick, & Jobsis-Vander Vliet, 1985; du Plessis & Johnston, 1999) and understanding cerebral hemodynamics (Cope & Delpy, 1988; du Plessis, 1995).

Few of the studies with infants have examined the effect of position on cerebral oxygen saturation. Using Doppler ultrasound to view vessels in healthy preterm infants, cerebral blood flow velocity was found to be lower in prone position than supine (Eichler et al., 2001; Vogelberg et al., 2004), and blood flow increased with age in both prone and supine positions (Eichler et al., 2001). Measured by near-infrared spectroscopy, cerebral oxygen saturation responded similarly with lower levels in a prone versus supine position. Other researchers suggested that the supine position drastically slowed cerebral venous blood flow in stable preterm infants causing venous pooling that worsened during apneic events compared to infants in prone position (Pichler, Schmolzer, et al., 2001). In still other studies, a midline head position and body tilting have been shown to increase cerebral blood flow compared to a horizontal or head turned position in both stable and critically ill preterm infants (Emery & Peabody, 1983). When preterm infants' heads were turned to the right or left, blood flow was lower than in a midline head position (Emery & Peabody, 1983). An elevated head, also known as body tilting, can decrease cerebral blood flow in healthy preterm infants (Pichler, van Boetzelar, et al., 2001) due to decreases in intracranial pressure as gravity pulls blood away from the head. These differences were not significant once the infant's head was elevated 30°. Other studies challenge this conclusion, finding no differences in cerebral blood flow due to positioning in critically ill preterm infants (Pellicer et al.,

2002; Yodh, 2009) or any significant cerebral hemodynamic changes between a flat, tilted, or prone position in stable preterm infants (Ancora et al., 2010).

The contradictory findings of these studies prohibit drawing conclusions about the best position in which to place infants to promote optimal cerebral blood flow and oxygenation. In addition, previous studies have examined only one or two positions and methods to measure cerebral blood flow varied between studies. Comparing multiple positions in the same study using the same measures will help clarify which position leads to an increase or decrease in cerebral oxygen saturation. Therefore, the aim of this study was to examine how cerebral oxygen saturation was affected by five different positions frequently used by NICU nurses: a) supine, head midline, 0° elevation; b) supine, head turned 45° to the left; c) supine, head turned 45° to the right; d) supine, head midline, elevated 15°; and e) prone, head turned 90° to the right, 0° elevation. Since positioning protocols have not been established based on cerebral oxygen saturation, stable NICU infants were chosen as the best infant population to safely examine multiple positions.

This study was guided by the theory of probabilistic epigenesis, a developmental systems theory, which emphasizes reciprocal interactions between the internal and external environments during development. The internal environment was represented by cerebral oxygen saturation and the external environmental influence was considered to be infant position. Also, cerebral blood flow and oxygenation are influenced by an infant's age (Eichler et al., 2001; Toet, Lemmers, van Schelven, & van Bel, 2006; Vogelberg et al., 2004) and as a result, post-menstrual age was added as a covariate.

2.2 Methods

2.2.1 Setting and Sample

The setting for this study was a 62-bed Level III NICU that cares for over 800 infants every year. Nine infants born between 2008 and 2010 with a weight at study entry greater than 2.5 kg were recruited for study participation. Infants weighing 2.5 kg or more not currently requiring respiratory support were studied to ensure the infant would be able to tolerate the manipulations. Infants may have previously required respiratory support by either mechanical ventilation or continuous positive airway pressure (CPAP), but study participation did not begin until the infant no longer required respiratory support and was deemed stable by the attending physician. Infants with identified neurological, gastrointestinal, or cardiovascular anomalies were excluded to decrease the effects of abnormal anatomy. Infants were primarily male (67%) and Caucasian (67%) with a mean birth weight of 2.76 kg. The average gestational age was 34+5/7 weeks and at the time of the first observation, the average post-menstrual age was 38+6/7 weeks (34-42 weeks PMA). Of the nine infants, one infant was diagnosed with periventricular leukomalacia, one infant with Trisomy 21, two infants had grade IV intraventricular hemorrhage, and two infants had undergone body cooling for hypoxic-ischemic encephalopathy (HIE).

2.2.2 Measures

2.2.2.1 Cerebral oxygen saturation. The FORE-SIGHT™ Cerebral Oximeter measured cerebral oxygen saturation every 2-seconds for 90 minutes during each observation time period. The FORE-SIGHT™ Cerebral Oximeter is a noninvasive instrument that measures cerebral oxygen saturation as a percentage ranging from 0 to

100%. The percentage reflects the amount of oxygenated hemoglobin out of the total hemoglobin measured by the oximeter probe and this instrument has been validated with full-term infants (Benni et al., 2005; Rais-Bahrami et al., 2006).

2.2.2.2 Infant position. Position was considered the independent variable and infants were placed in five different positions throughout the observational period. Table 2 shows the time period, order of position, and observed mean cerebral oxygen saturation levels per position. The first, third, and fifth time periods were assigned a supine, head midline position, considered a neutral and consistent position to return to after every head position change. For the second and fourth time periods, infants were randomized to a 45° head turn to the left or right side verified by the use of a 45° angled pillow. Infants remained in a supine, head midline position for the sixth time period with the addition of a 15° elevated head. Infants were positioned prone with their head turned to the right for the final position that lasted 30 minutes.

2.2.2.3 Post-menstrual age. Post-menstrual age (PMA) was calculated as gestational age at birth plus the number of weeks since birth and was used as a covariate to control for maturation. Gestational age was determined from either the first day of a woman's last menstrual period or an obstetric ultrasound to calculate expected date of confinement (EDC). If these dates differed by more than 2 weeks from the Ballard assessment of gestational age at birth, the results of the Ballard were used to determine gestational age (Ballard et al., 1991).

2.2.2.4 Time. Time was represented as the amount of time in each position over the observation period, measured in 1-minute intervals.

Table 2. Infant Positions and Time

Position	Time in Position	Time Used in Analysis ^a	Mean Cerebral Oxygen Saturation (Range)
Supine, head midline	10 minutes	8 minutes	78.3% (65.1-88.8)
Supine, head position randomized to left or right	10 minutes	8 minutes	77.5% (63.1-88.9)
Supine, head midline	10 minutes	8 minutes	78.6% (67-85.5)
Supine, head turned opposite of first turned head position	10 minutes	8 minutes	78.2% (69.2-86)
Supine, head midline	10 minutes	8 minutes	78.4% (68.5-86.3)
Supine, head midline and elevated 15°	10 minutes	8 minutes	78.3% (64.5-88.8)
Prone, head to right	30 minutes	8 minutes	78.4% (70.2-87.5)

^a Washout period of 2 minutes removed from the beginning of each position

2.2.3 Procedures

The institutional review board of the medical center approved this study and parental consent was obtained to enroll each infant. Nine infants contributed 12 observations since the observation was repeated for infants who continued to be hospitalized 1 week after the first observation point. Observations were scheduled to occur between feedings or scheduled nurse assessment times and at a time when parents did not plan to interact with their infant. Cerebral oxygen saturation was collected for a total of 90-minutes as the infant was placed in five different positions. A 90-minute observation time was chosen to fit between the anticipated every 3-hour nursing

assessment and also allowing for sufficient time within a position before changing to a subsequent position. Five positions were chosen for this study to assess varying levels of possible vessel compression or changes in cerebral pressures. For example, Poiseuille's law states that blood flow is dependent on vessel diameter (Pichler, Schmolzer, et al., 2001). When vessel diameter decreases, less blood flow is permitted to pass through the vessel. An infant placed in a certain position may increase or decrease vessel diameter, which will result in more or less blood flow.

A cart was brought to the infant's bedside that carried a FORE-SIGHT™ Cerebral Oximeter and laptop. The cerebral oximeter was connected to the infant using a cerebral oximeter probe. Although a difference has been shown to exist between different regions of the brain (Lemmers & van Bel, 2009), the literature does not currently support monitoring one side of the forehead over the other. Therefore, the cerebral oximeter probe was placed on the infant's left side of his/her forehead, left of midline, and 1 cm above the brow since language development would be of interest for a potential follow-up study. An elastic band secured the probe and was used to minimize the risk of skin breakdown that would have occurred with adhesive tape. The cerebral oximeter transmitted data in real-time through a USB extension cable to the laptop to produce a Microsoft Office Excel file. Infants were randomized to either a left or right turned head for the first turned head position and then assigned the opposite turned head for the second turned head position. At the end of the assessment, the cerebral oximeter probe was removed from the subject's forehead. This identical assessment was repeated 1 week later if the subject was not discharged from the hospital.

2.2.4 Data Analysis

Due to the longitudinal nature of the cerebral oxygen saturation data, general linear mixed models were used to examine cerebral oxygen saturation during five different infant positions. Cerebral oxygen saturation data was collected every 2-seconds during each 90-minute observation. Each observation contained roughly 2700 2-second data points that were averaged into 1-minute means resulting in approximately 90 1-minute mean time points per observation. A handling or carry over effect, the effect of a previous position affecting the subsequent position, was a concern since all infants in this study experienced a sequence of position changes. In order to compare cerebral oxygen saturation between positions, the first 2-minutes of each position was removed from the analyses so eight 1-minute time points remained for each position. For analyses, post-menstrual age was calculated by subtracting post-menstrual age of the youngest infant in the study, 34 +6 days old, from each infant's post-menstrual age so that the intercept equaled the value at 34 +6 days post-menstrual age. Quadratic and cubic effects of time along with time-by-position interactions were examined.

A general linear mixed model compared the last 8-minutes of cerebral oxygen saturation in the second supine, head midline position, since it is considered to be a neutral position, to the last 8-minutes of the six other positions. The six comparisons were 1) the first supine, head midline position versus the second supine, head midline position; 2) the first turned head position versus the second supine, head midline position; 3) the second turned head position versus the second supine, head midline; 4)

the third supine, head midline position versus the second supine, head midline position; 5) the second supine, head midline position versus a supine, head midline position elevated with a 15° elevation, and 6) prone position versus the second supine, head midline position.

A backwards step-wise regression technique was chosen to obtain a final reduced model. The analysis contained a full model that included all six positions along with time, the quadratic and cubic forms of time, and the interaction between each time variable and position. Parameters with greater than a 0.05 probability level were removed from the model taking into consideration lower level parameters such that the quadratic effect of time was not removed if an interaction between a position and time² was significant. A final model was achieved when all non-significant parameters were removed from the model. SAS output and code are located in Appendix 1.

2.3 Results

Table 3 displays the reduced model that includes all comparisons. The analyses between the six position comparisons identified only one statistically significant position difference. Infants placed in the third supine, head midline position, had significantly higher cerebral oxygen saturation values than when placed in the same position 20-minutes earlier. No other position or its interaction with time was found to be significantly different from the second, supine head midline position. Post-menstrual age was non-significant (See Appendix A for SAS output).

Table 3. Mixed Model Results: Comparison of Five Infant Positions to a Neutral Position- Supine, Head Midline

Position Comparisons	Parameter Estimate	SE	p-value
Intercept ^a	78.4	3.37	< .001
First Supine, Head Midline Position vs Second Supine, Head Midline Position	0.29	0.73	0.7
First Turned Head Position vs Second Supine, Head Midline Position	0.98	0.6	0.13
Second Turned Head Position vs Second Supine, Head Midline Position	0.37	0.49	0.47
Third Supine, Head Midline Position vs. Second Supine, Head Midline Position	2.43	0.77	< 0.05
Supine, Head Midline, Elevated 15 vs Second Supine, Head Midline Position	0.32	0.62	0.61
Prone Position vs Second Supine, Head Midline Position	0.15	0.62	0.81
Time ^b	-0.28	0.14	0.06
Time ²	0.02	0.01	0.08
Third Supine, Head Midline Position* Time	1.07	0.32	< 0.05
Third Supine, Head Midline Position* Time ²	-0.1	0.04	< 0.05
PMA	0.77	0.58	0.18

^a Intercept begins at 34 +6 weeks post-menstrual age

^b Time in 1-minute means

Additionally, the third, supine head midline position had a significant time-by-position interaction with the linear and quadratic forms of time. In the third supine, head midline position, cerebral oxygen saturation significantly increased over the first 3 of 8 minutes and then slowly decreased in the last 5 minutes compared to the stable cerebral oxygen saturation in the second supine, head midline position (Figure 2).

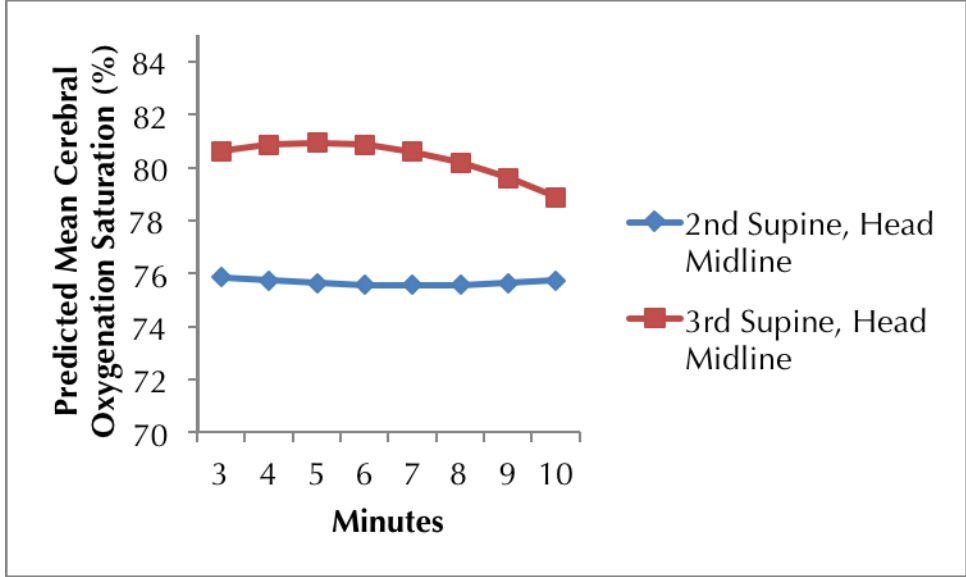


Figure 2. The Effect of Time on Cerebral Oxygen Saturation in the 3rd Supine, Head Midline Position vs the 2nd Supine, Head Midline Position By Minute

2.4 Discussion

This study compared the effects of five different infant positions on cerebral oxygen saturation to a neutral supine, head midline position in nine stable infants. No statistical differences were found except with the third time the infant was placed in the supine, head midline position when compared to the second supine, head midline position. In general, the same position should yield the same cerebral oxygen saturation levels. Yet cerebral oxygen saturation (third supine, head midline) was 2% higher when the infants were in the same position only 20-minutes later and even higher (3-5%) over time. When the infant had been placed in the third supine, head midline position, 42-50 minutes of time had past and the infant had been touched a minimum of five times for each position change. These infants were late preterm or term infants based on post-menstrual age. The amount of tactile stimulation experienced by these infants may have exceeded what is advised for developmental care (Als et al., 1986), which could

affect the metabolism of oxygen even in these older and more stable infants. An increase in stimulation should increase oxygen demand and consumption (Dunser & Hasibeder, 2009) resulting in lower cerebral oxygen saturation as cerebral oxygenation predominantly reflects the percentage of saturated hemoglobin in the venous vasculature. In contrast, cerebral oxygen saturation values were higher later in the positioning sequence, but only for the third supine, head midline position. It is unlikely but possible that in the third supine position infants had been able to adjust to the stimulation, but by the fourth position change, infants' ability to compensate was overwhelmed and 'shut down'.

Another possible explanation for these findings is due to changes in hemoglobin level. A similar study with sequenced position changes looked at the effects of position on cerebral oxygen saturation in premature infants (Ancora et al., 2010) and found no difference with position on cerebral oxygen saturation. Within their sequenced positions, the position following two head turns had the highest hemoglobin level of all other tested positions, which is the same timing as this study's positioning sequence when the third supine, head midline position was significant. Cerebral oxygen saturation is calculated based on the amount of oxygenated hemoglobin out of the total hemoglobin (deoxygenated + oxygenated hemoglobin). If total hemoglobin levels were higher, but cerebral oxygen saturation remained unchanged, more deoxygenated hemoglobin must have entered the pathway of the cerebral oximeter probe. Hemoglobin levels were not measured in the current study, but the amount and type of hemoglobin (fetal or adult) and its affinity to oxygen may be another factor that needs to be taken into consideration when examining cerebral oxygen saturation.

The results of the current study are limited based on the observation time length, the restrictions of using mixed models, and the positions examined. In selecting the time frame for observation, overstimulation and interfering with nursing care were a concern (Als et al., 1986). One 90-minute observation captures only a small window of time compared to the time an infant stays in the NICU. The weight restriction of > 2.5 kg made it difficult to include multiple observations as infants this size are often close to discharge and only three of nine infants contributed a second observation. More frequent and shorter observation times measuring cerebral oxygen saturation in different positions with infants of various weights may uncover differences not revealed in one or two time points with larger infants. Consequently, these results can only be generalized to older, more stable NICU infants and not to premature infants less than 34 weeks post-menstrual age.

Each observation averaged approximately 2,700 2-second time points that were averaged to 56 1-minute time points. A general linear mixed model was chosen to analyze the data in order to take into account the multiple time points and the possible effects of time. However, small changes in cerebral oxygen saturation values may have been lost when the data were averaged. The cerebral oximeter provided a sampling rate of 2-seconds; yet mixed models in SAS were unable to converge thousands of data points with only 9 subjects and 12 observations. Therefore, the statistical method was unable to capture the potential sensitivity of the cerebral oximeter. Statistical methods to analyze thousands of time points per observation such as time series analysis may be more accurate and able to identify precise changes of cerebral oxygen saturation.

Lastly, only five positions were examined in this study compared to the many positions nurses place infants in during their hospital stay. Additional positions, such as right or left lateral, may show other differences when compared to a supine, head midline position. Before assumptions can be made about the effects of positioning on cerebral oxygen saturation more positions typically used in the NICU need to be examined.

Previous studies report vascular compression and disruption of blood flow as a primary problem with non-midline positions when examining the effects of cerebral blood flow and positioning in NICU infants (Eichler et al., 2001; Emery & Peabody, 1983; Pichler, Schmolzer, et al., 2001; Pichler, van Boetzlar, et al., 2001; Vogelberg et al., 2004). In this study and others (Ancora et al., 2010; Pellicer et al., 2002; Yodh, 2009), cerebral oxygen saturation measures changed minimally with changes in infant position. Cerebral blood flow may have been compromised in the selected positions, but cerebral oxygen saturation was preserved. These infants were able to maintain stable cerebral oxygen saturations according to a cerebral oximeter and compensation may have occurred with cerebral blood flow increasing or decreasing depending on position. These findings indicate that stable NICU infants' cerebral oxygen saturation may not be affected by position. Lower birth weight infants who are critically ill may react differently physiologically. Maturation in cerebral oxygen saturation may present itself if measuring cerebral oxygen saturation had occurred earlier in life and repeatedly over time. Examining the effect of varied positions on cerebral oxygen saturation in critically ill infants may warrant different findings and are necessary to examine before practice decisions are changed.

3. The Developmental Trajectory of Cerebral Oxygen Saturation in Premature Infants

Intraventricular hemorrhage, (IVH), characterized as bleeding in the germinal matrix primarily during the first week of life (Madan, Hamrick, & Ferriero, 2005), occurs in 1 in 4 premature infants probably due to fluctuations in cerebral perfusion (Inder & Volpe, 2004). However, clinicians have no method to monitor cerebral perfusion changes in infants at risk for IVH. If IVH is a result of fluctuations in cerebral blood flow, cerebral oxygen saturation as a proxy for cerebral blood flow may provide noninvasive screening at the bedside for impending IVH. Thus, infants who later develop IVH would be expected to have patterns of cerebral oxygen saturation that differ from those who do not develop IVH. If cerebral oxygen saturation patterns can be related to risk for an IVH, cerebral oxygen saturation could be used to detect an imminent IVH and lead to research on preventative interventions.

Currently, neonatal intensive care units (NICU) across the country are introducing cerebral oximeters to measure cerebral oxygen saturation, the amount of oxygen present in the cerebral vasculature (Bruns et al., 2009). These values provide noninvasive, continuous, real-time data for care decisions and observation of the effects of interventions on cerebral vasculature functioning. However, to effectively implement this instrument in clinical practice, knowledge of normative values of cerebral oxygen saturation is necessary, but normative values have only been examined in two studies (McNeill et al., 2011; Roche-Labarbe et al., 2012). Neither study examined normative values using the FORE-SIGHT Cerebral Oximeter. Currently, reported cerebral oxygen saturation values for premature infants during the first day of life range widely

from 55.1% to 96.4% (Sorensen & Greisen, 2009). Cerebral oxygen saturation values decreased over the next 2 weeks of life to values as high as 66% (Verhagen, Keating, ter Horst, Martijn, & Bos, 2009) and as low as 57% (Roche-Labarbe et al., 2010). These values provide a starting point; yet these studies did not describe the mean cerebral oxygen saturation values for premature infants at varying postnatal or gestational ages, nor did they describe how cerebral oxygen saturation values changed as a premature infants matured over hospitalization, which averages 20 days (Kornhauser & Schneiderman, 2010). Thus, longitudinal examination is needed to capture the development of cerebral oxygen saturation values as premature infants mature and to supply clinicians with typical cerebral oxygen saturation values to guide care decisions.

Limited research has focused on identifying IVH risk using cerebral oxygen saturation monitoring. Through the use of optical tomography, the amount of deoxygenated hemoglobin was found to be higher on the same side of the brain as the IVH than on the unaffected side (Austin et al., 2006). The formula for calculating cerebral oxygen saturation values divides the amount of oxygenated hemoglobin by the total hemoglobin, which is comprised of oxygenated and deoxygenated hemoglobin (Owen-Reece et al., 1999). If deoxygenated hemoglobin increases on the ipsilateral side of an IVH, then the cerebral oxygen saturation values will decrease and cerebral oxygen saturation values will be lower compared to levels in unaffected cerebral locations. Differences in cerebral oxygen saturation values for infants with and without IVH have been confirmed in one prospective study with 73 premature infants on the first day of life (Sorensen, Leung, & Greisen, 2008). Cerebral oxygen saturation values ranged from 67.7% to 82.1% for infants without IVH and 53.3% to 86.4% in infants with an IVH

(Sorensen, Leung, et al., 2008). Studies in the literature measured cerebral oxygen saturation using different cerebral oximeter devices. Caution should be taken in comparing values between studies as different cerebral oximeter prototypes use dissimilar algorithms to calculate cerebral oxygen saturation. Further research is needed that considers infant age and examines cerebral oxygen saturation values past the first day of life.

In addition to maturation, caffeine and the location of the cerebral oximeter probe may also affect measures of cerebral oxygen saturation. Caffeine is a methylxanthine drug prescribed to premature infants with apnea of prematurity (O'Donnell, Stone, & Morley, 2002). Most recently it was shown to decrease cerebral oxygen saturation values in premature infants less than 34 weeks gestational age (Tracy, Klimek, Hinder, Ponnampalam, & Tracy, 2010). Variations in cerebral oxygen saturation values also exist between different regions of the brain due to oximeter probe placement differences. The right frontal hemisphere produced higher cerebral oxygen saturation values than the left frontal hemisphere (Lemmers & van Bel, 2009). Therefore, the location of the cerebral oximeter probe must be considered if the study includes a change in probe location from the right to the left frontal lobes.

The current study was guided by the theory of probabilistic epigenesis, a developmental systems theory that focuses on the reciprocal interactions between physiologic maturation and the external environment and their effects on health outcomes. Environmental effects were represented by caffeine; physiologic maturation was represented by postnatal age, gestational age, and longitudinal measures of cerebral oxygen saturation values; and IVH was chosen as a health variable. The purpose of this

study was to a) to determine the developmental trajectory of cerebral oxygen saturation during the hospitalization period of premature infants born less than 32 weeks gestational age after covarying for gestational age at birth, probe location, and receipt of caffeine and b) to describe how an IVH diagnosis affected the developmental trajectory of cerebral oxygen saturation values.

3.2 Methods

3.2.1 Participants

A convenience sample of 24 premature infants was enrolled in this study over a 1-year timeframe from November 2010 to 2011. The sample size obtained for this study exceeded or was similar to the sample size in other studies that longitudinally examined cerebral oxygen saturation values in premature infants (McNeill et al., 2011; Roche-Labarbe et al., 2010; Verhagen et al., 2009). All infants born at Duke University Hospital who were less than 32 weeks gestational age were considered for inclusion. This gestational age range was chosen because this age group is most at risk for intraventricular hemorrhage and other neurological issues, which may be identified by altered cerebral oxygen saturation values (Blackburn & Ditzenberger, 2007; Inder & Volpe, 2004; Madan, Hamrick, et al., 2005). Infants with identified anomalies affecting the neurological, gastrointestinal, or cardiovascular systems were excluded from the study to decrease confounding effects of abnormal anatomy that may affect cerebral oxygen saturation values. Furthermore, infants born elsewhere and transferred to Duke University Hospital were excluded because it was difficult to obtain consent within the first 48 hours of life. Also, unlike infants born in-house, infants transported from other institutions experience additional stressors related to neonatal transport, which may

have confounded cerebral oxygen saturation results (Markakis et al., 2006; Ohning, 2006).

3.2.2 Measures and variables

To describe developmental trajectories of cerebral oxygen saturation values in premature infants, cerebral oxygen saturation was measured longitudinally because cerebral oxygen saturation is hypothesized to mature with postnatal age of the infant (Roche-Labarbe et al., 2010; Tina et al., 2009). Moreover, mean cerebral oxygen saturation values were compared between infants with and without a diagnosis of IVH. This comparison shows the extent to which infants with IVH exhibit different trajectories of cerebral oxygen saturation values than infants without an IVH.

3.2.2.1 Cerebral oxygen saturation values. Cerebral oxygen saturation values, measured by a cerebral oximeter, are the percentage of oxygen present in arteries and veins of the brain (Bruns et al., 2009). The FORE-SIGHT™ Cerebral Oximeter was used to noninvasively measure cerebral oxygen saturation values for each 20-minute observation. The FORE-SIGHT™ Cerebral Oximeter consisted of an oximeter probe attached to a monitor cable that was connected to a cerebral oximeter monitor. At one end of the oximeter probe, a laser light was sent to penetrate the skull and cerebrum (Brazy & Vander-Vliet, 1989) and a light detector on the other end of the oximeter probe received the laser light sent from the light source. Using a modified Beer-Lambert law (Owen-Reece et al., 1999), the percentage of cerebral oxygen saturation within the arteries and veins was automatically calculated from the difference in light received and sent from the two ends of the oximeter probe. Cerebral oxygen saturation values ranged from 0% to 100% in whole numbers and were displayed on the cerebral oximeter screen. A laptop with software

created exclusively for this study downloaded 1-second cerebral oxygen saturation values from the FORE-SIGHT™ Cerebral Oximeter to a Microsoft® Office Excel spreadsheet in real-time.

3.2.2.2 Intraventricular hemorrhage (IVH). Intraventricular hemorrhage was defined as a routine head ultrasound finding of blood within or around the ventricles of the brain (Madan, Hamrick, et al., 2005), diagnosed by a pediatric radiologist. At study completion, the electronic medical record was reviewed for the presence or absence of an IVH diagnosis for each infant because IVH is not diagnosed until 7 days of life or later. Therefore, the actual timing of the development of an IVH is unknown. Since all infants' IVH diagnoses were mild (grade I), the IVH variable was coded into two categories (0 for no IVH, 1 for any grade of IVH).

3.2.2.3 Post-natal age (PNA). PNA was used as a measurement of time and was calculated as the number of days since birth.

3.2.2.4 Covariates. This study controlled for one time invariant covariate, gestational age, and two time varying covariates, probe location and caffeine, thought to impact the developmental progression of cerebral oxygen saturation values.

3.2.2.4.1 Gestational age. Gestational age was determined from the expected date of confinement calculated for either the first day of a woman's last menstrual period or an obstetric ultrasound. If these dates differed by more than 2 weeks from the Ballard assessment of gestational age at birth, the Ballard was used to determine gestational age (Ballard et al., 1991).

3.2.2.4.2 Probe location. Infants were placed in a second randomized position after the supine, head midline position examined in this analysis. The cerebral oximeter probe

was placed either right or left of center on the forehead above the brow. The chosen probe location was dependent on which side of the forehead would potentially detect the most change in cerebral oxygen saturation values in the second randomized position. For example, an infant turned from the supine, head midline position to a prone position with their head turned to the left would have had left sided cerebral oxygen saturation monitoring. Probe location was dummy coded as a 0 for the left side and 1 for the right side.

3.2.2.4.3 Caffeine. Caffeine use changes throughout an infant's hospitalization. At each observation, any route of caffeine administration was documented from the medication administration record. Infants who received a therapeutic dose of caffeine, 5-8 mg/kg (Young & Mangum, 2003), within 24 hours of an observation were assigned a 1 and those infants who do not receive caffeine or who received less than a therapeutic dose were assigned a 0. Each infant had the potential to be counted as a recipient of caffeine or not for each observation.

3.2.2.5 Demographic variables. Maternal and infant demographic variables were collected from electronic medical records for the purpose of describing the research sample. Maternal health characteristics such as age and medications used during pregnancy and infant characteristics including gender and birth weight at the time of infant enrollment were gathered.

3.2.2.6 Procedures. Institutional Review Board approval was obtained and parental consent was acquired prior to study enrollment. Observations took place at the infant's bedside in the NICU once between 2 and 48 hours of life, once between 49 and 96 hours of life, on Day of Life 7, and every 7 days thereafter until discharge from Duke University Hospital or 40 weeks post-menstrual age, whichever came first. The 46-hour

window of time for the first observation provided hospital personnel time to stabilize the infant. The three observations in the first week of life were analyzed to identify changes in cerebral oxygen saturation values during the transition from fetal to extrauterine life and to describe differences in cerebral oxygen saturation trajectories between infants with and without IVH since most IVH occurs during the first week of life (Inder & Volpe, 2004). Thereafter, weekly cerebral oxygen saturation values were collected to describe how cerebral oxygen saturation values changed over the course of a premature infant's hospital stay. Observations occurred between feedings or scheduled nurse assessment times. If an infant required surgery, the observation was postponed for 2 days to decrease the effects of anesthesia and post-operative recovery on study results. If the infant was unable to tolerate the study procedures for the scheduled day, observation was postponed until the next day and the times for subsequent observations were changed and calculated from this new day.

A cart was brought to the infant's bedside for each observation that carried the instrumentation required for this study (cerebral oximeter and a laptop). The FORE-SIGHT™ Cerebral Oximeter was connected to the infant via a cerebral oximeter probe placed on the infant's left or right side of his/her forehead and above the brow using an elastic headband to secure the probe during each observation. An elastic band was used to secure the probe, because unlike adhesive tape, it does not cause skin breakdown. The FORE-SIGHT™ Cerebral Oximeter was connected to a laptop using a USB extension cable. Data transmitted from the FORE-SIGHT™ Cerebral Oximeter to the laptop to produce one Microsoft Office Excel file.

Observations began 10-minutes after applying the cerebral oximeter probe to the infant as a prior study showed patient manipulation may affect cerebral oxygen saturation values for the first few minutes (Mann, Holditch-Davis, & Brandon, 2010). Observations occurred in a supine, head midline position for 20-minutes during the first part of each observation period.

3.2.4 Data analysis

Two statistical methods were used to describe the developmental trajectory of cerebral oxygen saturation in premature infants born less than 32 weeks gestation. State space time series analysis was the first method to examine the nature of cerebral oxygen saturation values within an individual infant over each 20-minute observation. With this approach, we modeled various components of the variability in cerebral oxygen saturation values over time including trends and cycles. The state-space approach identified the trajectory of cerebral oxygen saturation values for each infant without imposing constraints on the form of the trajectory.

The second method used general linear mixed models with SAS 9.3 to describe the developmental trajectories of cerebral oxygen saturation values over hospitalization. The second analysis method modeled variation across infants and compared trajectories between infants with and without an IVH diagnosis. The trajectory of cerebral oxygen saturation values for each infant was estimated with postnatal age as the time variable and adjusting for gestational age, probe location, and receipt of caffeine. Over the year of collecting data, combined electronic and manual observations of cerebral oxygen saturation values occurred 27% of the time due to unforeseen laptop issues. The sampling rate for electronic data was 1- and 2-seconds and 30-seconds for manual

observations. The 1, 2, and 30-second cerebral oxygen saturation values were averaged to 1-minute mean values resulting in twenty cerebral oxygenation values for each observation. Thus, for example, an infant with 5 observations contributed 20, one-minute mean values of cerebral oxygenation multiplied by five observations equaling 100 data points to this analysis. One-minute averages were chosen for clinical meaning, as a second-to-second change could be difficult to detect by clinicians. For analyses, gestational age was calculated by subtracting the gestational age of the youngest infant in the study, 25 +5 days old, from each infant's gestational age so that the intercept equaled the value at 25 +5 days gestational age.

General linear mixed models allowed for the inclusion of covariates that varied over time. A hierarchical approach was taken by adding the IVH diagnosis to the analysis of the first week of observations and the analysis of all of the observations to assess whether there was a significant difference in the trajectories between infants with and without an IVH. The first model examined observations during the first week of life with IVH as a predictor and the interactions of time with caffeine, probe location, and IVH were also assessed. In the second model, all observations were included to examine the impact of IVH on the development of cerebral oxygen saturation values during hospitalization. Quadratic effects of time with the interactions of caffeine, probe, and IVH were also added.

3.3 Results

Twenty-four premature infants were analyzed with a mean gestational age of 29 weeks (25.7-31.9 weeks). The sample included two sets of triplets and one set of twins. A second set of twins was enrolled but only one of these infants was included as the

second infant was excluded due to a cardiac defect diagnosed in the first week of life. A total of 138 observations occurred over 30 different postnatal ages ranging from 1 to 77 days (Figure 3). The number of observations ranged from 1 to 13 per infant with an average of 5.75 per infant. Of the 24 infants, seven were diagnosed with IVH, all with a grade I IVH with two of these infants having a resolved IVH by Day of Life 14 and 25.

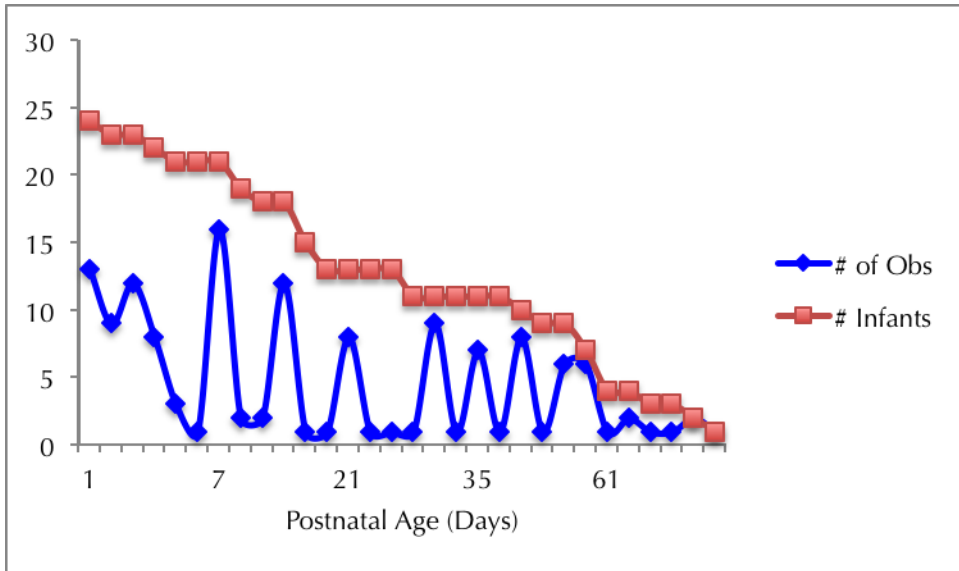


Figure 3. Number of Observations Obtained and Number of Remaining in Study By Postnatal Age

Based on raw means, cerebral oxygen saturation values for all infants began at 78% on the first 2 days of life and then slowly decreased over time to the 60s with fluctuations between 46% and 78% starting around 48 days of life (Figure 4). After 56 days of life, four infants contributed seven observations to the last six observation time points.

3.3.2 Time Series Analysis

Using STAMP software, each observation was assessed using fit statistics (q , Q , AIC) for the best fitting model from the potential six time series analysis models that

were composed of varied combinations of stochastic and fixed level and/or slope. State space time series analysis allowed for the decomposition of each data series for each observation at the 2-second level compared to possible trends reflected in longer periods of time (e.g. week to week changes). A stochastic level, no slope model fit 96% of all observations with the remaining 4% unable to be identified due to insufficient data. A stochastic level, no slope model, also known as a random walk, indicated there was no apparent systematic change of cerebral oxygen saturation values over each 20-minute observation (Commandeur & Koopman, 2007).

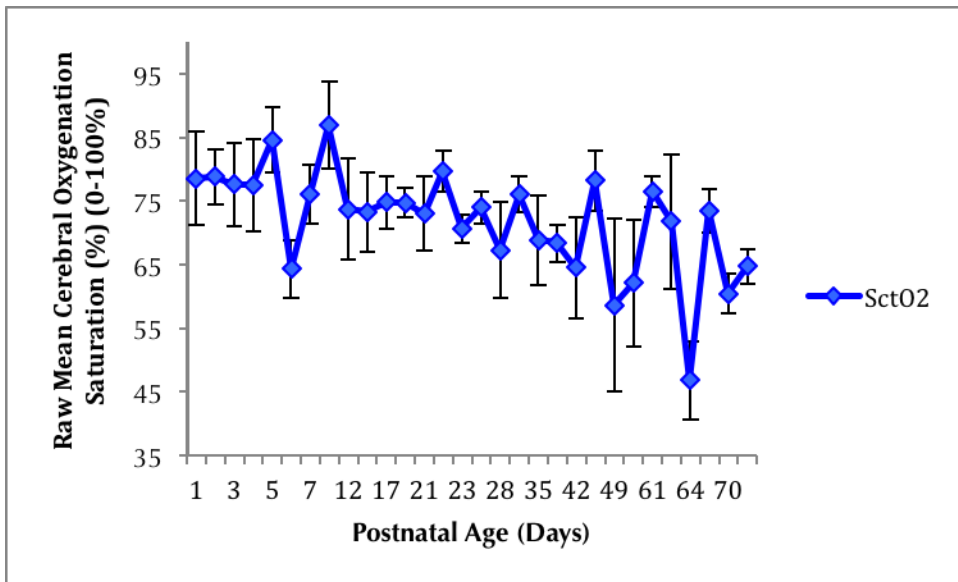


Figure 4. Raw Mean Cerebral Oxygen Saturation Values With One Standard Deviation Over All Observations (N= 138)

3.3.3 Trajectory of Cerebral Oxygenation

A general linear mixed model was used to analyze the trajectory of cerebral oxygen saturation values. In an initial mixed model, one minute means of cerebral oxygen saturation values were the dependent variables with postnatal age as the

primary independent variable. Gestational age, caffeine, and probe location were covariates. Through a backwards step-wise regression, variables were eliminated if $> .05$ alpha. Gestational age and the quadratic interaction of time squared with probe location were not significant (Table 4). Even though the effect of quadratic time on cerebral oxygen saturation was significant, the effects were small (Figure 5). Significant differences in cerebral oxygen saturation existed between the probe located on the right or left frontal lobe. On postnatal day 1, both probe locations measured approximately the same cerebral oxygen saturation (79%), but around postnatal day 27, cerebral oxygen saturation values steadily decreased faster when the left frontal lobe was monitored compared to the right frontal lobe monitoring (Figure 6) (See Appendix B for SAS Output).

Table 4. Mixed Models Results: Mean Longitudinal Measures of Cerebral Oxygen Saturation Over All Observations^e

Variable	Parameter Estimate	SE	p-value
Intercept ^a	79.53	1.12	< .001
Time ^b	-0.28	0.1	< .001
Time ²	0.0001	0.0007	.87
Caffeine ^c	-0.06	0.7	.94
Caffeine x Time	-0.17	0.06	< .01
Caffeine x Time ²	0.005	0.001	< .001
Probe ^d	0.06	0.35	.86
Probe x Time	-0.04	0.01	< .01

^a Intercept equals expected value for all infants starting at 25 +5 weeks

^b Time measured as postnatal age

^c Caffeine = 0 when dummy coded 1 for therapeutic dose, 0 for all other

^d Probe location = 0 when dummy coded 0 for left side, 1 for right side

^e Analysis based on ~ 2,760 data points

Caffeine and the interaction of linear and quadratic effects of time with caffeine were significant (Figure 7). When infants received caffeine, there was a linear decrease

in cerebral oxygen saturation with an increase in postnatal age. Cerebral oxygen saturation had a curvilinear pattern for those infants not receiving a therapeutic dose of caffeine. Cerebral oxygen saturation slowly decreased from 79% to 69% until postnatal day 36 when cerebral oxygen saturation values began to rise.

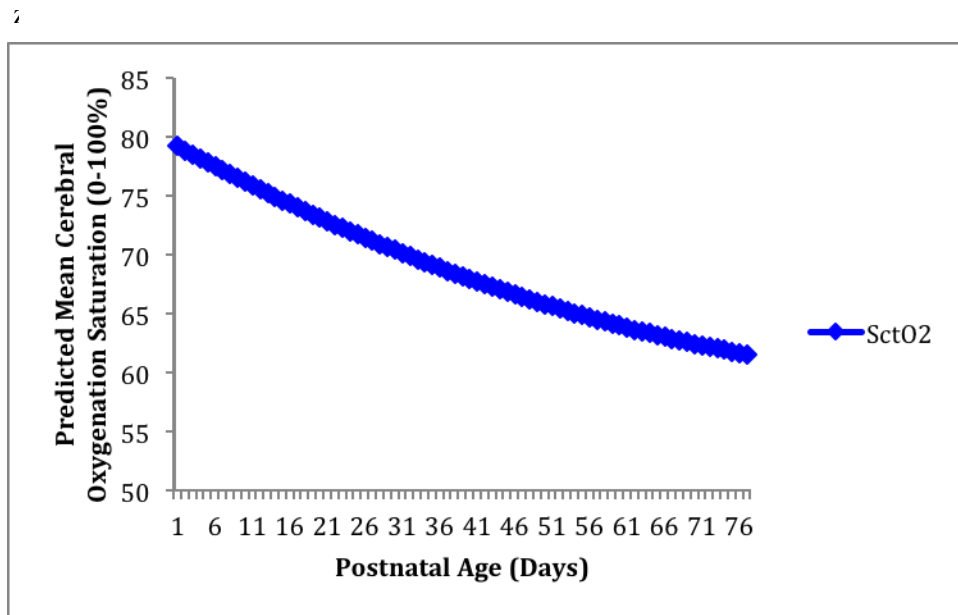


Figure 5. Main Effects of Postnatal Age on Cerebral Oxygenation.

3.3.3.1 IVH Analyses. The IVH analyses included two models: observations in the first week of life only and all observations. The full model for the first week included all variables in the initial model plus the addition of IVH and the linear and quadratic effects of time on IVH. Through a backwards step-wise regression, gestational age and the linear and quadratic effects of time with IVH were not significant at the 0.05 alpha level. Table 5 shows the final IVH model for the first week of life. Cerebral oxygen saturation values during the first week of life did not differ between infants at risk for IVH and those not at risk. Caffeine and probe location had a

significant interaction with time. Those infants who received caffeine on the first day of life had lower cerebral oxygen saturation values than those who did not receive caffeine.

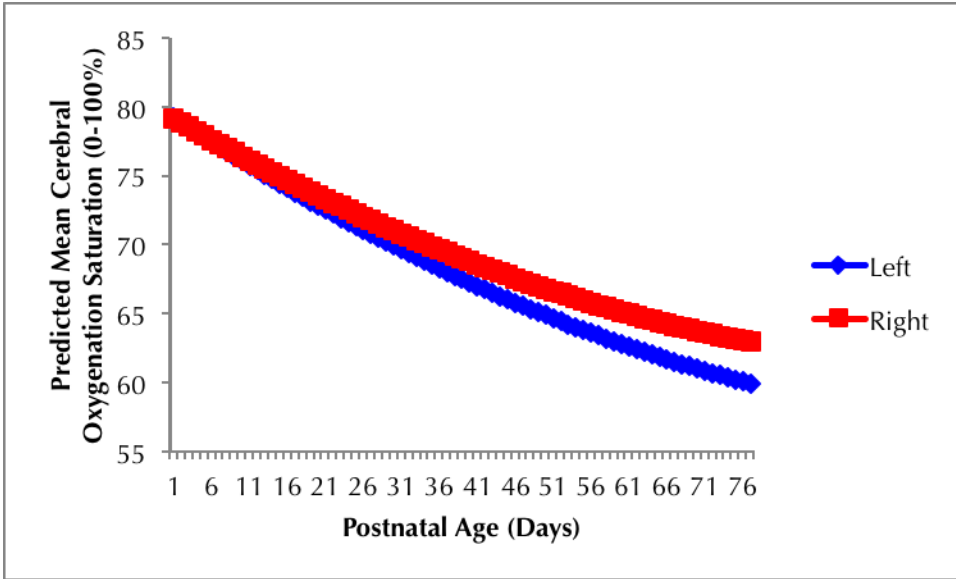


Figure 6. Simple Effects of Postnatal Age on Cerebral Oxygenation by Probe Location.

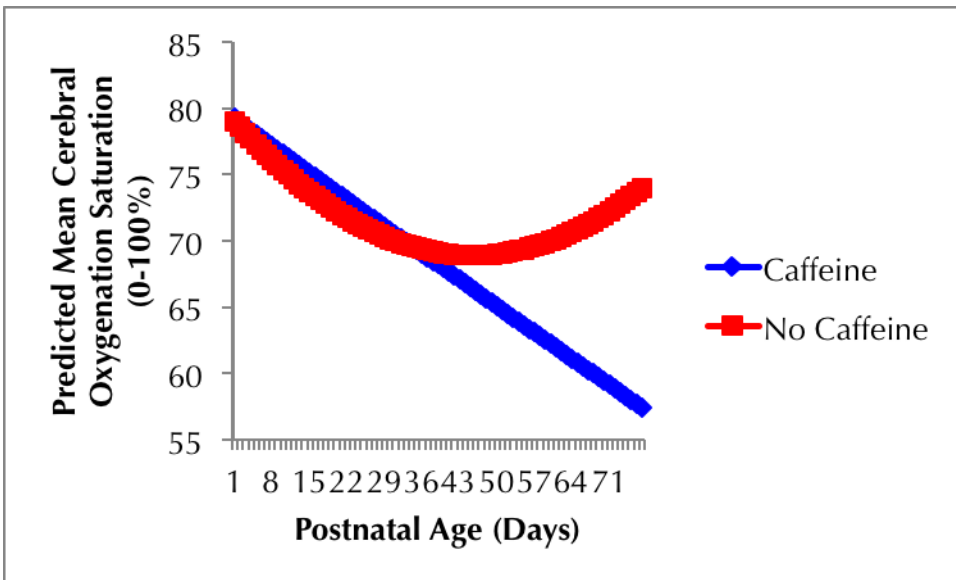


Figure 7. Predicted Mean Cerebral Oxygen Saturation Over All Observations By Caffeine Use (N= 138)

Additionally, cerebral oxygen saturation values in those infants receiving caffeine slowly increased over the first week of life while those who did not receive caffeine had increasing cerebral oxygen saturation values over the first part of the week and then decreased during the second part of the first week of life. Cerebral oxygen saturation values decreased over the first week of life over all infants. However, cerebral oxygen saturation monitored on the right side of the forehead steadily decreased over time while the left side of the forehead produced cerebral oxygen saturation values that increased during the first half of the week and then decreased over the second half of the week (See Appendix C for SAS output).

Table 5. Mixed Models Results: Mean Longitudinal Measures of Cerebral oxygen saturation values in 1st Week of Life: Differences Between IVH (N= 7) and No IVH (N= 17)^f

Variable	Parameter Estimate	SE	p-value
Intercept ^a	88.4	3.09	< .001
Time ^b	-3.32	0.62	< .001
Time ²	0.25	0.06	< .001
Caffeine ^c	-2.8	1.26	.03
Probe ^d	-15.3	1.36	< .001
Caffeine x Time	5.32	0.67	< .001
Probe x Time	5.79	0.79	< .001
Caffeine x Time ²	-1	0.1	< .001
Probe x Time ²	-0.39	0.1	< .001
IVH ^e	-2.13	3.51	0.54

^a Intercept equals expected value for all infants starting at 25 +5 weeks

^b Time measured as postnatal age

^c Caffeine = 0 when dummy coded 1 for therapeutic dose, 0 for all other

^d Probe location = 0 when dummy coded 0 for left side, 1 for right side

^e IVH = 0 when dummy coded 0 for no IVH diagnosis, 1 for IVH diagnosis

^f Analysis based on 1,213 data points

The second IVH model included all observations and used the initial model from Table 4 (time, time², caffeine, caffeine x time, caffeine x time², probe, probe x time) plus IVH and the linear and quadratic effects of time with IVH. Probe location, the interaction of the linear and quadratic forms of time by probe, and gestational age were not significant. Table 6 shows the final IVH analysis model over all observations. Predicted mean cerebral oxygen saturation values over all observations followed a similar pattern to the first week model by steadily decreasing over time (Figure 5). Those infants with an IVH diagnosis had significantly lower cerebral oxygen saturation values compared to those infants without IVH, but this difference did not occur until approximately the third week of life (Figure 8). Caffeine use over all observations significantly decreased cerebral oxygen saturation values similarly to the first week IVH analysis (Figure 7) (See Appendix D for SAS Output).

Table 6. Mixed Models Results: Mean Longitudinal Measures of Cerebral Oxygen Saturation: Differences Between IVH and No IVH Over All Observations^e

Variable	Parameter Estimate	SE	p-value
Intercept ^a	78.86	1.92	< .001
Time ^b	-0.24	0.1	.03
Time ²	-0.003	0.001	< .001
Caffeine ^c	0.26	0.7	.72
Caffeine* x Time	-0.21	0.05	< .001
Caffeine* x Time ²	0.006	0.001	< .001
IVH ^d	0.79	2.34	.73
IVH** x Time	-0.05	0.13	.7
IVH** x Time ²	0.004	0.001	< .001

^a Intercept equals expected value for all infants starting at 25 +5 weeks

^b Time measured as postnatal age

^c Caffeine = 0 when dummy coded 1 for therapeutic dose, 0 for all other

^d IVH = 0 when dummy coded 0 for no IVH diagnosis, 1 for IVH diagnosis

^e Analysis based on 2,621 data points

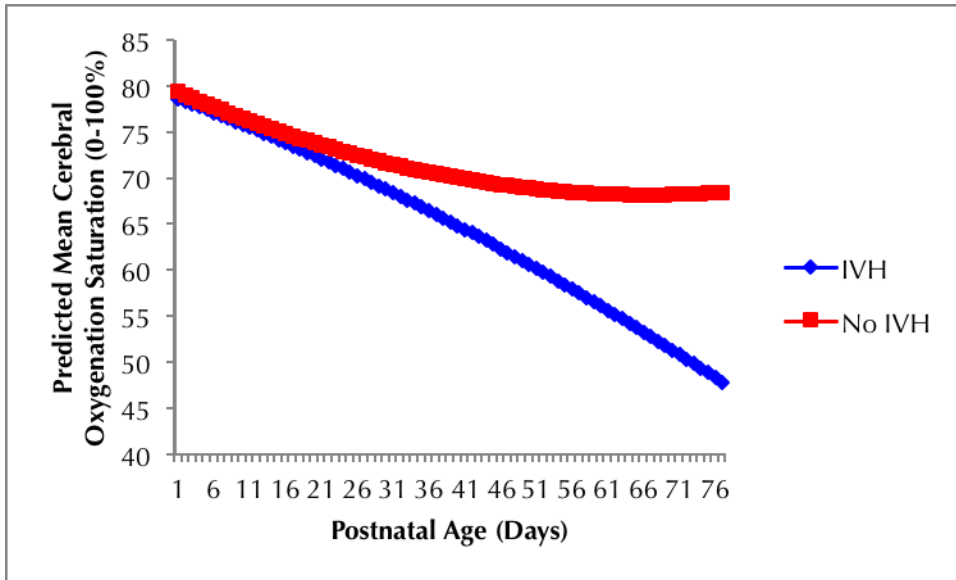


Figure 8. Simple Effects of Postnatal Age on Cerebral Oxygenation by IVH Status: IVH (N= 7) vs. No IVH (N= 17)

3.4 Discussion

This study is the first to describe the trajectory of cerebral oxygen saturation values using the FORE-SIGHT™ Cerebral Oximeter in infants born less than 32 weeks gestational age. Two other longitudinal studies cerebral oxygen saturation reported similar cerebral oxygen saturation values up to 15 weeks in infants between 24 and 37 weeks gestation (McNeill et al., 2011; Roche-Labarbe et al., 2012). These two studies used the INVOS Cerebral Oximeter and a custom-made cerebral oximeter, respectively. Oximeters use different algorithms for calculating cerebral oxygen saturation values (Elser, Holditch-Davis, & Brandon, 2011). Caution has been advised when comparing studies using different cerebral oximeters because of the variations in calculations

(Dullenkopf, Frey, Baenziger, Gerber, & Weiss, 2003). However, this study and the other two studies found similar numeric values for cerebral oxygen saturation.

During the first 2 days of life, cerebral oxygenation averaged in the high 70s and then decreased with age to the mid-60s. The reason why cerebral oxygen saturation values decreased over time is not fully understood. Cerebral oxygen saturation values are mathematically calculated to primarily reflect the presence of oxygen in the venous circulation (Benni et al., 2005). Lower cerebral oxygen saturation values could indicate that more oxygen is being metabolized in the arterial circulation, which would leave less saturated hemoglobin in the venous circulation. Even though cerebral blood flow increased as the infant ages (Kehrer & Schoning, 2009; Meek et al., 1998; Tsuji, Saul, du Plessis, et al., 2000; Volpe, 2001b, 2008), metabolic processes such as ketogenesis, glyconeogenesis, and lipolysis become managed by infants as they transition to the extrauterine life compared to the fetus in utero (Avery, 1974), which increases oxygen consumption. Increased oxygen use would result in higher amounts of deoxygenated hemoglobin or lower amounts of oxygenated hemoglobin, both of which would lead to lower cerebral oxygen saturation values levels over time.

Statistically significant differences occurred between the right side of the forehead and the left side on cerebral oxygen saturation values over time but only during the first week of life. Cerebral oxygen saturation values for the right frontal cortex were higher than values monitored on the left side. Similar findings in previous research indicated that right side frontal cortex monitoring was higher by as much as 10% than the left frontal cortex (Lemmers & van Bel, 2009). Comparable findings with the current study showed a maximum of 3% difference between the right and left frontal

cortex with the right side measuring higher cerebral oxygen saturations. The different values cerebral oxygen saturation values are hypothesized to be due to the right side of the brain being dominant in regulating cerebral oxygen (Lemmers & van Bel, 2009).

Caffeine also had a significant effect on cerebral oxygenation in all models. Lower cerebral oxygen saturation values were expected for those infants receiving caffeine (Tracy et al., 2010) in the first week of life primarily due to a decrease in cerebral blood flow with caffeine use (Cameron, Modell, & Hariharan, 1990; Lunt, Ragab, Birch, Schley, & Jenkinson, 2004). However, in this study, cerebral oxygen saturation during the first week of life, specifically the first few days of life, was higher for those infants receiving caffeine than those infants who did not receive caffeine. The reason for this finding is unknown. Another factor affecting these results might be the clinical approach to caffeine treatment at this study's facility. The caffeine dose was calculated weekly to maintain accurate weight-based doses, and then at 34 weeks post-menstrual age, if the infant was not showing signs of apnea, caffeine was discontinued. In other NICUs, infants may be allowed to grow out of their caffeine dose instead of discontinuing the drug. Caffeine was discontinued as early as 15 days of life and by 59 days postnatal days, no infant was prescribed caffeine.

Cerebral oxygen saturation values were examined for differences between infants with and without an IVH diagnosis during only the first week of life and over the entire hospitalization. Over the entire hospitalization, cerebral oxygen saturation values became significantly lower after the third week of life in those infants with an IVH, which may imply that over time, those infants with an IVH deviate with respect to cerebral metabolism or cerebral blood flow patterns. However, no differences were

found between infants who developed and did not develop an IVH during the first week of life. One of the primary reasons for monitoring cerebral oxygen saturation values during the first week of life in this study was to determine whether or not infants' cerebral oxygen saturation patterns predicted an IVH diagnosis. The literature contradicts the finding of this study as cerebral oxygen saturation values on the first day were found to predict those infants who eventually develop an IVH (Sorensen, Leung, et al., 2008). The study by Sorensen et al. (2008) included infants with minor to severe (grade I-IV) IVH diagnoses, whereas the current study only included infants with grade I IVH. Thus, differences in the results between these two studies may be due to differences in the severity of IVH present in each sample.

Sensor movement and attrition over time limits the generalizability of this study. The oximeter probe was secured in place by a headband and not by adhesive. The probe location was monitored during all observations and if the probe appeared out of place, the probe was quickly readjusted. Cerebral oxygen saturation values when the probe was out of position could have altered the final results, even though there would have been few potentially altered values. Twenty-four infants contributed to 138 observations, but most infants were discharged home or transferred to another hospital before the sixth observation. Therefore, fewer infants contributed to each later time point and the few infants represented at later postnatal ages were sicker infants who had longer hospitalizations compared to healthier infants who were discharged earlier. This pattern reflects the NICU population as premature infants meet discharge criteria at various ages or are sent to other hospitals for step-down care. Thus, the study design captured infants with similar illness severity.

In addition to these limitations, consideration of the maturation of the infants' skull and skin is needed. During each observation, the oximeter probe was placed in the same location (right or left), but due to infant head growth, the identical area of the brain could not be captured because the distance between the oximeter probe light emitter and light receiver is a fixed distance. Infant head growth and shape varies over time within and between infants. Therefore, the area of the brain included in the light arc by the oximeter probe covers a smaller area of the brain over time as the head gets larger. Consequently, the oximeter probe did not capture the same area of the brain over time. Additionally, the thickness of the infant's skin and shape of the head could also have changed the depth and the angle of the light arc emitted and received by the oximeter probe. Over the course of several weeks after birth, the stratum corneum thickens (Rutter, 1988) and a premature infant's skull takes on a dolichocephaly shape or an elongated, narrowed face (Hummel & Fortado, 2005) due to the malleable nature of a premature infants' head and the effects of positioning. A thickened stratum corneum and change in head shape may only represent a few millimeters difference or a few degrees in the angle of the arc. Nevertheless, cerebral oxygen saturation values monitored slightly different areas of the brain as the infant grew. Over time with this particular oximeter probe penetrating only 12.5 mm (Rais-Bahrami et al., 2006) even a few millimeters could change cerebral oxygen saturation values.

In conclusion, these findings suggest that cerebral oxygen saturation values mature by decreasing over the hospitalization period for infants born less than 32 gestational age. Infants without an IVH had similar cerebral oxygen saturation patterns to those infants with an IVH diagnosis until the third week of life when those

infants with an IVH showed significantly lower cerebral oxygen saturation values. Thus, IVH changed the overall pattern of cerebral oxygen saturation values over time; yet this pattern was not predictive in the first week of life when it would be helpful for preventing IVH from occurring. Both caffeine and probe location affected cerebral oxygen saturation and need to be considered in future analyses. Future research should also include infants with more severe IVH diagnoses. The hypothesis regarding fluctuations in cerebral blood flow as measured by cerebral oxygen saturations may only be present with more severe grades of IVH. A sample including more severe grades of IVH may help assist in examining whether cerebral oximetry is a viable method to prevent central nervous system damage or only helpful in monitoring the effects of the severity of central nervous system damage.

4. The Effects of Environmental Noise and Infant Position on Cerebral Oxygenation

Infants' early experiences with the environment establish how neurons in the maturing brain communicate with each other. Therefore, reducing the negative impact of the environment is essential. The more immature an infant at the time of neonatal intensive care (NICU) environment exposure, the more vulnerable the infant's brain to alterations in function and structure (Purves et al., 2008b). The neuronal pathways established from early experiences guide how the brain will experience future encounters with the environment (Purves et al., 2008b). Thus, premature infants' experiences within the NICU environment may affect their brain processing for the rest of their lives.

Noise and positioning of the infant are two factors in the NICU care environment that could influence the structure and function of a premature infant's brain. One way in which noise and body position may influence the brain is through alterations in cerebral blood flow. Cerebral blood flow provides the brain with glucose and oxygen necessary for brain development (Singh & Stock, 2006). However, in infants born less than 32 weeks gestation, fluctuations in cerebral blood flow can result in cerebral damage (Inder & Volpe, 2004). Auditory stimulation from the NICU environment could disrupt the pathway of neurological signals in the less mature brain (Johnson, 2001) that could eventually alter the distribution of cerebral blood flow to the brain and potentially result in cerebral damage. Particular head and body positions such as a turned head or lying prone may reduce or reduce and then increase blood flow to

the brain due to mechanical obstruction (Cowan & Thoresen, 1985; Pamphlett et al., 1999; Watson, 1974).

One method to measure fluctuations in cerebral blood flow during position changes and peak sound levels is cerebral oximetry. Cerebral oxygen saturation is the amount of oxygen saturated hemoglobin in the cerebral vasculature (Bruns et al., 2009) and it has been shown to correlate with cerebral blood flow (Volpe, Herscovitch, Perlman, Kreusser, & Raichle, 1985). Therefore, monitoring cerebral oxygen saturation may be a method for clinicians to detect cerebral blood flow fluctuations. Changes in cerebral oxygen saturation during loud sounds or specific infant positions may permit interventions to prevent fluctuations in cerebral blood flow that are hypothesized to result in cerebral damage (Inder & Volpe, 2004; McLendon et al., 2003).

Average sound levels in the NICU have decreased over the last few decades, but peak sound levels continue to be a problem (Brandon et al., 2007; Philbin et al., 1999; Surethiran et al., 2003; Thomas & Uran, 2007). The current recommendation is that peak sound levels be no greater than 65 decibels (Committee to Establish Recommended Standards for Newborn ICU Design, 2007), but levels often exceed 100 decibels (American Academy of Pediatrics Committee on Environmental Health, 1997; Bremmer et al., 2003; Thomas & Uran, 2007). Intermittent changes in sound levels can also be used to identify noise, defined by peak sound values of 5 to 15 decibels above ambient sound levels (United States Environmental Protection Agency, 1978). Sound levels exceeding 45 decibels affect premature infants by disrupting sleep-wake states (Fajardo, Browning, Fisher, & Paton, 1990; Surethiran et al., 2003; Thomas & Uran, 2007), and as sound values increase, premature infant's metabolic demand for oxygen increases

(Thomas & Uran, 2007), which in turn increases cardiac functioning (Surenthiran et al., 2003). As a result, peripheral oxygen saturation decreases and respiratory rate increases, especially in infants with respiratory compromise (Als et al., 1986). Consequently, the heart rate either increases or decreases as the infant tries to compensate from the exposure to the loud sound (Bremmer et al., 2003; Surenthiran et al., 2003). Yet to date, the effects of peak sound values on cerebral oxygen saturation values during premature infants' hospital stays have not been examined.

Another environmental factor, premature infant position may alter cerebral oxygenation because body or head positions can crimp blood vessels, slowing, changing, or halting blood flow patterns (Cowan & Thoresen, 1985; Pamphlett et al., 1999; Watson, 1974). Specific head or body positions believed to be benign may lead to fluctuations in cerebral blood flow that may be captured by monitoring cerebral oxygen saturation.

Most studies have examined the effect of infant position on cerebral blood flow rather than cerebral oxygenation. Using Doppler ultrasound to view various vessels, cerebral blood flow velocity was found to be lower in prone position than supine, and it increased with age even in prone position (Eichler et al., 2001; Vogelberg et al., 2004). However, other studies suggested that prone position was the best position to alleviate apneic events in preterm infants by promoting cerebral blood flow (Pichler, Schmolzer, et al., 2001). In another study, a midline head position and tilting have been shown to promote cerebral blood flow (Pichler, Schmolzer, et al., 2001). When preterm infants' heads were turned to the right or left, blood flow was lower than in a midline head position (Emery & Peabody, 1983). However, these differences were not significant once

the head was elevated 30° (Emery & Peabody, 1983). An elevated head, also known as tilting, can decrease cerebral blood flow (Pichler, van Boetzlar, et al., 2001) due to decreases in intracranial pressure as gravity pulls blood away from the head. Other studies challenge this conclusion, finding increased cerebral blood volume (Pichler et al., 2004) and no differences in cerebral blood flow between a flat or tilted position (Pellicer et al., 2002). Contradictory findings in these studies prohibit drawing any definitive conclusions about the best position to promote optimal cerebral blood flow and oxygenation.

Although most studies examined cerebral blood flow, a few studies have monitored cerebral oxygen saturation in different infant positions. Cerebral oxygen saturation values were lower in the prone versus supine position in full-term infants; however, cerebral oxygen saturations decreased in both prone and supine positions over time (Wong et al., 2011). Yet two studies have found no difference in cerebral oxygen saturation during sequenced positions using flat, tilted, or a prone position (Ancora et al., 2010; Elser, Holditch-Davis, Brandon, & Levy, 2012). The current literature on the effects of infant position on cerebral oxygen saturation is inconclusive.

Assumptions exist in practice and in the literature that a supine, head midline position is the best position to promote cerebral blood flow and reduce risk for cerebral damage (Carteaux et al., 2003; McLendon et al., 2003) despite the contradictory findings. In addition, once the threat of initial cerebral damage such as an intraventricular hemorrhage passes, whether position or peak sound levels continue to threaten cerebral blood flow or cause cerebral damage is unknown. Longitudinal

examination of how peak sound levels and position effect cerebral oxygen saturation is needed to clarify these findings.

Clearly, noise and infant position are two aspects of the NICU environment that may negatively impact cerebral blood flow. Since brain development requires cerebral blood flow nourishment, monitoring cerebral oxygen saturation may be one method to measure the effects of the NICU environment. Yet, more must be known about the effects of infant position and NICU sound on cerebral oxygen saturation to identify potential interventions to ameliorate any untoward effects. Therefore, the purpose of this study was to assess how environmental noise and different infant positions effected cerebral oxygen saturation over time in premature infants born less than 32 weeks gestational age.

In addition to peak sound levels and infant position, caffeine and cerebral oximeter probe location also affect cerebral oxygen saturation. In a recent study, caffeine administration, a methylxanthine drug prescribed to premature infants with apnea of prematurity (O'Donnell et al., 2002) was related to lower cerebral oxygen saturations in premature infants (Tracy et al., 2010). Decreased cerebral oxygen saturations values have also been noted when measuring various regions of the brain based on different areas of cerebral oximeter probe placement. Cerebral oxygen saturation was lower with left frontal hemisphere monitoring compared to the right frontal hemisphere (Lemmers & van Bel, 2009). Therefore, location of the cerebral oximeter probe must be considered in study analyses if study procedures include a switch in probe location between the right and left frontal lobes.

This study was guided by the theory of probabilistic epigenesis, a developmental systems theory that emphasizes the mutual influences between a person's internal environment (e. g. physiologic maturation) and external environment during developmental periods in premature infants (Gottlieb, 2007). The internal environment was measured by cerebral oxygen saturation values, and sound levels and infant position represented two factors of the external environment that premature infants are exposed to during hospitalization. Cerebral oxygenation was measured longitudinally as cerebral oxygen saturation is hypothesized to be dependent on the age of the infant.

4.2 Methods

4.2.1 Participants

The study enrolled a convenience sample of 24 premature infants at a Level III NICU in southeast United States to longitudinally investigate the effect of sound and infant position on cerebral oxygen saturation measurements in premature infants. All infants born less than 32 weeks gestational age were considered for inclusion in the study because this age group is at risk for intraventricular hemorrhage and other neurological issues, which may be affected by altered cerebral oxygenation during specific positions or peak sound levels (Blackburn & Ditzenberger, 2007; Inder & Volpe, 2004; Madan, Hamrick, et al., 2005).

Infants with identified congenital neurological, gastrointestinal, or cardiovascular anomalies were excluded from the study to decrease confounding effects of abnormal anatomy that may affect cerebral oxygen saturation. Furthermore, infants transferred to the research site were excluded because it was difficult to obtain consent within the first 48 hours of life. Also, infants transported from other institutions

experience additional stressors related to neonatal transport, which may have confounded cerebral oxygen saturation results (Markakis et al., 2006; Ohning).

4.2.2 Measures and variables

Infant position and environmental sound were monitored continuously during each observation to assess the effects of the external environment on cerebral oxygen saturation (Table 7).

4.2.2.1 Cerebral oxygen saturation. Cerebral oxygen saturation, measured by a cerebral oximeter, is the amount of oxygen present in arteries and veins of the brain (Bruns et al., 2009). The FORE-SIGHT™ Cerebral Oximeter was used to noninvasively measure cerebral oxygen saturation during an entire 40-minute observation. An oximeter probe attached to a monitor cable that was connected to a cerebral oximeter monitor. At one end of the oximeter probe, a light source penetrated the skull and cerebrum using fiber optics (Brazy & Vander-Vliet, 1989) to emit laser light (CAS Medical Systems, 2008). At the other end of the oximeter probe, a light detector received the laser light sent from the light source. The amount of cerebral oxygen present within the arteries and veins of the brain was calculated automatically using a modified Beer-Lambert law (Owen-Reece et al., 1999) with a range from 0% to 100% in whole numbers and displayed on the cerebral oximeter screen that was updated every 1-second. A laptop with software created exclusively for this study downloaded real-time cerebral oxygen saturation values from the FORE-SIGHT™ Cerebral Oximeter to a Microsoft® Office Excel spreadsheet.

4.2.2.2. Peak sound. The NoiseProDL Noise Dosimeter, made by Quest Technologies, was used to measure sound levels in 1-decibel increments from 40 to 140 decibels during the first 20-minutes of each 40-minute observation. The first 20-minutes

only was monitored because all infants in the study were placed in the same body position, supine, head midline, unlike the last 20-minutes where they were randomized to different body positions. Average sound levels (Leq) were determined for each 1-minute period (National Instruments Corporation, 2009). Using QuestSuite Professional II Software, the noise dosimeter data was downloaded to a laptop computer at the completion of each observation. The first sound level 5 decibels (Leq) greater than the average for the entire 20-minute observation was treated as a peak sound, based on the intermittent peak sound value criteria (United States Environmental Protection Agency, 1978). Peak sound values were used to see if the change in sound level would elicit a physiologic response as evidenced in cerebral oxygen saturation. Cerebral oxygen saturation measurements 30 seconds before and 2 minutes after a qualified peak sound level were extracted as a data set from each observation for statistical analysis to assess whether a peak sound level changed cerebral oxygen saturation. A peak sound level variable was coded as 0 before the peak sound event and coded 1 in 30-second increments (total of four 30-seconds) after the peak sound event.

4.2.2.3 Infant position. Each observation included two positions each lasting 20 minutes. The first position was always a supine, head midline for every infant. The second position was randomly assigned to 1 of 5 positions (see Table 7). A 45°-angled foam pillow was used to verify 45° head angles in the two randomized, supine positions. The five positions were rotated in a different random order for each infant at each new observation. These five positions were a subset of the 14 positions used by nurses to care for premature infants in the NICU. Five positions were chosen because five observations were estimated to be achievable during an average length of stay, 23 days, in the proposed infant population at the chosen research site. The supine, head midline during the first 20-minutes was coded as 1 and each

randomized position was coded 2 to 6 in the order listed in Table 7.

4.2.2.4 Gestational age. Gestational age was determined from either the first day of a woman’s last menstrual period or an obstetric ultrasound to calculate expected date of confinement (EDC). If these dates differed by more than 2 weeks from the Ballard assessment of gestational age at birth, the Ballard was used to determine gestational age (Ballard et al., 1991).

Table 7. Observation Timeline

Timeframe	Cerebral Oxygenation	Infant Position	Sound
0-20 minutes ^a	X	Supine, head midline, 0° elevation	X
21-40 minutes ^a	X	Randomized to one of the following positions: Right lateral with head of bed elevated 15° Prone with head to the left, 0° elevation Left lateral with head of bed at 0° elevation Supine with head 45° to the right, 0° elevation Supine with head 45° to the left, 15° elevation	

4.2.2.5 Post-menstrual age. Post-menstrual age (PMA) was used as the time variable in the positioning analysis. PMA was calculated as gestational age at birth plus the number of weeks since birth in whole weeks.

4.2.2.6 Demographic variables. Maternal and infant demographic variables were collected from electronic medical records for the purpose of describing the research sample. Maternal health characteristics such as maternal age, medications used during pregnancy and infant characteristics including gender and birth weight at the time of infant enrollment

were collected.

4.2.2.7 Covariates. This study controlled for caffeine and probe location as covariates hypothesized to impact cerebral oxygen saturations.

4.2.2.7.1 Caffeine. Caffeine citrate is a methylxanthine drug prescribed to premature infants with apnea of prematurity (O'Donnell et al., 2002) and has been shown to decrease cerebral oxygen saturations in premature infants (Tracy et al., 2010). Caffeine was a time varying covariate in this study, as its use changed throughout an infant's hospitalization. At each observation, an infant given any route of caffeine administration as a therapeutic dose within the last 24 hours of the observation was considered a recipient of caffeine. Those infants who received caffeine were coded as 1 and those who did not receive caffeine were coded as 0. Each infant had the potential to contribute to either category of caffeine for each observation.

4.2.2.7.2 Probe location. The cerebral oximeter probe was placed either right or left of center on the forehead above the brow. The chosen probe location was dependent on which side of the forehead would potentially detect the most change in cerebral oxygen saturation in the second randomized position. For example, an infant turned from the supine, head midline position to a prone position with their head turned to the left would have had left sided cerebral oxygen saturation monitoring. The left side monitoring compared to right side would be best at capturing the potential for the vasculature in the neck to be disrupted due to the position. Probe location was dummy coded as a 0 for the left side and 1 for the right side in both positioning and sound analyses.

4.2.3 Procedures

Institutional Review Board approval and parental consent were obtained prior to study enrollment. Cerebral oxygen saturation was measured longitudinally in two different infant positions between 2 and 48 hours of life, once between 49 and 96 hours of life, on Day 7 of life, and every 7 days thereafter until discharge home, transferred to another hospital, or 40 weeks post-menstrual age, whichever came first. Each observation lasted 40-minutes. Peak sound levels were only measured during the first 20-minutes of each observation since position change could confound the potential effect of sound. Infants were positioned supine, head midline with 0° elevation during the first 20-minutes and then for the last 20 minutes, randomized to one of five positions. Table 7 shows the position assignments for each 20-minute time period. Three observations in the first week of life identified the effect of sound and infant position on cerebral oxygen saturation as the infant transitioned to extrauterine life compared to weekly observations when less dramatic effects of sound and position are expected to affect cerebral oxygen saturation over time. If an infant required surgery, the observation was postponed for 2 days to decrease the effects of anesthesia and post-operative recovery on study results. If the infant was unable to tolerate the study procedures for the scheduled day, the observation was postponed until the next day and the time for the subsequent observation was reset from this new day.

A cart was brought to the infant's bedside, which contained a cerebral oximeter, noise dosimeter, and laptop. The FORE-SIGHT™ Cerebral Oximeter was connected to the infant via a cerebral oximeter probe placed on the infant's left or right side of his/her forehead above the brow using an elastic headband to secure the probe during

each observation. An elastic band was used to secure the probe, rather than adhesive tape, to avoid skin breakdown. The FORE-SIGHT™ Cerebral Oximeter was connected to a laptop using USB extension cables and the cerebral oxygen saturation values were downloaded into a Microsoft Office Excel file. The noise dosimeter microphone was taped inside the isolette port closest to the infant's head for those infants in an isolette and for those infants not in an isolette, the noise dosimeter microphone was placed within 6 inches of the infant's head to measure sound levels experienced by the infant.

Observations began 10-minutes after applying the cerebral oximeter probe to the infant as a prior study showed patient manipulation may affect cerebral oxygen saturation for several minutes (Mann, Holditch-Davis, Brandon, & Levy, 2010). Observation of cerebral oxygen saturation occurred through two different positions each lasting 20-minutes for a total of 40-minutes between feedings or scheduled nurse assessment times. Average sound levels were collected only during the first 20-minutes of each observation. At the end of each observation, sound data was downloaded via infrared transfer from the noise dosimeter to a laptop.

4.2.4 Data analysis

General linear mixed models were used to examine whether peak sound levels and positions from a supine, head midline position to a second position affected cerebral oxygen saturation in premature infants. Figure 9 shows the data management process for the sound analysis. Gestational age, probe location, and caffeine were the three covariates.

For each observation, cerebral oxygen saturation was measured in the supine, head midline position and then in one of the five randomly assigned positions to

determine the effects of position change on cerebral oxygen saturation. Five comparisons resulted from contrasting the supine, head midline position with the 5 randomized positions. For statistical purposes, differences in mean cerebral oxygen saturation were calculated in order to keep both positions within the same observation paired together. For example, mean cerebral oxygen saturation for Position 1 minus the mean cerebral oxygen saturation for Position 2 within the same infant, same observation. The difference between each random position and the neutral position was used as a reference conducting five mixed models. In order, each group contained differences in cerebral oxygen saturation between a supine, head midline and the following: 1) right lateral, elevated head of bed 15° (N=16); 2) prone, head turned to the left, 0° elevation (N= 18); 3) left lateral, 0° elevation (N=24); 4) supine, right head turn 45°, 0° elevation (N= 19); and 5) supine, left head turn 45°, 15° elevation (N= 24). Probe location, caffeine, and gestational age were the covariates along with quadratic and cubic effects of time and their interactions with the covariates.

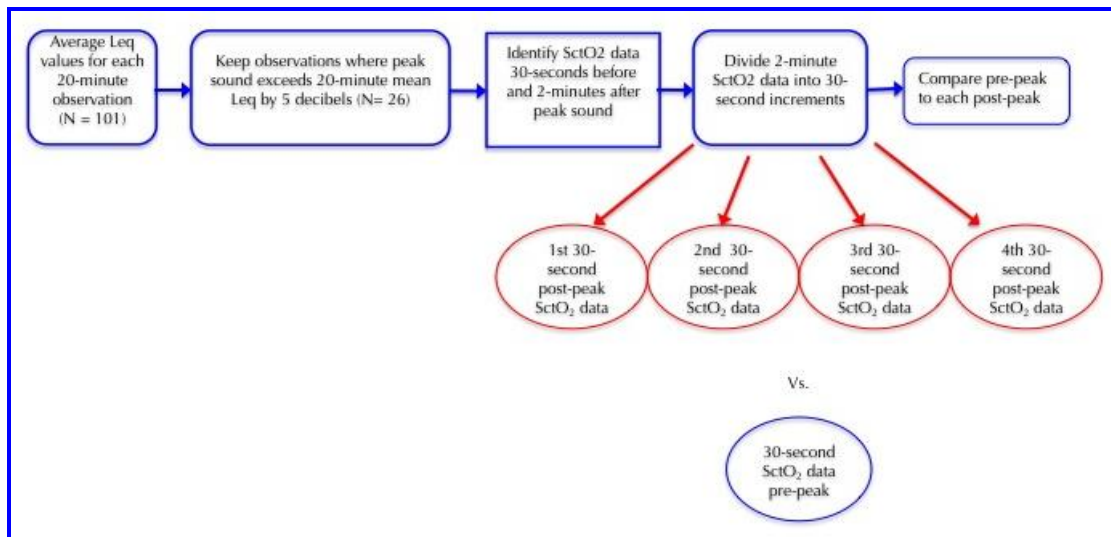


Figure 9. Data Management Process for Sound Analysis

4.3 Results

4.3.1 Peak sound value

In the 26 observations meeting criteria for examining peak sound effects, mean cerebral oxygen saturation pre-peak was 71.4% and the four 30-second post-peak average cerebral oxygen saturations were 69.6%, 69.9%, 72.4%, and 72.8%, respectively. Mean sound level at pre-peak was 58.7 decibels (ranging from 50-68.6 decibels) and the four 30-second post-peak mean sound levels were 65.6, 65.1, 60.2, and 60.1 decibels, respectively. Peak sound levels 5 decibels above the average ambient sound level did not significantly change cerebral oxygen saturation values (Table 8). Gestational age and probe location were covariates and found to be non-significant. Those infants who did not receive caffeine during a qualified observation had significantly higher cerebral oxygenation values compared to those infants who received a therapeutic dose of caffeine (See Appendix E for SAS output).

Table 8. Mixed Model Results: Effect of Peak Sound on Cerebral Oxygenation

Variable	Parameter Estimate	SE	p-value
Intercept ^a	69.66	4.66	< .0001
1 st 30-seconds post-peak	1.5	0.97	.13
2 nd 30-seconds post-peak	1.16	0.97	.24
3 rd 30-seconds post-peak	0.35	0.98	0.72
4 th 30-seconds post-peak	-0.03	0.98	0.98
Caffeine ^b	6.34	1.69	< .001

^a Intercept equals expected value for all infants starting at 25 +5 weeks

^b Caffeine= 0, coded 1 when receiving a therapeutic dose, 0 for all others

4.3.2 Infant Position

Differences in cerebral oxygen saturation were compared between the supine, head midline position and five other randomized positions. A total of 101 observations

were analyzed across 24 premature infants. Table 9 shows average cerebral oxygen saturation values in each of the six positions. In all five models, differences in cerebral oxygen saturation between a supine, head midline position and all other positions became smaller as the infants aged. Differences in cerebral oxygen saturation were significantly less when infants were changed from a supine, head midline position to a right lateral, 15° head elevation compared to a left lateral, 0° elevation position (Table 10). The intercept was also found to be significantly different from zero. Caffeine, probe location, the quadratic and cubic effects of time, and the interactions with these two covariates were all non-significant (See Appendix F for SAS output).

Table 9. Mean Cerebral Oxygen Saturation Values By Position

Position	Mean Cerebral Oxygenation (%)	Standard Deviation
1- Supine, head midline	72.9	9.6
2- R lateral, elevated 15°	71.9	8.8
3- Prone, head to left, elevated 0°	69.3	8.9
4- L lateral, elevated 0°	71.7	11.9
5- Supine, head turned 45° to R	76	8.5
6- Supine, head turned 45° L, elevated 15°	73.6	9.9

4.4 Discussion

Five different infant positions and peak sound levels were not found to significantly affect cerebral oxygen saturation values in premature infants over time. In 2003, reducing environmental sound and maintaining a neutral head position were two of many methods suggested to reduce brain injury when caring for infants in the NICU (McLendon et al., 2003). If brain injury results from fluctuations in cerebral blood flow, using cerebral oxygen saturation as a proxy for cerebral blood flow within varying

positions and during peak sound levels could examine the validity of these recommendations.

Table 10. Mixed Model Results: Differences in Cerebral Oxygen Saturation Between Supine, Head Midline 0° Elevation and Right Lateral, 15° Head Elevation Compared to All Other Positions

Variable	Parameter Estimate	SE	p-value
Intercept ^a	8.12	3.84	< .05
PMA ^b	-0.57	0.15	< .01
Position 3 ^c	-1.43	1.48	.33
Position 4 ^c	-2.9	1.36	.04
Position 5 ^c	-0.87	1.44	.55
Position 6 ^c	-1.08	1.36	.43

^a Intercept represents difference in cerebral oxygen saturation between Position 1 (supine, head midline and Position 2 (Right lateral, 15° head elevation)

^b PMA- post-menstrual age begins at 25 +5 weeks

^c Represents difference in cerebral oxygen saturation between Position 1 (supine, head midline) and identified position (Position 3= prone, head to left, Position 4= left lateral, Position 5= supine, head turned right 45°, and Position 6= supine, head turned left 45°, elevated 15°)

This is the first study to analyze the effects of sound on cerebral oxygen saturation in premature infants. Previous research suggested that premature infants consumed more oxygen when stressed from loud sounds in the NICU environment (Thomas & Uran, 2007). As a result, cerebral oxygen saturation values were hypothesized to be significantly lower because the stimulation from the sound would increase oxygen metabolism. Findings from this study appeared to refute this hypothesis. Cerebral oxygen saturation values were similar when pre- and post-peak sound values were compared. Peak sound levels were a minimum of 5 decibels above the average ambient sound level for each observation. Although a 5-decibel level may be seen as a small change, an increase in 1 decibel is logarithmic and therefore a small increase in sound has the potential to significantly change physiology in medically

fragile infants. Also, observations exceeded 45 decibels, the sound level shown to impact infant physiology (Fajardo et al., 1990; Surenthiran et al., 2003; Thomas & Uran, 2007).

In general, the research setting had low to moderate levels of ambient sound during sampling times with average decibels ranging from 50.8 to 68.6 and the highest peak sound at 77 decibels compared to peak sound levels of greater than 100 decibels in previous studies (Thomas & Uran, 2007). As NICUs continue to strive for quieter units (Brandon et al., 2007), only small elevations in environmental sound values are typical. Given the inevitable exposure to some changes in sound levels, these findings are reassuring in that peak sound levels of 5 decibels above a quiet ambient sound level did not affect cerebral oxygenation. Therefore, NICUs making considerable efforts to reduce sound levels are probably also protecting infants' cerebral oxygen saturation levels.

The randomized positions also had little influence on cerebral oxygen saturation. Unexpectedly, the movement required to change an infant from supine, head midline to a prone position did not significantly change cerebral oxygen saturation. When infants were changed from a supine, head midline position to any of the other five randomized second positions, differences in cerebral oxygen saturation between the two positions became smaller as infants aged. The sampled population included primarily fragile and severely ill infants. Thus with an improvement in health status, these infants were likely to have become less affected by daily care tasks like positioning, which was evident in the effect of post-menstrual age in Table 10.

The differences in the change of cerebral oxygen saturation from a neutral position to a right lateral, elevated head was significantly lower as compared to

changing to a left lateral, non-elevated position. The variation in cerebral oxygen saturation between these two lateral positions may reflect a difference in head elevation since the right lateral position included a head elevation of 15° and the left lateral position was horizontal at 0° . An elevated head would pull blood away from the head due to gravity (Pichler, van Boetzelar, et al., 2001), which could potentially decrease the amount of blood to the brain reducing the availability of oxygen. As a result, the right lateral, head elevated 15° would have lower cerebral oxygen saturation. Yet this does not explain why cerebral oxygen saturation was not significantly different between the two supine, head turned positions (supine, head turned 45° to the left, elevated 15° and supine, head turned right 45° , 0° elevation). The manipulation involved with turning an infant to a lateral position in combination with the head elevation could be drastically different compared to the manipulation required to turn the head 45° and elevate the head.

The idea that a turned head causes a crimp or occlusion in the vasculature (Cowan & Thoresen, 1985; Pamphlett et al., 1999; Watson, 1974) and lowers cerebral oxygenation was not confirmed, as all tested positions that included a turned head were not significantly different from the midline position. The head and hips were kept in alignment when the infants were turned to a lateral position. Therefore, it is unclear why a midline head and body position would change cerebral oxygen saturation while a turned head, potentially altering the pathway of blood flow, did not affect cerebral oxygen saturations values. Although the two lateral positions kept the head and body midline, it is possible that lateral positions bent the angle of the neck laterally decreasing cerebral blood flow as pillows and other head supports are not typically used

with NICU infants. To further explore these findings, cerebral oxygen saturation will need to be monitored during a change from a supine, head midline position to a left and right lateral position in both an elevated and non-elevated head while simultaneously assessing the lateral angle of the neck.

Cerebral oxygen saturation steadily decreased with age for infants receiving caffeine. Infants who did not receive caffeine had lower cerebral oxygen saturation values until 5 weeks of life and then cerebral oxygen saturation values rose again. These effects of caffeine on cerebral oxygenation were previously found in another analysis with this sample (see Figure 7 of Chapter 3).

The relatively small number of positions examined and the inability to analyze a supine, head midline position limited this study. Only five positions were examined out of the 14 that nurses frequently use in the NICU. Also, more extreme positions such as a head turned 90° were not included as these positions were shown to reduce cerebral blood flow (Watson, 1974). Eight more positions (supine, head midline and elevated; supine, head turned right and elevated; supine, head turned left; right lateral; left lateral and head elevated; prone, head to the right; prone, head to the right and elevated; and prone, head to the left and elevated) including the supine, head midline position while measuring cerebral oxygen saturation need to be examined to conclude whether or not position affects cerebral oxygen saturation. Although a supine, head midline position was included in this study; it was used as a reference position because it is considered to be the neutral position and thus, its effects were not examined. Also, it is unclear why the two lateral positions caused the most significant change in cerebral oxygen saturation when several positions that did not keep the head and body aligned were also

examined. The remaining unexamined positions may help explain these unclear position findings from this study.

The supine, head midline position was the reference position subtracted from the five other randomized positions to determine a difference score associated with each position change. A significant intercept at 8.12 in Table 10 represents the predicted difference in cerebral oxygen saturation between a supine, head midline and a right lateral, 15° head elevation position for the youngest infant in the study. This difference is important because in Chapter 3, I found that the trajectory of cerebral oxygen saturation in these infants over several weeks slowly decreased by approximately 15% (78-63%). A decrease in cerebral oxygen saturation over 8% during a position change is approximately half of the amount that cerebral oxygen saturation decreased over several weeks of aging. This study only compared differences in cerebral oxygen saturation from what was considered a neutral position and five randomized positions and did not specifically examine the neutral position as part of the analysis. Thus, another study is necessary to include a supine, head midline position as a comparison position since the assumption that it is a neutral position may be incorrect.

At this time, reasonable variations in sound levels (5 decibels) above ambient sound and infant position do not seem to significantly affect cerebral oxygen saturation. Striving to meet sound level recommendations and using various infant positions should continue to be acceptable for clinical practice regarding their effects on cerebral oxygenation. Peak decibel levels less than 65 and no more than 15 decibels above ambient sound are recommended goals for NICUs (Committee to Establish

Recommended Standards for Newborn ICU Design, 2007; United States Environmental Protection Agency, 1978).

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5. The Relationship of Cerebral Oxygen Saturation to Heart Rate and Peripheral Oxygenation in Premature Infants

Cerebral oxygen saturation, as measured by a cerebral oximeter, is a promising vital sign for premature infants in the neonatal intensive care unit (NICU) (Toet & Lemmers, 2009). Currently, heart rate (HR) and peripheral oxygenation (SpO_2) are two vital signs used to continuously monitor perfusion and receipt of oxygen throughout a premature infant's body. Although clinicians assume these vital signs are adequate to detect changes in perfusion, as many as 50% of premature infants develop neurological disabilities and these problems are theorized to be related to severe fluctuations in cerebral blood flow (Inder & Volpe, 2004). Clinicians have no method to observe infants at risk for changes in cerebral blood flow until it is too late and a neurological complication is diagnosed by head ultrasound.

Cerebral blood flow delivers oxygen to the brain and changes in blood flow are reflected in changes in cerebral oxygenation (Volpe et al., 1985). Monitoring cerebral oxygen saturation as a proxy for cerebral blood flow may be a method to assist clinicians in detecting infants at risk for changes in cerebral blood flow, allowing them

to intervene to reduce neurological complications. More information is needed to determine whether cerebral oxygen saturation values would provide unique knowledge about cerebral blood flow in addition to the information currently obtained through vital signs measured in the clinical setting.

Physiological properties suggest that currently monitored vital signs should be adequate to detect changes in cerebral blood flow. For example, delivery of oxygenated blood to the brain depends on the amount of blood pumped by the heart, or cardiac output. The products of heart rate and stroke volume estimate cardiac output. Premature infants' hearts are unable to accommodate larger volumes of blood to increase stroke volume (Lagercrantz et al., 2002), and as a result, cardiac output in premature infants is dependent on heart rate only. The correlation of heart rate and peripheral oxygenation with cerebral oxygen saturation should be positive; an increase in heart rate delivers more oxygen to the body by raising cardiac output that will in turn raise peripheral and cerebral oxygen saturation.

Although physiology theoretically contributes knowledge about potential relationships between cerebral oxygen saturation and current vital signs, limited empirical evidence exists to explain these relationships in *any* patient population. One study performed during the first 6 hours of life in healthy newborns between 30 and 42 weeks gestation is the only study to examine relationships between cerebral oxygen saturation and heart rate and peripheral oxygenation (Tina et al., 2009). Results showed infants born at younger gestational ages had higher cerebral oxygen saturation values than older infants. Cerebral oxygen saturation was significantly, positively correlated with heart rate and peripheral oxygenation.

In addition to the relationship between cerebral oxygen saturation and heart rate and peripheral oxygenation, other factors may affect these relationships. Caffeine and the location of the cerebral oximeter probe have been shown to affect measures of cerebral oxygen saturation (Lemmers & van Bel, 2009; Tracy et al., 2010). Caffeine is a drug prescribed to premature infants with apnea of prematurity (O'Donnell et al., 2002). Caffeine has been shown to decrease cerebral oxygen saturation values in premature infants less than 34 weeks gestational age (Tracy et al., 2010). Differences in cerebral oxygen saturation values also exist between different regions of the brain as measured by cerebral oximeter probe placement. The right frontal hemisphere produced higher cerebral oxygen saturation values than the left frontal hemisphere (Lemmers & van Bel, 2009). Therefore, the location of the cerebral oximeter probe must be considered if the probe location varies from the right to the left frontal lobes.

Cerebral oxygen saturation values may provide information similar to heart rate or peripheral oxygenation or it may provide valuable physiologic information not currently monitored. Results from the one empirical study (Tina et al., 2009) only apply to healthy premature and full-term infants within the first few hours of life and cannot be generalized to extremely ill or premature infants who stay in the hospital for many weeks. Due to the lengthy hospitalization and severity of illness, use of cerebral oxygen saturations values as a valuable vital sign requires longitudinal assessment compared to other vital signs in premature infants who are at greatest risk for neurological complications. Therefore, the purpose of this longitudinal study was to examine the relationships between cerebral oxygen saturation and heart rate and peripheral oxygenation in premature infants born less than 32 weeks gestation from birth until

hospital discharge. The research questions answered were a) what are the relationships between cerebral oxygenation and heart rate and peripheral oxygenation across infants covarying for postnatal age, caffeine, and probe location?, b) what are the relationships between cerebral oxygenation and heart rate and peripheral oxygenation in individual premature infants over time? and c) what is the systematic change between cerebral oxygen saturation and heart rate and peripheral oxygenation as infants age?

5.2 Methods

5.2.1 Participants

The study enrolled a convenience sample of 24 premature infants over a 12-month timeframe in a repeated measures design. This sample size exceeded or was similar to samples of studies that examined cerebral blood flow or cerebral oxygen saturation in premature infants (Cowan & Thoresen, 1985; Pichler, Schmolzer, et al., 2001; Pichler et al., 2004; Pichler, van Boetzlar, et al., 2001; Roche-Labarbe et al., 2010).

All infants born at Duke University Hospital and who were less than 32 weeks gestational age and without congenital neurological, cardiac, or gastrointestinal anomalies were considered for study inclusion. Infants born less than 32 weeks gestational age have longer lengths of stay in the hospital than older infants (Russell et al., 2007) so the relationships between heart rate and peripheral oxygenation and cerebral oxygen saturation were examined longitudinally. Infants with identified anomalies affecting the neurological, gastrointestinal, or cardiovascular systems were excluded to decrease potential confounding effects of abnormal anatomy that may affect cerebral oxygen saturation. Furthermore, infants born elsewhere and transferred to

Duke University Hospital were excluded because it would be difficult to obtain consent within the first 48 hours of life.

5.2.2 Measures and Variables

Three 20-minute observation points occurred within the first week of life (within 2-48 hours of life, 49-96 hours of life, and Day of Life 7), and continued weekly thereafter until hospital discharge or 40-weeks post-menstrual age. This study was part of a larger study in which the observation time was 40 minutes. During the first 20-minutes of each 40-minute observation, all infants were placed in the same position, supine, head midline, which allowed for consistent comparisons within and between infants. Analyses in this paper involved the first 20 minutes only.

5.2.2.1 Cerebral oxygen saturation. Cerebral oxygen saturation, measured by a cerebral oximeter, is the percentage of oxygen saturating hemoglobin in the arteries and veins of the brain. The FORE-SIGHT™ Cerebral Oximeter was used to noninvasively measure cerebral oxygen saturation values for each 20-minute observation. The FORE-SIGHT™ Cerebral Oximeter consists of an oximeter probe attached to a monitor cable that is connected to a cerebral oximeter monitor. At one end of the oximeter probe, a laser light is sent to penetrate the skull and cerebrum (Brazy & Vander-Vliet, 1989) and a light detector on the other end of the oximeter probe receives the laser light sent from the light source. Using a modified Beer-Lambert Law (Owen-Reece et al., 1999), the amount of cerebral oxygen saturation within the arteries and veins is calculated from the difference in light received and sent from the two ends of the oximeter probe. Cerebral oxygen saturation values ranging from 0% to 100% in whole numbers is displayed on the cerebral oximeter screen. A laptop with software created exclusively for this study downloaded cerebral

oxygen saturation values from the FORE-SIGHT™ Cerebral Oximeter to a Microsoft® Office Excel spreadsheet in real-time.

5.2.2.2 Heart rate. Heart rate (HR) was monitored during the 20-minute assessment using the Masimo SET Radical-7™ pulse oximeter. Heart rate was downloaded in real-time to a laptop using software designed specifically for this study.

5.2.2.3 Pulse oximetry. Peripheral oxygenation (SpO₂) was monitored continuously during the 20-minute assessment using the Masimo SET Radical-7™ pulse oximeter. The Masimo SET Radical-7™ pulse oximeter was connected to a laptop to collect SpO₂ values that ranged from 0% to 100% in whole numbers. The Masimo SET Radical-7™ pulse oximeter used LNCS™ Neo adhesive sensors, which are recommended for infants weighing less than 3 kg.

5.2.2.5 Caffeine. Caffeine is a methylxanthine drug prescribed to premature infants with apnea of prematurity (O'Donnell et al., 2002) and has been shown to decrease cerebral oxygen saturation in premature infants (Tracy et al., 2010). Caffeine was a time varying covariate in this study, as its use changed throughout an infant's hospitalization. At each observation, any route of caffeine administration was documented from the medication administration record. Infants who received a therapeutic dose of caffeine within 24 hours of an observation were assigned a 1 and all other infants were assigned a 0. Each infant had the potential to be counted as a recipient of caffeine or not for each observation.

5.2.2.6 Probe location. Infants were placed in a second randomized position after the supine, head midline position examined exclusively in this analysis. The cerebral oximeter probe was placed either right or left of center on the forehead above the brow. The chosen probe location was dependent on which side of the forehead would potentially detect

the most change in cerebral oxygen saturation values in the second randomized position. For example, an infant turned from the supine, head midline position to a supine, head turned to the left would have had left sided cerebral oxygen saturation monitoring. Probe location was dummy coded as 0 for the left side and 1 for the right side.

5.2.2.7 Postnatal age. Postnatal age (PNA) was used as a measurement of infant age and was calculated as the number of days since birth.

5.2.2.8 Post-menstrual age. Post-menstrual age (PMA) was calculated as gestational age at birth plus the number of weeks since birth. Gestational age was determined from either the first day of a woman's last menstrual period or an obstetric ultrasound to calculate expected date of confinement (EDC). If these dates differed by more than 2 weeks from the Ballard assessment of gestational age (Ballard et al., 1991) at birth the results of the Ballard were used to determine gestational age.

5.2.2.8 Demographic variables. Maternal and infant demographic variables were collected from electronic medical records for the purpose of describing the research sample. Maternal health characteristics such as maternal age and medications used during pregnancy and infant characteristics including gender and birth weight at the time of infant enrollment were collected.

5.2.3 Procedures

Institutional review board approval was obtained and parental consent was acquired prior to the initial observation. Observations took place at the infant's bedside in the NICU once between 2 and 48 hours of life, once between 49 and 96 hours of life, on Day of Life 7, and every 7 days thereafter until discharge from Duke University Hospital or 40 weeks post-menstrual age, whichever came first. The 46-hour window

for the first observation provided hospital personnel time to stabilize infants.

Observations occurred between feedings or scheduled nurse assessment times. If an infant required surgery, the observation was postponed for two days to decrease the effects of anesthesia and post-operative recovery on study results. If the infant was unable to tolerate the study procedures for the scheduled day, the observation was postponed until the next day and the time for the subsequent study observation was reset from that new day.

A cart was brought to the infant's bedside, which carried the cerebral oximeter, pulse oximeter, and laptop. The FORE-SIGHT™ Cerebral Oximeter was connected to the infant via a cerebral oximeter probe placed on the infant's left or right side of his/her forehead and above the brow using an elastic headband to secure the probe during each observation. An elastic band was used to secure the probe, because unlike adhesive tape, it has not been shown to cause skin breakdown. One LNCS™ Neo adhesive pulse oximeter probe was used to measure peripheral oxygenation and heart rate from a Masimo SET Radical-7™ pulse oximeter. The FORE-SIGHT™ Cerebral Oximeter and Masimo SET Radical-7™ pulse oximeter were connected to a laptop using USB extension cables. Data transmitted from the two oximeters to the laptop provided two Excel files, one from each instrument. The observation began 10-minutes after applying the cerebral oximeter probe and pulse oximeter probe to the infant as a prior study had shown patient manipulation may affect cerebral oxygen saturation for several minutes (Mann, Holditch-Davis, & Brandon, 2010).

5.2.4 Data analysis

Three analyses using two statistical methods were chosen to describe how cerebral oxygenation related to heart rate and peripheral oxygenation. The first analysis used general linear mixed models to examine the overall relationship between cerebral oxygenation with heart rate and peripheral oxygenation using the average value of each variable at each observation from the raw 1-, 2-, and 30-second data. Throughout the 1-year enrollment period, electronic and manual data were collected due to unforeseen computer issues. The sampling rate for electronic data was 1- and 2-seconds and 30-seconds for manual observations. The raw data was averaged over the 20-minute time period and yielded 138 values; one for each observation over all subjects. Caffeine was a time varying covariate, and time was measured using post-natal age in days with the potential for quadratic and cubic time forms to account for non-linear relationships.

The second analyses used state space time series analysis to examine the nature of the relationships of cerebral oxygenation over the 20 minute time frame within an individual infant at each observation. Initial models included trend and cyclic components of the variations in only cerebral oxygenation over this time period (without including heart rate of peripheral oxygenation). Next, heart rate was added to the state space model as a fixed predictor at each time point. The strength and direction of this relationship was therefore assumed to be constant on each of the 1 or 2 second time points within each 20 minute observation period. This process was then reversed, with heart rate serving as the dependent variable and cerebral oxygenation serving as the predictor. These same two analyses were performed with peripheral oxygenation

and cerebral oxygenation. Therefore, each infant at each observation had a total of 4 models fit: 1) $Y=HR$, $X=SctO_2$, 2) $Y=SctO_2$, $X=HR$, 3) $Y=SpO_2$, $X=SctO_2$, and 4) $Y=SctO_2$, $X=SpO_2$.

The last analysis modeled change in the strength of the relationships between vital signs over the first several weeks of the infants' life while in the NICU. The regression coefficients derived from the previously described time series analyses were used as the dependent variable with postnatal age of the infant at each observation as the primary independent variable. Caffeine and probe location were covariates. Thus, a summary statistic from each of the 20 minute observation periods was used as the primary unit of analysis with each general linear mixed model.

5.3 Results

5.3.1 Means by Observation

The relationships between cerebral oxygen saturation ($SctO_2$) and heart rate and peripheral oxygenation were analyzed using means from each observation from each observation for each variable in a general linear mixed model. In each of these models, subject was modeled as a random effect and assumed to account for all covariance between data points within each subject. A backwards step-wise regression approach was used for variable selection. The full models included the linear and quadratic effects of postnatal age, the covariates caffeine and probe location, and the interactions with postnatal age and caffeine. Table 11 shows the two final reduced models.

Without considering variation in age, cerebral oxygen saturation was higher with lower heart rate and higher cerebral oxygen saturation was related to higher peripheral oxygenation. As the demand for oxygen increased as shown in lower cerebral

oxygenation values, heart rate increased. The presence or absence of caffeine affected the trajectory of cerebral oxygenation over this post natal age period. This analysis only shows the linear relationship between postnatal age and cerebral oxygenation and this linear trend over time changes with the presence or absence of caffeine. Probe location and the interaction of age with either heart rate or peripheral oxygenation were not significant in any of the models. Heart rate increased over time for those who did and did not receive caffeine, but heart rate began to decrease earlier for those infants receiving caffeine (postnatal day 32) than those infants not receiving caffeine (postnatal day 44). The effects of caffeine on cerebral oxygenation are described in Chapter 3 and displayed in Figure 7 (See Appendix G for SAS output).

**Table 11. Mixed Models Results: Relationships Between Observations
Using Averaged 1-Minute Means^d**

Model	Variable	Parameter Estimate	SE	p-value
1- Dependent variable = SctO ₂				
Independent variable = HR				
	Intercept ^a	86.75	5.01	< .001
	Mean HR	-0.07	0.03	.048
	PNA ^b	-0.18	0.05	< .001
	Caffeine ^c	2.6	2.08	0.214
	Caffeine x Time	-0.16	0.06	0.007
2- Dependent variable = SctO ₂				
Independent variable = SpO ₂				
	Intercept ^a	-24.5	17.3	0.17
	Mean SpO ₂	1.05	0.18	< .001
	PNA ^b	-0.19	0.04	< .001
	Caffeine ^c	2.39	1.87	0.204
	Caffeine x Time	-0.15	0.05	0.006

a Intercept equals expected value for all infants starting at 25 +5 weeks

b Time measured in minutes

c Caffeine =0 when coded 1 for therapeutic dose, 0 all others

^d Analysis used 138 data points

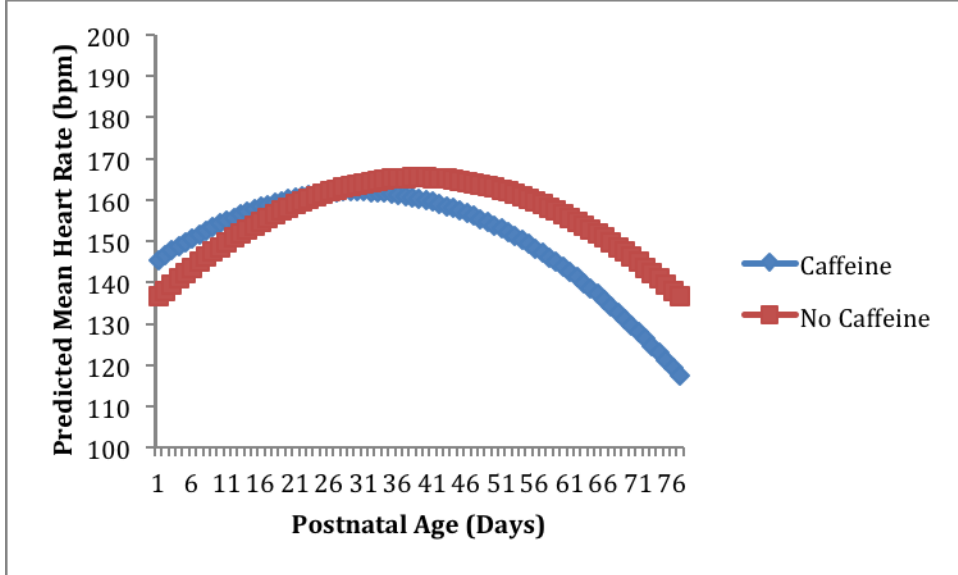


Figure 10. The Effect of Caffeine on the Predicted Mean HR regressed on Cerebral Oxygen Saturation Over Postnatal Age

5.3.2 Time series analysis

Relationships between cerebral oxygen saturation and heart rate and peripheral oxygenation were modeled within each 20 minute observation period. Initially, for each observation the variability in cerebral oxygenation values over a given 20 minute time period was decomposed into a maximum of three cycles and a trend. In the majority of these twenty minute time periods (96%), the best fitting model was a stochastic level, no slope model with varying numbers of cycles with the remaining 4% unable to be identified due to insufficient data. A stochastic level, no slope model, mathematically called a random walk, indicates that there was no apparent systematic change in cerebral oxygen saturation during each 20-minute observation for each infant (Commandeur & Koopman, 2007). Four subsequent analyses were performed on each observation. Each model included cyclic parameters to describe cerebral oxygenation alone over time, plus one fixed parameter to capture the relationship between cerebral

oxygenation and either heart rate or peripheral oxygenation. This parameter quantified the bivariate relationship between cerebral oxygenation and either heart rate or peripheral oxygenation at any second in the 20 minute time period being analyzed. This process was then repeated, but with either heart rate or peripheral oxygenation being the dependent variable with cerebral oxygenation as the independent variable. Results are shown in Table 12. The timing and frequency of these significant relationships did not show any particular pattern. Even though there was a relationship in some observations, conclusions could not be drawn from these findings.

Table 12. Time Series Analysis Results

Model	Number Significant/ N Observations	Percent Significant
1- Y=HR, X=SctO ₂	25/129	19.4%
2- Y=SctO ₂ , X=HR	23/130	17.7%
3- Y=SpO ₂ , X=SctO ₂	41/126	32.5%
4- Y=SctO ₂ , X=SpO ₂	29/128	22.7%

5.3.3 State space time series analysis regression coefficients

In the third analysis, general linear mixed models utilized the regression coefficients for each observation from the four state space time series analyses to determine whether the strength of the relationships changed systematically with postnatal age (Table 12). The relationship became stronger with increased postnatal age when cerebral oxygen saturation was used to predict peripheral oxygenation (Figure 11). Caffeine and probe location did not significantly affect this relationship. When peripheral oxygenation was used to predict cerebral oxygen saturation, the relationship was not significant and again caffeine and probe location had no effect on the relationship. There was no significant systematic change in the relationship between heart rate and cerebral oxygen saturation when heart rate was used to

predict cerebral oxygen saturation. However, a cerebral oximeter probe location on the left significantly affected the strength of the relationship when cerebral oxygen saturation was used to predict heart rate (See Appendix H for SAS output).

Table 12. Mixed Models Analysis Using State Space Time Series Analysis Regression Coefficients

Model	Variable	Parameter Estimate	SE	p-value
1- Dependent variable = HR				
Independent variable = SctO ₂	Intercept ^a	-0.37	0.72	.61
N= 130	PNA ^b	-0.03	0.02	.12
	Caffeine ^c	0.02	0.88	.98
	Probe ^d	1.57	0.73	.04
2- Dependent variable = SctO₂				
Independent variable = HR	Intercept ^a	0.16	0.1	.14
N= 129	PNA ^b	-0.004	-0.01	.14
	Caffeine ^c	-0.01	-0.01	.93
	Probe ^d	-0.07	-0.07	.53
3- Dependent variable = SpO₂				
Independent variable = SctO ₂	Intercept ^a	1.07	0.73	.16
N= 128	PNA ^b	0.04	0.02	.04
	Caffeine ^c	0.09	0.83	.91
	Probe ^d	-0.39	0.67	.56
4- Dependent variable = SctO₂				
Independent variable = SpO ₂	Intercept ^a	0.08	0.48	.87
N= 126	PNA ^b	0.02	0.01	.17
	Caffeine ^c	-0.67	0.48	.16
	Probe ^d	0.69	0.37	.06

^a Intercept equals expected value for all infants starting at 25 +5 weeks

^b PNA= postnatal age

^c Caffeine =0 when coded 1 for therapeutic dose, 0 all others

^d Probe = 0 when coded 1 for right side, 0 for left side monitoring

5.4 Discussion

Results in this study demonstrated an overall relationship between cerebral oxygen saturation and vital signs when using averaged 1-minute means of each variable. Infants with higher averaged peripheral oxygenation compared to the group of infants at the same postnatal age also had higher cerebral oxygen saturations values; infants with higher heart

rates had lower cerebral oxygenation. It is unknown why a higher heart rate was associated with a lower cerebral oxygen saturation as this finding was not supported by previous literature

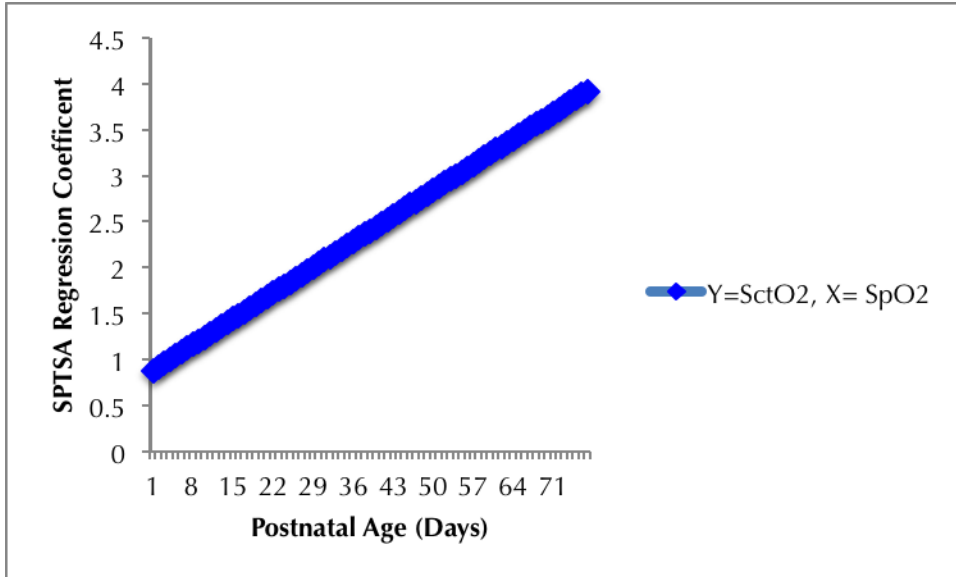


Figure 11. Relationship When SctO₂ Predicts SpO₂ Using State Space Time Series Analysis Regression Coefficients in a Mixed Model

Tina et al. (2009) used Pearson product correlations to examine the relationship between heart rate and cerebral oxygen saturation during only the first 6 hours of life and found higher heart rates were associated with higher cerebral oxygenation. In contrast, this study examined the relationship between heart rate and cerebral oxygenation using general linear mixed models for several weeks, well beyond the first 6 hours of life. As a result, the contradictory findings between this study and Tina et al. (2009) could demonstrate how the relationship between heart rate and cerebral oxygen saturation may differ during the first 6 hours of life only and across several weeks of life, which may be due to increased oxygen consumption.

State space time series analysis allowed for the next step the statistical analysis to move from the relationships assessed over a period of weeks to those assessed over 20 minutes (within an observation). A minority of the state space time series analysis showed significant relationships within individual observations between cerebral oxygenation and heart rate and peripheral oxygenation (18-33% of all observations). However, conclusions could not be derived about the presence or direction of these significant relationships.

Regression coefficients from the state space time series analysis were used in four general linear mixed models to look at how the relationships changed with infant age. The only significant change in relationship was found when cerebral oxygen saturation predicted peripheral oxygenation; this relationship became stronger with increased postnatal age. It is possible that earlier in life the two vital signs characterized two different physiologic processes but became more similar over time represented by the larger predicted state space time series analysis regression coefficients. This would suggest that cerebral oxygen saturation is a better method to monitor oxygen in the brain and cerebral oxygen saturation should be monitored separately from peripheral oxygenation. After several weeks, monitoring could potentially be reduced to one oxygen monitoring tool. The suggested time period for one oxygenation tool is currently unknown, but a lag analysis could help determine which of the two vital signs changed first in relationship to the other and when this change becomes almost simultaneous resulting in the ability to go from two oxygenation monitors to one.

Caffeine also significantly affected the relationship between cerebral oxygen saturation and heart rate and peripheral oxygenation. Caffeine increases heart rate and

peripheral oxygenation and decreases cerebral oxygen saturation in infants (Tracy et al., 2010). A decrease in cerebral oxygen saturation with caffeine use is thought to be due to an increase in cerebral metabolism and/or vasoconstriction. Cerebral oxygen saturation reflects oxygen content in the veins (70%) after much of the oxygen has been consumed or metabolized in the arteries whereas peripheral oxygenation measures arterial oxygen content (Schnapp & Cohen, 1990). Thus, an increase in cerebral metabolism due to caffeine could be the factor that distinguishes the variations in the relationship between cerebral oxygen saturation and peripheral oxygenation since both measure amounts of oxygen.

Although the aims were achieved for this study, attrition and multiple sampling rates limited the findings. A repeated measures design with 24 premature infants is a respectable sample size, but over time, fewer and fewer infants contributed to the observations. Observations were scheduled until infants were discharged home or transferred to another hospital facility. By Postnatal Day 27, only half of the infants remained in the study and three or fewer infants were included in the last four postnatal ages. Therefore, there is less confidence in later findings. Seriously ill infants were most likely contributing to the later observations in which critical care monitoring is necessary compared to infants who were often home at this time who already met discharge criteria.

Different sampling rates may have changed the overall relationships. Manual observations at the 30-second sampling rate accounted for approximately 27% of all observations for this study. The sampling rate for each variable within an observation was equivalent (30-second heart rate and 30-second cerebral oxygen saturation), but the

final analyses included all 1-second, 2-second, and 30-second sampling rates. The 30-second sampling rate may not have allowed for patterns of each variable to be discovered, which could have contributed to the inconclusive findings for the state space time series analysis. However, equipment failure is inevitable during any research study and the researcher collecting data at a 30-second sampling rate was the best method to continue with the study.

In conclusion, relationships between cerebral oxygenation and peripheral oxygenation and heart rate were apparent in the group analysis using means by observation and in the general linear mixed models with the state space time series regression coefficients where systematic change increased with age when peripheral oxygenation predicted cerebral oxygen saturation. Individual analyses using state space time series analysis did not show any discernible trends in cerebral oxygenation over the 20 minute time periods. State space time series analysis allowed for variables to be deconstructed into the level and cycle(s). By using the regression coefficients from state space time series analysis, the deconstructed variable only included the level of the variable whereas when significance was found using the means per observation, cycles were included in the value of the variable. Future analyses should extract the cycles for each variable and compare the cycles between variables to assess whether it is the cycles that are the common factor between the variables associated with the significant relationships found in this current study. Lags would also be of interest to further examine if patterns exist when one vital sign changes in relationship to another vital sign. These approaches would further assist in understanding the relationships between cerebral oxygen saturation and two currently monitored vital signs, heart rate and

peripheral oxygenation, to help decide the necessity of cerebral oxygen saturation as an added monitored physiologic variable.

4

6. Conclusion

This dissertation measured cerebral oxygen saturation longitudinally in premature infants; evaluated how environmental variables controlled by nursing, positioning and noise, affected cerebral oxygen saturations; and examined the relationship between cerebral oxygen saturation and two currently measured vital signs. In the subsequent sections, I will discuss my results organized by the concepts of probabilistic epigenesis, the conceptual framework used for this dissertation (Figure 12).

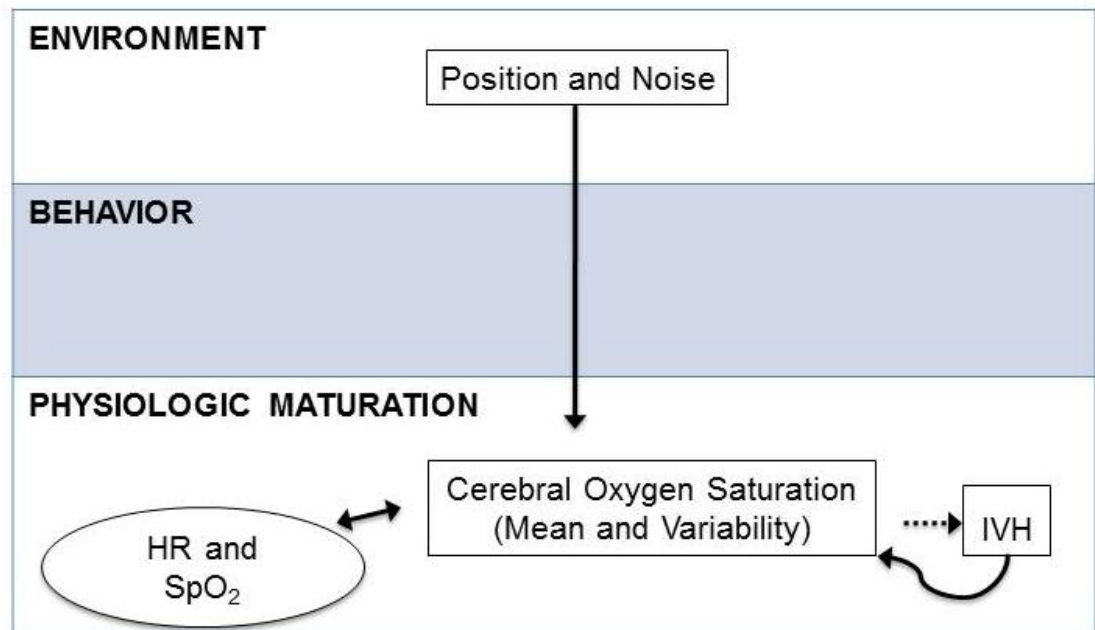


Figure 12. Development of Cerebral Oxygenation in Premature Infants

6.1 Physiologic Maturation

Until recently, the trajectory of cerebral oxygen saturation values over the course of a premature infant's hospitalization was unknown (McNeill et al., 2011; Roche-Labarbe et al., 2012). Findings from this dissertation showed the developmental trajectory of cerebral oxygen saturation values in premature infants' began in the high 70s during the first 2 days of life and then significantly decreased into the mid-60s over

several weeks during hospitalization in a neonatal intensive care unit (NICU). Cerebral oxygen saturation values served as a substitute for measuring cerebral oxygenation, which was also assumed to be a proxy for cerebral blood flow. In a previous study, cerebral blood flow increased over time in premature infants (Volpe, 2001a), but in the current study, cerebral oxygen saturation decreased over time. The opposing findings between these two measures may show that monitoring cerebral oxygen saturation is not a suitable replacement for monitoring cerebral blood flow. Instead, cerebral oxygen saturation may better represent a measure of cerebral metabolism that could be affected by cerebral blood flow. Lower values over time may be indicative of better utilization of oxygen within the cells of the brain and brain function. If values are lower than these norms over time, cerebral metabolism or oxygen demand could be too high or blood flow is inadequate to supply enough oxygen to the brain. In either case, cerebral oxygen saturation values that are obviously outside the normative values identified in Chapter 3 require further clinical evaluation.

Although cerebral oxygen saturation decreased over time and varied slightly between premature infants, these normative values set a general range for cerebral oxygen saturation values and are similar to cerebral oxygen saturation values reported in the literature (McNeill et al., 2011; Roche-Labarbe et al., 2012). The dissertation findings compliment the two empirical articles by McNeill et al. (2011) and Roche-Labarbe et al. (2012) demonstrating that both the INVOS® and FORE-SIGHT™ cerebral oximeters obtain similar cerebral oxygen saturation values in premature infants. In addition, for the first time, covariates suggested in the literature such as caffeine and probe location were also examined and found in certain situations to have a

significant effect on cerebral oxygen saturation values.

Cerebral oxygen saturation was used as a proxy for cerebral blood flow to examine if cerebral oxygen saturation values could noninvasively screen at the bedside for impending IVH. According to the findings of this dissertation, the trajectory of cerebral oxygen saturation during the first week of life in those infants who developed an IVH did not significantly differ from those infants without IVH. At this time, use of cerebral oxygen saturation to identify those infants at risk for IVH during the first week of life cannot be supported. However, the findings did indicate that cerebral oxygen saturation monitoring could potentially monitor the severity of the impact of IVH later during hospitalization as those infants with an IVH had significantly lower cerebral oxygen saturation values at the third week of life. In this case, cerebral oxygen saturation might help to understand the long-term degree of neurological damage. These two findings, cerebral oxygenation trajectories not differing with an IVH diagnosis in the first week of life and the effect of IVH on cerebral oxygenation values, are depicted in Figure 12. A new arrow was added showing the new relationship from IVH to cerebral oxygenation and a dashed arrow represents the lack of the relationship between cerebral oxygenation showing the development of IVH. In the future, cerebral oxygen saturation monitoring could be used to indicate the timing for intervening to decrease neurological damage when cerebral oxygen saturation values begin to fall outside of normative values.

Heart rate and peripheral oxygenation were chosen as the two physiologic variables to compare to cerebral oxygen saturation and represented a horizontal examination between concepts according to probabilistic epigenesis. Average cerebral

oxygen saturation was lower with higher heart rate and higher cerebral oxygen saturation was related to higher peripheral oxygenation. Peripheral oxygenation that is already routinely measured in premature infants appears to not provide an accurate measure of the changes in cerebral oxygen saturation, as findings from a general linear mixed model showed peripheral oxygenation could not be used to predict cerebral oxygen saturation. Furthermore, heart rate did not predict cerebral oxygen saturation and cerebral oxygen saturation was unable to predict heart rate. Therefore, cerebral oxygenation appears to measure a different physiological process and monitoring cerebral oxygen saturation would be of particular importance in select infants in whom cerebral metabolism is known to be much higher such as infants diagnosed with hypoxic-ischemic encephalopathy or seizures to assess in danger of neurological damage. Cerebral oxygen saturation would be critical to monitor separate from peripheral oxygenation in these two types of infants, as cerebral oxygen saturation values could provide more accurate information about cerebral metabolism.

Also, other care procedures such as suctioning or intubation not examined in this dissertation may influence cerebral oxygen saturation values. During these procedures, monitoring cerebral oxygen saturation would identify how oxygen in the brain is affected and assist in learning new ways to preserve cerebral oxygenation compared to peripheral oxygenation saturation. Cerebral oxygen saturation values may be particularly important to incorporate into patient care when the integrity of the nervous system is in jeopardy.

6.2 Environment

The external environment is the last concept from the probabilistic epigenesis theory that was examined in this dissertation. Sound and positioning were chosen to represent two frequently encountered components of the neonatal intensive care environment that also influence infant cerebral oxygen saturation.

6.2.1 Environmental sound

This dissertation evaluated changes in cerebral oxygen saturation due to a small increase in peak sound level over the usual quiet ambient research setting. A peak in sound from the ambient sound level was only 5 decibels and found to not have a significant effect on cerebral oxygen saturation values. In other NICUs, peak sound levels may exceed 5 decibels (American Academy of Pediatrics Committee on Environmental Health, 1997; Bremmer et al., 2003; Thomas & Uran, 2007), which would allow for further research to examine how high peak sound levels (> 10 decibels above ambient sound) affect cerebral oxygen saturation. In addition, future work could purposively study the relationship between cerebral oxygenation and noise levels during times that are less conducive to noise reduction strategies such as periods of unit redesign and construction where there are uncontrolled, intermittent peak sound levels greater than 5 decibels. Creating a noisy environment to examine this relationship could potentially cause harm and would be unethical. Currently, small changes in ambient sound levels do not appear to alter cerebral oxygen saturation values.

6.2.2 Infant position

In addition to sound, positioning was another aspect of care studied in the neonatal intensive care environment. Few guidelines exist to advise nurses on how to

best position infants or how to select a position that will support optimal physiologic stability. Examining the effect of position on cerebral oxygen saturation was anticipated to help develop more specific guidelines for positioning premature infants and reduce cerebral damage caused by hypoxic episodes. A neutral position considered the gold standard—supine, head midline—was compared to five other positions widely used by NICU nurses. However, results showed positions with a turned head did not significantly differ in cerebral oxygen saturation from the neutral position. Therefore, continuing to place infants in positions with a turned head no greater than 45° appears to cause no harm. Yet, differences in cerebral oxygen saturation were found between two lateral positions (left lateral and right lateral, head elevated 15°) with an elevated head measuring lower cerebral oxygen saturation levels. An elevated head can cause a decrease in cerebral blood flow (Pichler, van Boetzlar, et al., 2001) and changes in cerebral oxygen saturation may not reflect cerebral metabolism as much as a lack in blood flow to the brain.

6.3 Limitations

The findings of this dissertation were limited by factors resulting from the complexity of the patient population in the NICU setting and attrition rate. Bilirubin, respiratory support, and blood transfusions are three primary aspects not accounted for in this dissertation. Bilirubin is a byproduct of lysed red blood cells that deposit in the skin resulting in a yellow or jaundice appearance. Over 80% of premature infants are estimated to be jaundiced due to the presence of bilirubin (Madan, MacMahon, & Stevenson, 2005) and bilirubin competes for light absorption with oxygenated hemoglobin within the near infrared light spectrum (Madsen, Skak, Rasmussen, &

Secher, 2000). On average, an increase by 100 $\mu\text{mol/L}$ bilirubin decreased cerebral oxygen saturation by 7.4% (Madsen et al., 2000). The average bilirubin level was 71 $\mu\text{mol/L}$ when cerebral oxygen saturation levels were lower compared to the maximum bilirubin level across all infants in this study of 12.4 $\mu\text{mol/L}$. Using the same mathematical equation as Madsen et al. (2000) on this dissertation data, an increase by 100 $\mu\text{mol/L}$ would decrease cerebral oxygen saturation reading by less than 1.5% making the impact of bilirubin presence negligible.

Another factor not considered in the dissertation analyses was respiratory modality and FiO_2 greater than room air (21%). Infants cared for in the NICU often require respiratory support via mechanical ventilation, oxygenation, or both. The 138 observations included the use of a jet ventilator (N= 2), conventional ventilator (N= 11), CPAP (N= 36), and nasal cannula (N= 22) and 15 observations using FiO_2 greater than 21% ranging from 22% to a maximum of 30%. Most respiratory modalities and supplemental oxygen change cerebral blood flow, often lowering it, which could have also affected cerebral oxygen saturation (Baenziger et al., 1994; Lundstrom, Pryds, & Greisen, 1995; Milan, Freato, Vanzo, Chiandetti, & Zaramella, 2009; Saoud Abd El-Moneim et al., 2008). However, infants in this sample represent typical infants requiring respiratory support for respiratory insufficiencies. Within a few weeks of life, most infants no longer require respiratory assistance. Those infants who required respiratory support would have received additional oxygen or increased air flow or pressure, which should have raised oxygen content. As already noted, cerebral oxygen saturation decreased over time. If the trajectory of cerebral oxygen saturation was significantly affected by respiratory modality use, cerebral oxygen saturation values would have

increased or stayed stable due to the increase in oxygen delivery and respiratory support.

Blood transfusions were another care factor not considered in this study. Throughout many premature infants' hospitalizations, a blood transfusion is warranted (Kirpalani et al., 2006) to increase oxygen carrying capacity via red blood cells that have dropped over time due to multiple blood draws and an immature hematopoietic system (Bednarek et al., 1998; Strauss, 1991, 1995). Oxygen attaches to hemoglobin on red blood cells and as infants become anemic, cerebral oxygen saturation values would decrease. During a blood transfusion, cerebral oxygen saturation values increased compared to values before the transfusion (Dani, Pratesi, Fontanelli, Barp, & Bertini, 2010). The decreasing trajectory of cerebral oxygen saturation could have been affected by the conservative blood transfusion treatment practiced in this research setting. Infants would have a lower capacity to carry oxygen due to low hemoglobin and/or hematocrit levels. If infants were managed in these low blood levels, then cerebral oxygen saturation values could have been lower than another NICU where blood transfusion were more readily ordered to treat low hemoglobin and/or hematocrit.

Additionally, a blood transfusion would have decreased the ratio of fetal hemoglobin to adult hemoglobin as blood transfusions are from adult donations. Fetal hemoglobin has a higher affinity to oxygen than adult hemoglobin. According to the inventor of the FORE-SIGHT™ Cerebral Oximeter used in this study, there is no difference in the amount of oxygen measured regardless of whether it is attached to fetal hemoglobin or adult hemoglobin (P. Benni, personal communication, 4/19/2012). In other words, both types of hemoglobin are captured in the near infrared light spectrum.

However, a blood transfusion might have changed the individual trajectory of an infant. Future research is needed to specifically inquire about the affect of blood transfusion on cerebral oxygen saturation.

Lastly, attrition rates may have affected the trajectory of cerebral oxygen saturation. After 42 postnatal days, predicted means were less certain due to fewer observations from fewer infants. Although the attrition rates reflect that healthier infants are discharged earlier from the NICU than more seriously ill infants, the predictive means within the general linear mixed models do not represent all infants in the study through 77 days postnatal age. In fact, the predicted means are potentially altered due to less representation of infants in the last several postnatal ages. However, this study design allowed for 24 infants to be captured while they required intensive care. Once infants meet criteria for discharge home, continuously monitoring vital signs is not necessary. A decision to only analyze data through 42 postnatal days or follow these infants to other hospitals (Durham Regional Hospital) may have resulted in slightly different findings, but NICU patients would have been misrepresented by including healthy infants into the sample. Thus, the findings would have been less useful clinically.

6.4 Implications for Research

This dissertation suggested a number of areas for future research before cerebral oximetry can be incorporated as a standard of care for premature infants. If this measure has the potential to identify infants at risk for IVH, the timing and severity of IVH needs to be considered. Cerebral oxygen saturation values were intermittently measured and it is highly possible that the expected fluctuations hypothesized to result

in IVH occurred at a time outside the 60-minutes of cerebral oxygenation monitoring (three, 20-minute observations) in the first week of life. Therefore, in order to capture an IVH occurring in the first week, continuous monitoring of cerebral oxygen saturation, rather than the intermittent sampling rate in this dissertation, is suggested. Continuous monitoring of cerebral oxygen saturation during the first week of life would also allow for the 1-second sampling rate of the cerebral oximeter to be appreciated using state space time series analysis. State space time series analysis requires time to be a continuous variable and several days measuring cerebral oxygen saturation at the 1-second sampling rate help to determine when fluctuations may have occurred. In this dissertation, the analyses were limited to several individual observations due to the repeated measures design.

Secondly, the severity of IVH ranges from a grade I to IV, but the enrolled sample for this study included only grade I IVH. Another study with all grades of IVH showed that cerebral oxygenation had predictive ability within the first 6 hours of life that was able to distinguish between those infants who did and did not develop an IVH later in the week (Sorensen, Maroun, et al., 2008). As a result, the range of IVH severity needs to be further investigated in a future study to determine if cerebral oxygen saturation can identify IVH preferably in real-time to intervene appropriately in a timely manner.

In chapter 4, cerebral oxygen saturations were compared in six different infant positions, but an additional eight other infant positions still remained unevaluated (Table 1). To determine the effects of position on cerebral oxygen saturation in premature infants born less than 32 weeks gestation, these eight positions need to be

assessed in a similar manner to the methods utilized in this dissertation. Only when all 14 positions have been examined can the effect of position on cerebral oxygen saturation be fully understood.

Lastly, normative values of cerebral oxygen saturation were shown to be affected by certain groups of infants who received caffeine and with different probe locations. As other covariates are examined, there is potential for more subgroups to be identified and as more subgroups become known, an ideal approach to convey longitudinal, normative cerebral oxygen saturation values would be to develop a nomogram for clinical use. This recommendation comes from the current, user friendly Clinical Practice Guideline for the Management of Hyperbilirubinemia created by the American Academy of Pediatrics (American Academy of Pediatrics Subcommittee on Hyperbilirubinemia, 2004). The hyperbilirubinemia nomogram has been used to guide unit protocols for hyperbilirubinemia and has simplified how and when clinicians should manage infants based on age and bilirubin levels. A cerebral oxygen saturation nomogram would provide expected values based on subgroups such as a left or right probe location or receipt of caffeine, but a larger sample size is required beyond what is provided in this dissertation.

6.5 Implications for Practice

This dissertation provided clinicians with fundamental knowledge about cerebral oxygen saturation in premature infants. Dissertation findings provided beginning suggestions for how cerebral oxygen saturation may be incorporated into clinical practice. First, education of clinicians on cerebral oxygen saturation monitoring should be a top priority. The nature of cerebral oxygen saturation is unique in the sense that

normative values are dissimilar to peripheral oxygenation as they begin in the 70s and slowly decrease into the 60s over several weeks. Since cerebral oxygen saturation and peripheral oxygenation are both measures of oxygen, clinicians will most likely compare the two vital signs and expect cerebral oxygen saturation values to reflect similar normative peripheral oxygenation values. Consequently, clinicians will be concerned with a low cerebral oxygen saturation and potentially act on increasing the value and cause potential damage. For instance, a clinician might administer supplemental oxygen thinking the additional oxygen could increase the cerebral oxygen saturation. Yet instead the infant is now at an increased risk for retinopathy of prematurity from the supplemental oxygen and at this time, it is not known how the additional FiO_2 affects cerebral oxygen saturation values. Normative values from Chapter 3 will need to be reviewed to make sure clinicians are aware that cerebral oxygen saturations start in the high 70s within the first few days of life and slowly decrease for several weeks into the mid-60s.

Secondly, clinicians need to continue to attempt to maintain a quiet sound environment and use different infant positions throughout an infant's hospitalization. Currently, cerebral oxygen saturation is not significantly impacted by small variations in sound levels or numerous infant positions. However, extreme head positions such as a 90° turned head is not suggested.

Lastly, cerebral oximetry was shown to be the best method to measure oxygen in the brain. Although heart rate, peripheral oxygenation, and other vital signs provide clinicians with a general oversight of infant health, cerebral oxygen saturation is the only current marker for explicitly monitoring continuous neurological activity in the

brain. As more research on cerebral oxygen saturation becomes available, clinicians will be able to decipher if currently monitored vital signs are sufficient to provide adequate medical care or if cerebral oxygen saturation adds value to this neurologically at-risk population.

6.6 Theoretical Examination

In this last section, I will critique how well probabilistic epigenesis guided and fit the findings of this dissertation. Gilbert Gottlieb's theory of probabilistic epigenesis provided moderate guidance in evaluating the development of cerebral oxygen saturation in premature infants and its relationship with other vital signs and the effects of the environment. Probabilistic epigenesis provided direction for how cerebral oxygen saturation changed over time and how different variables within the two conceptual levels might also relate to each other. Relationships between variables could either be horizontal (physiologic-physiologic) or vertical (physiologic-external environment). In this dissertation horizontal relationships appeared to be more prominent than vertical relationships. For example, a horizontal examination between cerebral oxygen saturation and heart rate and peripheral oxygenation was significant compared to the vertical assessment looking at the effects of position or sound levels on cerebral oxygen saturation. This finding does not indicate that the theory is incorrect in postulating the existence of vertical relationships. Vertical relationships may have been more apparent in this dissertation because as behavioral variables may have mediated the effects between positioning and sound and cerebral oxygen saturation. Without a variable to measure behavior such as sleep-wake states, the expected relationship between sound and cerebral oxygen saturation or infant position and cerebral oxygen saturation, was

stretched two conceptual levels, which could have dampened the strength of an apparent relationship. Future studies including infant behaviors may highlight currently non-significant relationships between physiologic and environmental factors.

;

Appendix A Chapter 2 SAS Output

Means by position
Prep for proc mixed on june 18 2011

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

		N					
	Position	Obs	N	Mean	Std Dev	Minimum	Maximum
<i>ff</i>							
<i>ffffffffffffffff</i>							
	1	96	96	78.2999272	5.0658331	65.0666667	88.8000000
	2	95	95	77.5417436	5.1256256	63.1000000	88.9000000
	3	96	96	78.5861744	3.9618627	67.0000000	85.5416667
	4	96	96	78.2192478	4.6887042	69.1666667	85.9900000
	5	96	96	78.4323211	4.5065171	68.5000000	86.3000000
	6	96	96	78.2631149	5.2502342	64.5000000	88.8433333
	7	96	96	78.4335549	4.8843256	70.2133333	87.4700000
<i>ff</i>							
<i>ffffffffffffffff</i>							

means by minute
prep for proc mixed on june 18 2011

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

		minutes since the start of a		N	Mean	Std Dev	Minimum	Maximum
		position	Obs	N				
<i>ff</i>								
<i>ffffffffffffffff</i>								
1	84	84	78.4970599	4.4823723	69.4000000	88.8000000		
2	84	84	78.4000725	4.3494737	66.4666667	88.5000000		
3	84	84	78.2370267	4.5452110	65.1000000	88.1233333		
4	84	84	78.2492378	4.6637163	65.0666667	87.8500000		
5	84	84	78.3205305	4.8535846	65.9666667	88.9000000		
6	84	84	78.0814149	5.0917613	63.1000000	88.8433333		
7	84	84	78.1267630	5.2516345	63.8000000	88.0566667		
8	83	83	78.1246442	5.1801721	65.0869565	88.7000000		
<i>ff</i>								
<i>ffffffffffffffff</i>								

means by position and minute
 prep for proc mixed on june 18 2011

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Position	minutes since the start of a position	N	Obs	N	Mean	Std Dev	Minimum	Maximum
1	1	12	12	79.2592460	4.4599610	72.6666667	88.8000000	
	2	12	12	78.0983333	5.5127746	66.4666667	86.6333333	
	3	12	12	77.8488889	5.9390647	65.1000000	87.6666667	
	4	12	12	78.0630556	5.9260298	65.0666667	86.4333333	
	5	12	12	78.3444444	5.0930726	65.9666667	84.5333333	
	6	12	12	78.1061111	4.6045217	68.7333333	85.4000000	
	7	12	12	78.2300000	5.5027218	66.5666667	87.3000000	
	8	12	12	78.4493386	4.7047464	70.1111111	86.1428571	
2	1	12	12	77.8697031	4.9253089	70.1666667	88.3448276	
	2	12	12	78.0161782	4.6933267	71.3666667	88.5000000	
	3	12	12	77.8280761	4.0408687	72.2000000	85.1666667	
	4	12	12	78.1268870	4.1208042	72.1666667	85.5000000	
	5	12	12	77.6592690	5.6284775	67.5666667	88.9000000	
	6	12	12	76.7160153	6.3853217	63.1000000	86.8666667	
	7	12	12	77.1123413	6.0863646	63.8000000	86.3333333	

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	minutes since the start of a	N	Obs	N	Mean	Std Dev	Minimum	Maximum
2	8	11	11	76.9567272	6.0510754	65.7666667	88.7000000	
3	1	12	12	78.9866667	3.7324198	72.4333333	84.3333333	
	2	12	12	78.7550000	3.2642206	72.9000000	84.2800000	
	3	12	12	78.6577778	3.1998641	72.9333333	85.1000000	
	4	12	12	78.3755556	3.6727510	71.6666667	83.6566667	
	5	12	12	77.7875000	4.4115418	67.0000000	82.4933333	
	6	12	12	78.0108333	4.7116505	67.1000000	83.2333333	
	7	12	12	78.6905556	4.6100001	71.8666667	85.1200000	
	8	12	12	79.4255065	4.7153176	72.5384615	85.5416667	
4	1	12	12	78.0286111	5.3804586	69.4000000	85.9900000	
	2	12	12	78.2644444	4.6608746	72.7666667	85.4000000	
	3	12	12	78.2269444	5.0971116	69.1666667	85.0766667	
	4	12	12	78.5394444	5.0159797	70.5666667	85.2333333	
	5	12	12	78.4127778	4.5587236	71.0766667	85.9100000	
	6	12	12	78.1738889	4.4863712	70.2933333	85.0266667	

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	minutes since the start of a	N	Obs	N	Mean	Std Dev	Minimum	Maximum
4	7	12	12	78.1444444	4.7074436	70.2000000	83.0666667	
	8	12	12	77.9634272	4.9702892	70.6625000	84.0187500	
5	1	12	12	77.7566667	3.9294627	71.7666667	83.7233333	
	2	12	12	78.1033333	3.6944485	72.8533333	83.3866667	
	3	12	12	78.0763889	4.3007369	71.6333333	84.8033333	
	4	12	12	78.5133333	4.5066425	71.3333333	84.5066667	
	5	12	12	79.0594444	4.5364655	72.5666667	85.8333333	
	6	12	12	79.2666667	5.0532718	72.4000000	86.3000000	
	7	12	12	78.6775000	5.4892764	68.5000000	85.5666667	
	8	12	12	78.0052355	5.3884882	69.8666667	86.0933333	
6	1	12	12	79.2950000	4.8976435	72.9000000	88.4433333	
	2	12	12	78.9169444	4.6611464	73.2333333	88.1100000	
	3	12	12	78.3866667	4.8404360	72.4333333	88.1233333	
	4	12	12	78.0127778	5.0400086	69.1666667	87.8500000	
	5	12	12	78.4175000	5.8049159	66.0666667	88.2500000	

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	minutes since the start of a	N	Obs	N	Mean	Std Dev	Minimum	Maximum
6	6	12	12	77.7205556	6.0936905	67.0333333	88.8433333	
	7	12	12	77.8038889	5.9547283	64.5000000	88.0566667	
	8	12	12	77.5515859	5.8638686	65.0869565	87.8933333	
7	1	12	12	78.2835256	4.7155668	71.3733333	87.4700000	
	2	12	12	78.6462739	4.6584310	70.9586207	86.3966667	
	3	12	12	78.6344444	5.0367914	70.2133333	86.4000000	
	4	12	12	78.1136111	5.2283285	70.3033333	86.5600000	
	5	12	12	78.5627778	4.9136801	70.9033333	86.3166667	
	6	12	12	78.5758333	4.9662321	71.2966667	86.0133333	
	7	12	12	78.2286111	5.4623258	71.6666667	85.9633333	
	8	12	12	78.4233621	5.5165015	70.3103448	85.9600000	

means by position and minute
 prep for proc mixed on june 18 2011

16:37 Sunday, April 22, 2012 692

Obs	Position	minute	_TYPE_	_FREQ_	mnco
1	.	.	0	671	78.2548
2	.	1	1	84	78.4971
3	.	2	1	84	78.4001
4	.	3	1	84	78.2370
5	.	4	1	84	78.2492
6	.	5	1	84	78.3205
7	.	6	1	84	78.0814
8	.	7	1	84	78.1268
9	.	8	1	83	78.1246
10	1	.	2	96	78.2999
11	2	.	2	95	77.5417
12	3	.	2	96	78.5862
13	4	.	2	96	78.2192
14	5	.	2	96	78.4323
15	6	.	2	96	78.2631
16	7	.	2	96	78.4336
17	1	1	3	12	79.2592
18	1	2	3	12	78.0983
19	1	3	3	12	77.8489
20	1	4	3	12	78.0631
21	1	5	3	12	78.3444
22	1	6	3	12	78.1061
23	1	7	3	12	78.2300
24	1	8	3	12	78.4493
25	2	1	3	12	77.8697
26	2	2	3	12	78.0162
27	2	3	3	12	77.8281
28	2	4	3	12	78.1269
29	2	5	3	12	77.6593
30	2	6	3	12	76.7160
31	2	7	3	12	77.1123
32	2	8	3	11	76.9567
33	3	1	3	12	78.9867
34	3	2	3	12	78.7550
35	3	3	3	12	78.6578
36	3	4	3	12	78.3756
37	3	5	3	12	77.7875

means by position and minute
prep for proc mixed on june 18 2011

16:37 Sunday, April 22, 2012 693

Obs	Position	minute	_TYPE_	_FREQ_	mnco
38	3	6	3	12	78.0108
39	3	7	3	12	78.6906
40	3	8	3	12	79.4255
41	4	1	3	12	78.0286
42	4	2	3	12	78.2644
43	4	3	3	12	78.2269
44	4	4	3	12	78.5394
45	4	5	3	12	78.4128
46	4	6	3	12	78.1739
47	4	7	3	12	78.1444
48	4	8	3	12	77.9634
49	5	1	3	12	77.7567
50	5	2	3	12	78.1033
51	5	3	3	12	78.0764
52	5	4	3	12	78.5133
53	5	5	3	12	79.0594
54	5	6	3	12	79.2667
55	5	7	3	12	78.6775
56	5	8	3	12	78.0052
57	6	1	3	12	79.2950
58	6	2	3	12	78.9169
59	6	3	3	12	78.3867
60	6	4	3	12	78.0128
61	6	5	3	12	78.4175
62	6	6	3	12	77.7206
63	6	7	3	12	77.8039
64	6	8	3	12	77.5516
65	7	1	3	12	78.2835
66	7	2	3	12	78.6463
67	7	3	3	12	78.6344
68	7	4	3	12	78.1136
69	7	5	3	12	78.5628
70	7	6	3	12	78.5758
71	7	7	3	12	78.2286
72	7	8	3	12	78.4234

Dep var is averaged 1 minuted sct02 16:37 Sunday, April 22, 2012 694
independent variables are minute, minute2, and position
plus their interactions
pma is a covariate january 18 2012
Final Model for Chapter 2

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect newid
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
d1	2	0 1
d2	2	0 1
d4	2	0 1
d5	2	0 1
d6	2	0 1
d7	2	0 1

Dimensions

Covariance Parameters	9
Columns in X	18
Columns in Z Per Subject	14
Subjects	12
Max Obs Per Subject	56

Dep var is averaged 1 minuted sct02 16:37 Sunday, April 22, 2012 695
independent variables are minute, minute2, and position
plus their interactions
pma is a covariate january 18 2012
Final Model for Chapter 2

The Mixed Procedure

Number of Observations

Number of Observations Read	671
Number of Observations Used	671
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	3851.73924960	
1	2	2797.67680936	0.04327837
2	1	2751.90944894	0.02957591
3	1	2721.67120975	0.01885355
4	1	2702.94977575	0.01064445
5	1	2692.66205652	0.00503197
6	1	2687.93368016	0.00182338
7	1	2686.28143451	0.00042147
8	1	2685.92023692	0.00004084
9	1	2685.88787010	0.00000065
10	1	2685.88738158	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	newid	21.7308
minute	newid	0.04419
d1	newid	2.9596

Dep var is averaged 1 minuted sct02 16:37 Sunday, April 22, 2012 696
independent variables are minute, minute2, and position
plus their interactions
pma is a covariate january 18 2012
Final Model for Chapter 2

The Mixed Procedure

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
d2	newid	1.9235
d4	newid	1.1819
d5	newid	1.0245
d6	newid	2.0186
d7	newid	2.0569
Residual		2.1317

Fit Statistics

-2 Res Log Likelihood	2685.9
AIC (smaller is better)	2703.9
AICC (smaller is better)	2704.2
BIC (smaller is better)	2708.3

Solution for Fixed Effects

Effect	Value	Pr > |t|	Standard Error	DF	t	
Intercept	78.3963	3.3782	10	23.21	<.0001	
d1	0	0.2862	0.7333	11	0.39	0.7037

Dep var is averaged 1 minute sct02
independent variables are minute, minute2, and position
plus their interactions
pma is a covariate january 18 2012
Final Model for Chapter 2

The Mixed Procedure
Solution for Fixed Effects

Effect	1 if	1 if	1 if	1 if	1 if	Standard			
Value	Pr > |t|	otherwise	otherwise	otherwise	otherwise	prone	Estimate	Error	DF t
d1	1					0	.	.	.
d2		0				0.9833	0.6044	11	1.63 0.1320
d2		1				0	.	.	.
d4			0			0.3669	0.4913	11	0.75 0.4708
d4			1			0	.	.	.
d5				0		2.4338	0.7699	11	3.16 0.0091
d5				1		0	.	.	.
d6					0	0.3231	0.6171	11	0.52 0.6110
d6					1	0	.	.	.
d7						0.1526	0.6223	11	0.25 0.8108
d7						0	.	.	.
minute						-0.2807	0.1368	11	-2.05 0.0647
minute2						0.02320	0.01331	572	1.74 0.0818
inter5						1.0691	0.3239	572	3.30 0.0010
inter52						-0.09926	0.03514	572	-2.83 0.0049
c_pma						0.7725	0.5802	572	1.33 0.1836

Dep var is averaged 1 minuted sct02 16:37 Sunday, April 22, 2012 698
independent variables are minute, minute2, and position
plus their interactions
pma is a covariate january 18 2012
Final Model for Chapter 2

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num		Den	
	DF	DF	F Value	Pr > F
d1	1	11	0.15	0.7037
d2	1	11	2.65	0.1320
d4	1	11	0.56	0.4708
d5	1	11	9.99	0.0091
d6	1	11	0.27	0.6110
d7	1	11	0.06	0.8108
minute	1	11	4.21	0.0647
minute2	1	572	3.04	0.0818
inter5	1	572	10.90	0.0010
inter52	1	572	7.98	0.0049
c_pma	1	572	1.77	0.1836

The MEANS Procedure

Analysis Variable : Pred Predicted

	Position	minutes since the start of a position	N	Obs	Mean	Std Dev	Minimum	Maximum	N	Miss
<i>ff</i>										
1	1	1	12	78.7138984	4.5744898	70.0784910	86.2179214	12	0	
		2	12	78.5028336	4.6724920	69.4655630	86.1737301	12	0	
		3	12	78.3381624	4.7764359	68.8990287	86.1759324	12	0	
		4	12	78.2198849	4.8859423	68.3788881	86.2245284	12	0	
		5	12	78.1480011	5.0006459	67.9051411	86.3195181	12	0	
		6	12	78.1225110	5.1201974	67.4777879	86.4609015	12	0	
		7	12	78.1434146	5.2442652	67.0968283	86.6486786	12	0	
		8	12	78.2107118	5.3725365	66.7622624	86.8828493	12	0	
2	1	1	12	78.0168103	4.5363801	71.0601747	86.7081740	12	0	
		2	12	77.8057454	4.6457966	70.4472467	86.6639826	12	0	
		3	12	77.6410743	4.7606767	69.8807124	86.6661850	12	0	
		4	12	77.5227968	4.8806346	69.3605718	86.7147810	12	0	
		5	12	77.4509130	5.0053051	68.8868248	86.8097707	12	0	
		6	12	77.4254229	5.1343451	68.4594716	86.9511541	12	0	
		7	12	77.4463264	5.2674333	68.0785120	87.1389312	12	0	
<i>ff</i>										

The MEANS Procedure

Analysis Variable : Pred Predicted

	Position	minutes since the start of a position	N	Obs	Mean	Std Dev	Minimum	Maximum	N	Miss
2	8	11	76.9778699	5.3233386	67.7439461	87.3731019	11	0		
3	1	12	79.0001456	3.6436651	73.6766737	84.8328260	12	0		
	2	12	78.7890808	3.7509160	73.0637457	84.6596666	12	0		
	3	12	78.6244096	3.8650202	72.4972114	84.5329008	12	0		
	4	12	78.5061321	3.9853890	71.9770708	84.4525287	12	0		
	5	12	78.4342483	4.1114722	71.5033238	84.4185503	12	0		
	6	12	78.4087582	4.2427606	71.0759706	84.4309656	12	0		
	7	12	78.4296618	4.3787858	70.6950110	84.4897746	12	0		
	8	12	78.4969590	4.5191202	70.3604451	84.5949772	12	0		
4	1	12	78.6332190	4.1807665	72.2988989	85.0619790	12	0		
	2	12	78.4221542	4.2842624	72.0356779	84.8888195	12	0		
	3	12	78.2574830	4.3939657	71.8188506	84.7620538	12	0		
	4	12	78.1392055	4.5094233	71.6484170	84.6816817	12	0		
	5	12	78.0673217	4.6302049	71.5243771	84.6477033	12	0		
	6	12	78.0418316	4.7559048	71.3079971	84.6601186	12	0		

The MEANS Procedure

Analysis Variable : Pred Predicted

	minutes since the start of a Position	position	N	Obs	Mean	Std Dev	Minimum	N	Maximum	N	Miss
4	7	12	78.0627352	4.8861435	70.9270375	84.7189275	12	0			
	8	12	78.1300324	5.0205678	70.5924716	84.8241302	12	0			
5	1	12	77.5362100	3.9431447	72.0645716	83.8662389	12	0			
	2	12	78.0965014	4.0484718	72.2229999	84.4644358	12	0			
	3	12	78.5046630	4.1602634	72.2292983	84.9105028	12	0			
	4	12	78.7606948	4.2780128	72.0834669	85.2044399	12	0			
	5	12	78.8645967	4.4012419	71.7855057	85.3462472	12	0			
	6	12	78.8163687	4.5295034	71.3354146	85.3359247	12	0			
	7	12	78.6160109	4.6623821	70.7331936	85.1734723	12	0			
	8	12	78.2635233	4.7994944	69.9788428	84.8588900	12	0			
6	1	12	78.6770861	4.7050087	70.9754176	88.1893842	12	0			
	2	12	78.4660213	4.8102161	70.5885780	88.0162248	12	0			
	3	12	78.3013501	4.9208928	70.2481320	87.8894590	12	0			
	4	12	78.1830726	5.0366781	69.9540798	87.8090869	12	0			
	5	12	78.1111888	5.1572282	69.7064212	87.7751085	12	0			

The MEANS Procedure

Analysis Variable : Pred Predicted

	minutes since the start of a	N	Obs	Mean	Std Dev	Minimum	Maximum	N	Miss
Position	position								
6	6	12	78.0856987	5.2822166	69.5051563	87.7875238	12	0	
	7	12	78.1066022	5.4113359	69.3502850	87.8463328	12	0	
	8	12	78.1738995	5.5442976	69.2418075	87.9515354	12	0	
7	1	12	78.8475261	4.4436151	71.9432233	86.5029341	12	0	
	2	12	78.6364613	4.5578017	71.6800024	86.3297747	12	0	
	3	12	78.4717901	4.6773211	71.4631751	86.2030089	12	0	
	4	12	78.3535126	4.8017750	71.2927415	86.1226368	12	0	
	5	12	78.2816288	4.9307898	71.1687016	86.0886584	12	0	
	6	12	78.2561387	5.0640170	71.0364546	86.1010737	12	0	
	7	12	78.2770423	5.2011327	70.8815833	86.1598827	12	0	
	8	12	78.3443395	5.3418377	70.7731058	86.2650853	12	0	

703

Obs	Position	minute	_TYPE_	_FREQ_	predmn
1	.	.	0	671	78.2548
2	.	1	1	84	78.4893
3	.	2	1	84	78.3884
4	.	3	1	84	78.3056
5	.	4	1	84	78.2408
6	.	5	1	84	78.1940
7	.	6	1	84	78.1652
8	.	7	1	84	78.1545
9	.	8	1	83	78.0987
10	1	.	2	96	78.2999
11	2	.	2	95	77.5417
12	3	.	2	96	78.5862
13	4	.	2	96	78.2192
14	5	.	2	96	78.4323
15	6	.	2	96	78.2631
16	7	.	2	96	78.4336
17	1	1	3	12	78.7139
18	1	2	3	12	78.5028
19	1	3	3	12	78.3382
20	1	4	3	12	78.2199
21	1	5	3	12	78.1480
22	1	6	3	12	78.1225
23	1	7	3	12	78.1434
24	1	8	3	12	78.2107
25	2	1	3	12	78.0168
26	2	2	3	12	77.8057
27	2	3	3	12	77.6411
28	2	4	3	12	77.5228
29	2	5	3	12	77.4509
30	2	6	3	12	77.4254
31	2	7	3	12	77.4463
32	2	8	3	11	76.9779
33	3	1	3	12	79.0001
34	3	2	3	12	78.7891
35	3	3	3	12	78.6244
36	3	4	3	12	78.5061
37	3	5	3	12	78.4342
38	3	6	3	12	78.4088

704

Obs	Position	minute	_TYPE_	_FREQ_	predmn
39	3	7	3	12	78.4297
40	3	8	3	12	78.4970
41	4	1	3	12	78.6332
42	4	2	3	12	78.4222
43	4	3	3	12	78.2575
44	4	4	3	12	78.1392
45	4	5	3	12	78.0673
46	4	6	3	12	78.0418
47	4	7	3	12	78.0627
48	4	8	3	12	78.1300
49	5	1	3	12	77.5362
50	5	2	3	12	78.0965
51	5	3	3	12	78.5047
52	5	4	3	12	78.7607
53	5	5	3	12	78.8646
54	5	6	3	12	78.8164
55	5	7	3	12	78.6160
56	5	8	3	12	78.2635
57	6	1	3	12	78.6771
58	6	2	3	12	78.4660
59	6	3	3	12	78.3014
60	6	4	3	12	78.1831
61	6	5	3	12	78.1112
62	6	6	3	12	78.0857
63	6	7	3	12	78.1066
64	6	8	3	12	78.1739
65	7	1	3	12	78.8475
66	7	2	3	12	78.6365
67	7	3	3	12	78.4718
68	7	4	3	12	78.3535
69	7	5	3	12	78.2816
70	7	6	3	12	78.2561
71	7	7	3	12	78.2770
72	7	8	3	12	78.3443

```
*****
*****
```

```
libname pos 'C:\Users\Heather\Desktop\Elser_Dis_files\Chapter 2\Ch2_Final_Files';
*ods rtf file = 'P:\Mann\2011\output\proc mixed_01182012';
```

```
*****
*****create interaction variabloes for proc mixed*****
*****
```

```
data prep;
set pos.agggregated_06172011;
*****
*****delete minutes past 8*****
*****
    if minute le 8;
    c_pma= 34.86-pma;
```

```

minute2=minute*minute;
minute3= minute*minute*minute;

```

```

*****
*****Compute interaction terms for minute by position*****
*****

```

```

inter1 = d1*minute;
inter2 = d2*minute;
inter4 = d4*minute;
inter5 = d5*minute;
inter6 = d6*minute;
inter7 = d7*minute;

```

```

inter12= d1*minute2;
inter22= d2*minute2;
inter42= d4*minute2;
inter52= d5*minute2;
inter62= d6*minute2;
inter72= d7*minute2;

```

```

proc sort data=prep out=preps;
by newid position minute;

```

```

*****
*****calculate means by position and minute*****
*****

```

```

proc means data=preps;
class position;
var meanco;
Title1' means by position';
title2'prep for proc mixed on june 18 2011';

```

```

proc means data=preps;
class minute;
var meanco;
Title1' means by minute';
title2'prep for proc mixed on june 18 2011';

```

```

proc means data=preps;
class position minute;
var meanco;
output out=rawmean mean=mnco;
Title1' means by position and minute';
title2'prep for proc mixed on june 18 2011';
proc print data=rawmean;

```

```

proc gplot data=rawmean;
where _TYPE_ eq 3;

```

```

symbol1 i = join color = blue line = 1;
symbol2 i = join color = red line = 1;
symbol3 i = join color = green line = 1;
symbol4 i = join color = orange line = 1;
symbol5 i = join color = brown line = 1;
symbol6 i = join color = purple line = 1;
symbol7 i = join color = black line = 1;
axis1 label=none;

```

```

axis2 label=none;
label mnco = ' ';
plot mnco*minute = position
    / vaxis = 75 to 80 by 1;

title1'raw mean cerebral oxygenation by';
title2' minute since position change';
    title3' for each position';
    title4' january 18, 2012';
*****
*****perform the proc mixed*****
*****
proc mixed data=preps;
class d1 d2 d4 d5 d6 d7;
model meanco = d1 d2 d4 d5 d6 d7 minute minute2 inter5 inter52
    c_pma /s outpred = meancopred;
random int minute d1 d2 d4 d5 d6 d7 /subject = newid type = vc;

title1' Dep var is averaged 1 minuted sct02 ';
title2' independent variables are minute, minute2, and position';
title3' plus their interactions ';
title4' pma is a covariate january 18 2012';
title5' Final Model for Chapter 2';
run;
*****
*****calculate predicted means by minute and position*****
*****
proc means data=meancopred mean std min max n nmiss;
class position minute;
var pred;
output out=mn mean = predmn;
title1' observed predicted means from proc mixed';

proc print data=mn;
proc gplot data=mn;
where _TYPE_ eq 3;

symbol1 i = join color = blue line = 1;
symbol2 i = join color = red line = 1;
symbol3 i = join color = green line = 1;
symbol4 i = join color = orange line = 1;
    symbol5 i = join color = brown line = 1;
symbol6 i = join color = purple line = 1;
symbol7 i = join color = black line = 1;
axis1 label=none;
axis2 label=none;
label predmn = ' ';
plot predmn*minute = position
    / vaxis = 75 to 80 by 1;

title1'predicted cerebral oxygenation by';
title2' minute since position change';
    title3' for each position';
    title4' january 18, 2012';
run;
ods rtf close;

```

4

Appendix B Chapter 3 SAS Output: Trajectory of Cerebral Oxygenation

The SAS System

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The CONTENTS Procedure

Data Set Name	WORK.ALL	Observations	212327
Member Type	DATA	Variables	16
Engine	V9	Indexes	0
Created	Friday, April 20, 2012 07:12:16 PM	Observation Length	136
Last Modified	Friday, April 20, 2012 07:12:16 PM	Deleted Observations	0
Protection		Compressed	NO
Data Set Type		Sorted	NO
Label			
Data Representation	WINDOWS_64		
Encoding	wlatin1 Western (Windows)		

Engine/Host Dependent Information

Data Set Page Size	12288
Number of Data Set Pages	2360
First Data Page	1
Max Obs per Page	90
Obs in First Data Page	70
Number of Data Set Repairs	0
Filename	C:\Users\Heather\AppData\Local\Temp\SAS Temporary Files_TD5932_HEATHER-THINK_\all.sas7bdat
Release Created	9.0301M0
Host Created	X64_7PRO

Alphabetic List of Variables and Attributes

#	Variable	Type	Len	Format	Informat	Label
8	Caffeine	Num	8			Caffeine
3	DC	Num	8			DC
7	GA	Num	8			GA
11	HR	Num	8			HR
9	IVH	Num	8			IVH
2	Infant	Num	8			Infant
15	Leq	Num	8			Leq
6	PA	Num	8			PA
5	PMA	Num	8			PMA
14	Position	Num	8			Position

The SAS System

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The CONTENTS Procedure

Alphabetic List of Variables and Attributes

#	Variable	Type	Len	Format	Informat	Label
16	Probe	Num	8			Probe
13	RR	Char	3	\$3.	\$3.	RR
1	Real_Date_Time	Char	19	\$19.	\$19.	Real_Date_Time
12	SctO2	Num	8			SctO2
4	Seconds	Num	8			Seconds
10	SpO2	Num	8			SpO2

The MEANS Procedure

Position	N	Obs	Variable	Label	N	Mean	Std Dev
	1	2729	meanco	average value of sct02 for a minute within a position	2687	72.9647173	9.6186761
			meanhr	average value of heart rate for a minute within a position	2638	152.8443136	19.6126328
			meanpo	average value of SpO2 for a minute within a position	2638	96.6859137	4.3316160
			meanleq	average value of Leq for a minute within a position	1920	59.1704077	4.6918698
	2	327	meanco	average value of sct02 for a minute within a position	309	71.9228194	8.7837847
			meanhr	average value of heart rate for a minute within a position	327	149.4512937	14.2092798
			meanpo	average value of SpO2 for a minute within a position	327	97.2620254	5.2531860
			meanleq	average value of Leq for a minute within a position	185	57.2414569	3.9455004
	3	347	meanco	average value of sct02 for a minute within a position	345	69.3762733	8.9307372
			meanhr	average value of heart rate for a minute within a position	328	159.6105595	14.9555117
			meanpo	average value of SpO2 for a minute within a position	328	97.4474091	2.6535050
			meanleq	average value of Leq for a minute within a position	193	57.7704350	4.6072495
	4	422	meanco	average value of sct02 for a minute within a position	416	71.5640254	11.9743923
			meanhr	average value of heart rate for a minute within a position	401	143.9655152	26.2440238
			meanpo	average value of SpO2 for a minute within a position	401	97.1947298	3.1114715
			meanleq	average value of Leq for a minute within a position	177	56.9728748	2.6224467
	5	391	meanco	average value of sct02 for a minute within a position	389	76.1497353	8.6837481
			meanhr	average value of heart rate for a minute within a position	390	152.7351524	18.4789449
			meanpo	average value of SpO2 for a minute within a position	390	96.2185683	4.3909170
			meanleq	average value of Leq for a minute within a position	183	59.2758431	3.5161898
	6	453	meanco	average value of sct02 for a minute within a position	439	73.6094363	9.8620427
			meanhr	average value of heart rate for a minute within a position	432	150.3169320	14.9204313
			meanpo	average value of SpO2 for a minute within a position	432	96.0606446	3.8294800

2.9842668			meanleq	average value of Leq for a minute within a position	281	57.1238344
7.2698917	12	40	meanco	average value of sct02 for a minute within a position	32	70.0798650
26.3224156			meanhr	average value of heart rate for a minute within a position	38	148.0313934
16.2648964			meanpo	average value of SpO2 for a minute within a position	38	98.6908267
3.6934941			meanleq	average value of Leq for a minute within a position	22	59.0123928

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 The MEANS Procedure

N						
Position	Obs	Variable	Label	N	Mean	Std Dev
	13	36	meanco	average value of sct02 for a minute within a position	35	65.5512470
9.7443379			meanhr	average value of heart rate for a minute within a position	32	171.4360796
19.0572957			meanpo	average value of SpO2 for a minute within a position	32	95.3473704
4.8011439			meanleq	average value of Leq for a minute within a position	25	60.7363968
5.4573899						
12.3688877	14	32	meanco	average value of sct02 for a minute within a position	31	70.4798951
29.2708508			meanhr	average value of heart rate for a minute within a position	32	149.3477687
4.9667945			meanpo	average value of SpO2 for a minute within a position	32	96.6057121
2.3412472			meanleq	average value of Leq for a minute within a position	15	58.8478889
8.2466090	15	23	meanco	average value of sct02 for a minute within a position	21	77.4249309
16.2745643			meanhr	average value of heart rate for a minute within a position	22	154.0336890
3.5173954			meanpo	average value of SpO2 for a minute within a position	22	96.5038194
3.9409733			meanleq	average value of Leq for a minute within a position	15	59.2817439
13.1063245	16	38	meanco	average value of sct02 for a minute within a position	38	73.2278862
15.4580698			meanhr	average value of heart rate for a minute within a position	38	154.4493803
8.9483362			meanpo	average value of SpO2 for a minute within a position	38	94.9210601
4.0905618			meanleq	average value of Leq for a minute within a position	27	59.5663891

ff
 fff

		N				
Position	Obs	Variable	Label	Minimum	Maximum	
<i>ff</i>						
<i>ffffffffffffffff</i>						
1	2729	meanco	average value of sct02 for a minute within a position	24.5666667		
98.5454545		meanhr	average value of heart rate for a minute within a position	25.0000000		
205.5000000		meanpo	average value of SpO2 for a minute within a position	42.0000000		
137.5000000		meanleq	average value of Leq for a minute within a position	46.7000000		
77.0000000						
2	327	meanco	average value of sct02 for a minute within a position	32.4166667		
99.0000000		meanhr	average value of heart rate for a minute within a position	104.0000000		
184.5000000		meanpo	average value of SpO2 for a minute within a position	53.0000000		
100.0000000		meanleq	average value of Leq for a minute within a position	48.5000000		
64.3983333						
3	347	meanco	average value of sct02 for a minute within a position	33.1500000		
87.9333333						
<i>ff</i>						
<i>ffffffffffffffff</i>						

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The MEANS Procedure

		N				
Position	Obs	Variable	Label	Minimum	Maximum	
<i>ff</i>						
<i>ffffffffffffffff</i>						
3	347	meanhr	average value of heart rate for a minute within a position	116.4814815		
202.9333333		meanpo	average value of SpO2 for a minute within a position	79.6833333		
100.0000000		meanleq	average value of Leq for a minute within a position	47.5000000		
68.1000000						
4	422	meanco	average value of sct02 for a minute within a position	15.0000000		
92.9666667		meanhr	average value of heart rate for a minute within a position	21.0000000		
182.0000000		meanpo	average value of SpO2 for a minute within a position	81.4166667		
100.0000000		meanleq	average value of Leq for a minute within a position	53.9000000		
69.4000000						
5	391	meanco	average value of sct02 for a minute within a position	53.3000000		
99.0000000		meanhr	average value of heart rate for a minute within a position	112.3000000		
197.5000000		meanpo	average value of SpO2 for a minute within a position	75.2500000		
100.0000000		meanleq	average value of Leq for a minute within a position	50.2050000		
67.4000000						

99.0000000	6	453	meanco	average value of sctO2 for a minute within a position	42.0000000
191.0000000			meanhr	average value of heart rate for a minute within a position	123.0000000
100.0000000			meanpo	average value of SpO2 for a minute within a position	77.8833333
64.7000000			meanleq	average value of Leq for a minute within a position	51.4416667
82.1111111	12	40	meanco	average value of sctO2 for a minute within a position	55.1463415
191.2000000			meanhr	average value of heart rate for a minute within a position	28.0000000
188.0000000			meanpo	average value of SpO2 for a minute within a position	63.0000000
65.0000000			meanleq	average value of Leq for a minute within a position	50.6000000
80.0000000	13	36	meanco	average value of sctO2 for a minute within a position	44.2000000
209.2500000			meanhr	average value of heart rate for a minute within a position	123.1304348
100.0000000			meanpo	average value of SpO2 for a minute within a position	81.6153846
71.1183333			meanleq	average value of Leq for a minute within a position	48.3000000
90.2500000	14	32	meanco	average value of sctO2 for a minute within a position	36.1428571
187.0000000			meanhr	average value of heart rate for a minute within a position	38.0000000
100.0000000			meanpo	average value of SpO2 for a minute within a position	74.0714286
62.8000000			meanleq	average value of Leq for a minute within a position	55.7000000
93.0000000	15	23	meanco	average value of sctO2 for a minute within a position	58.4318182

The MEANS Procedure

Position	N Obs	Variable	Label	Minimum	Maximum
	15	23	meanhr	average value of heart rate for a minute within a position	121.7600000
	190.5000000		meanpo	average value of SpO2 for a minute within a position	87.8000000
	100.0000000		meanleq	average value of Leq for a minute within a position	49.6237288
	64.2000000				
	16	38	meanco	average value of sctO2 for a minute within a position	31.0000000
	93.0000000		meanhr	average value of heart rate for a minute within a position	132.4166667
	196.0000000		meanpo	average value of SpO2 for a minute within a position	57.0000000
	100.0000000		meanleq	average value of Leq for a minute within a position	54.3000000
	73.4000000				

		N					
DC	Obs	Variable	Label	N	Mean	Std Dev	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
	1	889	meanco	average value of sct02 for a minute within a position	833	78.5246437	6.8183290
			meanhr	average value of heart rate for a minute within a position	791	138.9610313	10.2850522
			meanpo	average value of SpO2 for a minute within a position	791	96.9906176	3.0766367
			meanleq	average value of Leq for a minute within a position	514	61.2488251	5.1080553
	2	845	meanco	average value of sct02 for a minute within a position	839	77.4411635	8.4220889
			meanhr	average value of heart rate for a minute within a position	844	143.5022728	13.6086469
			meanpo	average value of SpO2 for a minute within a position	845	97.1460613	3.2847495
			meanleq	average value of Leq for a minute within a position	443	58.9025616	4.5945213
	3	701	meanco	average value of sct02 for a minute within a position	697	75.8984068	6.4244331
			meanhr	average value of heart rate for a minute within a position	699	147.3296297	15.1905858
			meanpo	average value of SpO2 for a minute within a position	699	97.3391809	4.6557462
			meanleq	average value of Leq for a minute within a position	406	57.3140918	3.3155433
	4	518	meanco	average value of sct02 for a minute within a position	512	73.1486169	6.8949683
			meanhr	average value of heart rate for a minute within a position	518	158.7402637	33.3313069
			meanpo	average value of SpO2 for a minute within a position	518	96.5544407	3.6386813
			meanleq	average value of Leq for a minute within a position	384	59.1285608	3.9079241
	5	373	meanco	average value of sct02 for a minute within a position	371	72.6733357	5.7793482
			meanhr	average value of heart rate for a minute within a position	328	161.8903079	15.6036552
			meanpo	average value of SpO2 for a minute within a position	327	97.2899984	3.1120929
			meanleq	average value of Leq for a minute within a position	225	59.0641148	3.5291854
	6	260	meanco	average value of sct02 for a minute within a position	256	67.8520606	8.4676097
			meanhr	average value of heart rate for a minute within a position	252	163.8225611	13.8245792
			meanpo	average value of SpO2 for a minute within a position	252	94.5280559	8.6302041

3.7013184	meanleq	average value of Leq for a minute within a position	237	60.6003985
6.1109792	7 250 meanco	average value of sct02 for a minute within a position	247	68.8552176
14.4406097	meanhr	average value of heart rate for a minute within a position	247	162.7108925
4.7029556	meanpo	average value of SpO2 for a minute within a position	247	96.3837999
4.4118316	meanleq	average value of Leq for a minute within a position	212	59.3040225

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 The MEANS Procedure

	N	DC	Obs	Variable	Label	N	Mean	Std Dev
9.3668920	8	299	meanco	average value of sct02 for a minute within a position	291	65.8001648		
14.3122486			meanhr	average value of heart rate for a minute within a position	297	162.8650051		
6.0286255			meanpo	average value of SpO2 for a minute within a position	297	95.5982051		
2.8274596			meanleq	average value of Leq for a minute within a position	193	57.4782724		
14.1177131	9	217	meanco	average value of sct02 for a minute within a position	210	60.0464689		
10.8919693			meanhr	average value of heart rate for a minute within a position	216	163.0417899		
3.8649990			meanpo	average value of SpO2 for a minute within a position	216	95.9326742		
2.7822744			meanleq	average value of Leq for a minute within a position	184	54.1712151		
11.9017055	10	221	meanco	average value of sct02 for a minute within a position	221	63.9808738		
15.9925671			meanhr	average value of heart rate for a minute within a position	221	163.4684132		
5.4928677			meanpo	average value of SpO2 for a minute within a position	221	96.3247157		
1.5549611			meanleq	average value of Leq for a minute within a position	147	55.8655689		
12.5288718	11	144	meanco	average value of sct02 for a minute within a position	144	66.1115407		
17.3857423			meanhr	average value of heart rate for a minute within a position	144	158.2827370		
5.0084624			meanpo	average value of SpO2 for a minute within a position	144	96.6292432		
2.8914422			meanleq	average value of Leq for a minute within a position	60	58.0416667		

3.6414640	12	83	meanco	average value of sctO2 for a minute within a position	83	61.3413655
			meanhr	average value of heart rate for a minute within a position	83	160.8554217
12.0318047			meanpo	average value of SpO2 for a minute within a position	83	96.9789157
3.7424912			meanleq	average value of Leq for a minute within a position	0	.
	13	38	meanco	average value of sctO2 for a minute within a position	38	64.9342105
2.7562486			meanhr	average value of heart rate for a minute within a position	38	135.0526316
10.4653802			meanpo	average value of SpO2 for a minute within a position	38	99.3552632
1.5977514			meanleq	average value of Leq for a minute within a position	38	52.5421053
3.4742786						

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	N					
	DC	Obs	Variable	Label	Minimum	Maximum
99.0000000		1	889	meanco	average value of sctO2 for a minute within a position	56.4666667
169.4000000				meanhr	average value of heart rate for a minute within a position	112.3333333
100.0000000				meanpo	average value of SpO2 for a minute within a position	75.2500000
75.1000000				meanleq	average value of Leq for a minute within a position	51.4416667
99.0000000		2	845	meanco	average value of sctO2 for a minute within a position	43.9090909
185.0000000				meanhr	average value of heart rate for a minute within a position	106.2500000
100.0000000				meanpo	average value of SpO2 for a minute within a position	64.5000000
70.0000000				meanleq	average value of Leq for a minute within a position	53.7000000
96.0833333		3	701	meanco	average value of sctO2 for a minute within a position	32.4166667
187.5000000				meanhr	average value of heart rate for a minute within a position	95.3333333
100.0000000				meanpo	average value of SpO2 for a minute within a position	42.0000000
69.2000000				meanleq	average value of Leq for a minute within a position	49.1000000
98.5454545		4	518	meanco	average value of sctO2 for a minute within a position	55.8571429
209.2500000				meanhr	average value of heart rate for a minute within a position	21.0000000
100.0000000				meanpo	average value of SpO2 for a minute within a position	80.9500000
71.1183333				meanleq	average value of Leq for a minute within a position	52.9000000
87.2166667		5	373	meanco	average value of sctO2 for a minute within a position	49.3666667
205.5000000				meanhr	average value of heart rate for a minute within a position	50.0000000
100.0000000				meanpo	average value of SpO2 for a minute within a position	64.3166667
77.0000000				meanleq	average value of Leq for a minute within a position	54.1000000
99.0000000		6	260	meanco	average value of sctO2 for a minute within a position	48.7666667
192.5000000				meanhr	average value of heart rate for a minute within a position	28.0000000
188.0000000				meanpo	average value of SpO2 for a minute within a position	53.0000000

67.5000000		meanleq	average value of Leq for a minute within a position	53.2000000
85.5000000	7 250	meanco	average value of sct02 for a minute within a position	44.7777778
200.9000000		meanhr	average value of heart rate for a minute within a position	107.1666667
100.0000000		meanpo	average value of SpO2 for a minute within a position	63.8666667
67.1000000		meanleq	average value of Leq for a minute within a position	50.4333333

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	N	DC	Obs	Variable	Label	Minimum	Maximum
99.0000000			8 299	meanco	average value of sct02 for a minute within a position	33.1500000	
189.7000000				meanhr	average value of heart rate for a minute within a position	76.0000000	
137.5000000				meanpo	average value of SpO2 for a minute within a position	67.9833333	
68.9000000				meanleq	average value of Leq for a minute within a position	53.9600000	
87.0000000			9 217	meanco	average value of sct02 for a minute within a position	15.0000000	
198.4833333				meanhr	average value of heart rate for a minute within a position	136.0000000	
100.0000000				meanpo	average value of SpO2 for a minute within a position	79.5500000	
69.6900000				meanleq	average value of Leq for a minute within a position	46.7000000	
93.2857143			10 221	meanco	average value of sct02 for a minute within a position	24.5666667	
205.9333333				meanhr	average value of heart rate for a minute within a position	133.9000000	
100.0000000				meanpo	average value of SpO2 for a minute within a position	57.0000000	
61.4416667				meanleq	average value of Leq for a minute within a position	53.7000000	
87.9333333			11 144	meanco	average value of sct02 for a minute within a position	37.5000000	
193.5000000				meanhr	average value of heart rate for a minute within a position	128.7333333	
100.0000000				meanpo	average value of SpO2 for a minute within a position	72.0000000	
65.0000000				meanleq	average value of Leq for a minute within a position	53.8000000	

71.5000000	12	83	meanco	average value of sct02 for a minute within a position	53.0000000
			meanhr	average value of heart rate for a minute within a position	120.0000000
182.6500000			meanpo	average value of SpO2 for a minute within a position	79.1500000
100.0000000			meanleq	average value of Leq for a minute within a position	.
	13	38	meanco	average value of sct02 for a minute within a position	57.5000000
70.0000000			meanhr	average value of heart rate for a minute within a position	117.0000000
160.0000000			meanpo	average value of SpO2 for a minute within a position	93.0000000
100.0000000			meanleq	average value of Leq for a minute within a position	48.5000000
65.3000000					

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		N				
PMA	Obs	Variable	Label	N	Mean	Std Dev
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25.6	41	meanco	average value of sct02 for a minute within a position	41	76.3169919	
2.6049289		meanhr	average value of heart rate for a minute within a position	0	.	.
2		meanpo	average value of SpO2 for a minute within a position	0	.	.
		meanleq	average value of Leq for a minute within a position	0	.	.
26	80	meanco	average value of sct02 for a minute within a position	69	82.3995911	
2.5174043		meanhr	average value of heart rate for a minute within a position	80	146.3191926	
8.2431973		meanpo	average value of SpO2 for a minute within a position	80	94.7920040	
4.3510906		meanleq	average value of Leq for a minute within a position	60	62.0350000	
2.8890691						
26.1	43	meanco	average value of sct02 for a minute within a position	43	78.4687492	
2.7961368		meanhr	average value of heart rate for a minute within a position	43	142.0454638	
11.9951811		meanpo	average value of SpO2 for a minute within a position	43	98.6325795	
0.7758732		meanleq	average value of Leq for a minute within a position	0	.	.
26.2	84	meanco	average value of sct02 for a minute within a position	84	85.0234866	
5.2009534		meanhr	average value of heart rate for a minute within a position	84	145.3760453	
5.7523157		meanpo	average value of SpO2 for a minute within a position	84	96.3160638	
2.0319370		meanleq	average value of Leq for a minute within a position	70	55.3296718	
1.2289152						
26.3	85	meanco	average value of sct02 for a minute within a position	84	74.8249227	
12.1866159		meanhr	average value of heart rate for a minute within a position	85	140.9063169	
4.0953269		meanpo	average value of SpO2 for a minute within a position	85	95.9526701	
2.2730534		meanleq	average value of Leq for a minute within a position	39	55.9885567	
1.0267863						
26.4	84	meanco	average value of sct02 for a minute within a position	84	73.2489326	
3.3886348		meanhr	average value of heart rate for a minute within a position	84	147.0079747	
4.0390096		meanpo	average value of SpO2 for a minute within a position	84	95.8433103	
4.8099941		meanleq	average value of Leq for a minute within a position	38	61.4803509	
0.8090003						

9.7963419	26.5	214	meanco	average value of sct02 for a minute within a position	212	70.5062307
11.7906264			meanhr	average value of heart rate for a minute within a position	214	144.9485928
5.0748156			meanpo	average value of SpO2 for a minute within a position	214	93.7452347
0.8487132			meanleq	average value of Leq for a minute within a position	63	55.4276948

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		N					
	PMA	Obs	Variable	Label	N	Mean	Std Dev
2.4170447	26.6	20	meanco	average value of sct02 for a minute within a position	20	69.5000000	
5.0731491			meanhr	average value of heart rate for a minute within a position	20	154.5000000	
4.2916688			meanpo	average value of SpO2 for a minute within a position	20	91.9500000	
0.3427443			meanleq	average value of Leq for a minute within a position	20	61.1800000	
6.2496133	27	61	meanco	average value of sct02 for a minute within a position	61	80.6157803	
15.2346556			meanhr	average value of heart rate for a minute within a position	61	151.1544399	
2.2338597			meanpo	average value of SpO2 for a minute within a position	61	96.8597678	
2.6346518			meanleq	average value of Leq for a minute within a position	41	66.8661789	
2.0969903	27.1	20	meanco	average value of sct02 for a minute within a position	20	94.1500000	
3.7595492			meanhr	average value of heart rate for a minute within a position	20	137.3500000	
0.1118034			meanpo	average value of SpO2 for a minute within a position	20	99.9750000	
			meanleq	average value of Leq for a minute within a position	0	.	.
5.5963717	27.2	105	meanco	average value of sct02 for a minute within a position	104	77.1097333	
14.3694018			meanhr	average value of heart rate for a minute within a position	105	149.6305190	
0.8800427			meanpo	average value of SpO2 for a minute within a position	105	99.4541028	
4.0550883			meanleq	average value of Leq for a minute within a position	82	58.4487195	
4.2007167	27.3	35	meanco	average value of sct02 for a minute within a position	35	70.7706633	
4.9527077			meanhr	average value of heart rate for a minute within a position	35	139.7268415	

0.0344145		meanpo	average value of SpO2 for a minute within a position	35	99.9930159
		meanleq	average value of Leq for a minute within a position	0	.
5.7508103	27.5	83 meanco	average value of sct02 for a minute within a position	83	75.0244040
10.7976192		meanhr	average value of heart rate for a minute within a position	83	170.7278987
3.4483851		meanpo	average value of SpO2 for a minute within a position	83	95.2680464
0.9568819		meanleq	average value of Leq for a minute within a position	83	55.3633534
1.0208356	28.1	20 meanco	average value of sct02 for a minute within a position	20	79.1000000
1.6212000		meanhr	average value of heart rate for a minute within a position	20	127.6250000
1.3066127		meanpo	average value of SpO2 for a minute within a position	20	97.6250000
0.2364207		meanleq	average value of Leq for a minute within a position	20	68.1700000

		N				
PMA	Obs	Variable	Label	N	Mean	Std Dev
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28.2	42	meanco	average value of sct02 for a minute within a position	42	65.3928571	
3.3028733		meanhr	average value of heart rate for a minute within a position	42	166.5000000	
5.0279705		meanpo	average value of SpO2 for a minute within a position	42	90.0833333	
2.5517012		meanleq	average value of Leq for a minute within a position	42	64.1190476	
0.3958554						
28.3	70	meanco	average value of sct02 for a minute within a position	69	73.4116945	
5.5665903		meanhr	average value of heart rate for a minute within a position	70	156.4554206	
17.0229333		meanpo	average value of SpO2 for a minute within a position	70	98.0265760	
4.2097406		meanleq	average value of Leq for a minute within a position	0	.	.
28.5	169	meanco	average value of sct02 for a minute within a position	169	69.9581657	
6.0118193		meanhr	average value of heart rate for a minute within a position	126	162.5604634	
10.0995392		meanpo	average value of SpO2 for a minute within a position	126	96.9137073	
2.4279047		meanleq	average value of Leq for a minute within a position	122	59.0567664	
2.7961409						
29	85	meanco	average value of sct02 for a minute within a position	83	79.3684464	
2.9995569		meanhr	average value of heart rate for a minute within a position	83	144.7443828	
9.6026526		meanpo	average value of SpO2 for a minute within a position	83	97.5482775	
3.9251030		meanleq	average value of Leq for a minute within a position	63	64.0701058	
1.4155591						
29.2	167	meanco	average value of sct02 for a minute within a position	167	72.3563286	
4.5650919		meanhr	average value of heart rate for a minute within a position	166	157.4633598	
9.8507893		meanpo	average value of SpO2 for a minute within a position	167	96.5983394	
3.1826305		meanleq	average value of Leq for a minute within a position	141	62.4217613	
3.7426004						
29.3	13	meanco	average value of sct02 for a minute within a position	13	82.8538462	
2.5533942		meanhr	average value of heart rate for a minute within a position	13	148.7423077	
30.1158309		meanpo	average value of SpO2 for a minute within a position	13	99.8410256	
0.2934955		meanleq	average value of Leq for a minute within a position	0	.	.

0.7374350	29.4	42	meanco	average value of sct02 for a minute within a position	42	83.2325847
5.2827686			meanhr	average value of heart rate for a minute within a position	42	132.0724599
0.6810521			meanpo	average value of SpO2 for a minute within a position	42	95.9845135
1.1940570			meanleq	average value of Leq for a minute within a position	42	62.4046561

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		N					
	PMA	Obs	Variable	Label	N	Mean	Std Dev
6.4253731	29.5	177	meanco	average value of sct02 for a minute within a position	177	71.0961123	
14.7367431			meanhr	average value of heart rate for a minute within a position	169	166.3020365	
3.2934776			meanpo	average value of SpO2 for a minute within a position	168	95.6281770	
5.8209116			meanleq	average value of Leq for a minute within a position	152	62.7274395	
5.9071921	29.6	85	meanco	average value of sct02 for a minute within a position	85	77.1786642	
6.0488119			meanhr	average value of heart rate for a minute within a position	85	152.8788789	
2.2271895			meanpo	average value of SpO2 for a minute within a position	85	98.1623444	
4.7895755			meanleq	average value of Leq for a minute within a position	62	59.0897089	
8.0718402	30	81	meanco	average value of sct02 for a minute within a position	81	80.3850213	
12.2745544			meanhr	average value of heart rate for a minute within a position	81	138.2930808	
2.3078731			meanpo	average value of SpO2 for a minute within a position	81	97.6849550	
1.5829984			meanleq	average value of Leq for a minute within a position	39	57.0794872	
2.0046882	30.1	23	meanco	average value of sct02 for a minute within a position	23	75.7826087	
5.3869077			meanhr	average value of heart rate for a minute within a position	23	168.2826087	
0.9678631			meanpo	average value of SpO2 for a minute within a position	23	98.8695652	
			meanleq	average value of Leq for a minute within a position	0	.	.
4.7369230	30.2	62	meanco	average value of sct02 for a minute within a position	62	59.3978893	
5.0230988			meanhr	average value of heart rate for a minute within a position	62	163.0247533	

4.4028535		meanpo	average value of SpO2 for a minute within a position	62	91.7612033
3.0594272		meanleq	average value of Leq for a minute within a position	57	62.0183094
5.8755616	30.3	85 meanco	average value of sct02 for a minute within a position	84	81.3049411
6.5740462		meanhr	average value of heart rate for a minute within a position	85	137.8629923
0.6952181		meanpo	average value of SpO2 for a minute within a position	85	99.3944751
3.2261363		meanleq	average value of Leq for a minute within a position	22	60.7031061
2.2965027	30.4	43 meanco	average value of sct02 for a minute within a position	43	75.0755333
6.1537177		meanhr	average value of heart rate for a minute within a position	43	123.8709140
1.3388952		meanpo	average value of SpO2 for a minute within a position	43	97.8729415
2.6579351		meanleq	average value of Leq for a minute within a position	21	67.4190476

		N					
	PMA	Obs	Variable	Label	N	Mean	Std Dev
7.0635439		30.5	139	meanco	average value of sct02 for a minute within a position	138	72.7804027
16.6094569				meanhr	average value of heart rate for a minute within a position	139	146.9761947
10.9844267				meanpo	average value of SpO2 for a minute within a position	139	95.4104695
4.3813671				meanleq	average value of Leq for a minute within a position	116	59.3086351
5.7314322		30.6	83	meanco	average value of sct02 for a minute within a position	83	71.2269309
5.5355760				meanhr	average value of heart rate for a minute within a position	83	142.8563747
2.7283287				meanpo	average value of SpO2 for a minute within a position	83	96.8964415
2.2331886				meanleq	average value of Leq for a minute within a position	83	56.3950891
6.3596729		31	63	meanco	average value of sct02 for a minute within a position	63	88.1187302
21.0580462				meanhr	average value of heart rate for a minute within a position	63	135.8367800
1.8423895				meanpo	average value of SpO2 for a minute within a position	63	98.1451247
				meanleq	average value of Leq for a minute within a position	0	.
3.3149247		31.1	74	meanco	average value of sct02 for a minute within a position	72	78.3479118
20.6994310				meanhr	average value of heart rate for a minute within a position	72	144.0896446
1.3107768				meanpo	average value of SpO2 for a minute within a position	72	98.9238960
5.1398457				meanleq	average value of Leq for a minute within a position	53	61.1698113
11.6910370		31.2	126	meanco	average value of sct02 for a minute within a position	124	73.4873032
12.4904689				meanhr	average value of heart rate for a minute within a position	112	155.6321934
5.5725653				meanpo	average value of SpO2 for a minute within a position	112	96.7383456
2.3328914				meanleq	average value of Leq for a minute within a position	63	59.4326455
5.6115497		31.3	89	meanco	average value of sct02 for a minute within a position	48	81.1295542
10.1803484				meanhr	average value of heart rate for a minute within a position	89	136.3222047
0.6480351				meanpo	average value of SpO2 for a minute within a position	89	99.6127722

6.3133255	32.2	126	meanco	average value of sct02 for a minute within a position	123	65.9294296
12.3276644			meanhr	average value of heart rate for a minute within a position	124	158.5134974
4.3740486			meanpo	average value of SpO2 for a minute within a position	124	97.8548647
1.1603850			meanleq	average value of Leq for a minute within a position	87	56.8416092
2.0051942	32.3	83	meanco	average value of sct02 for a minute within a position	79	75.1750808
9.0060080			meanhr	average value of heart rate for a minute within a position	83	139.8389602
3.9722748			meanpo	average value of SpO2 for a minute within a position	83	95.8264805
3.7462257			meanleq	average value of Leq for a minute within a position	59	59.4038983
14.2088368	32.5	104	meanco	average value of sct02 for a minute within a position	101	53.5053982
8.2329638			meanhr	average value of heart rate for a minute within a position	104	169.5155300
5.0572972			meanpo	average value of SpO2 for a minute within a position	104	93.0031364
2.6041194			meanleq	average value of Leq for a minute within a position	79	56.2152351

		N					
	PMA	Obs	Variable	Label	N	Mean	Std Dev
4.0540096	32.6	143	meanco	average value of sct02 for a minute within a position	142	78.5196448	
1.9735997			meanhr	average value of heart rate for a minute within a position	143	141.2203402	
1.0041175			meanpo	average value of SpO2 for a minute within a position	143	98.8492528	
3.9322789			meanleq	average value of Leq for a minute within a position	119	57.0115649	

		N				
	PMA	Obs	Variable	Label	Minimum	Maximum
80.5300000	25.6	41	meanco	average value of sct02 for a minute within a position	72.1433333	
			meanhr	average value of heart rate for a minute within a position	.	.
			meanpo	average value of SpO2 for a minute within a position	.	.
			meanleq	average value of Leq for a minute within a position	.	.
88.0000000	26	80	meanco	average value of sct02 for a minute within a position	76.9000000	
164.2833333			meanhr	average value of heart rate for a minute within a position	128.6000000	
98.1500000			meanpo	average value of SpO2 for a minute within a position	77.8833333	
66.3000000			meanleq	average value of Leq for a minute within a position	59.1000000	
84.2666667	26.1	43	meanco	average value of sct02 for a minute within a position	72.3333333	
174.6666667			meanhr	average value of heart rate for a minute within a position	124.4500000	
99.9000000			meanpo	average value of SpO2 for a minute within a position	96.7333333	
			meanleq	average value of Leq for a minute within a position	.	.
94.0000000	26.2	84	meanco	average value of sct02 for a minute within a position	73.8333333	
160.3000000			meanhr	average value of heart rate for a minute within a position	121.6500000	
98.7166667			meanpo	average value of SpO2 for a minute within a position	90.2166667	
62.6200000			meanleq	average value of Leq for a minute within a position	54.1000000	
93.0000000	26.3	85	meanco	average value of sct02 for a minute within a position	56.4666667	

161.3500000	meanhr	average value of heart rate for a minute within a position	130.4166667
97.9000000	meanpo	average value of SpO2 for a minute within a position	81.2333333
58.7483333	meanleq	average value of Leq for a minute within a position	54.8033333
79.8000000	26.4 84 meanco	average value of sct02 for a minute within a position	62.9000000

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	N	PMA	Obs	Variable	Label	Minimum	Maximum
159.8166667	26.4	84	meanhr	average value of heart rate for a minute within a position	135.8666667		
100.0000000			meanpo	average value of SpO2 for a minute within a position	79.7166667		
64.6066667			meanleq	average value of Leq for a minute within a position	60.8000000		
88.0833333	26.5	214	meanco	average value of sct02 for a minute within a position	32.4166667		
171.0000000			meanhr	average value of heart rate for a minute within a position	104.0000000		
100.0000000			meanpo	average value of SpO2 for a minute within a position	69.7000000		
58.2400000			meanleq	average value of Leq for a minute within a position	54.4050000		
73.0000000	26.6	20	meanco	average value of sct02 for a minute within a position	65.5000000		
165.0000000			meanhr	average value of heart rate for a minute within a position	148.0000000		
97.0000000			meanpo	average value of SpO2 for a minute within a position	83.5000000		
61.8000000			meanleq	average value of Leq for a minute within a position	60.7000000		
99.0000000	27	61	meanco	average value of sct02 for a minute within a position	73.0000000		
178.0000000			meanhr	average value of heart rate for a minute within a position	131.5000000		
99.7083333			meanpo	average value of SpO2 for a minute within a position	92.1166667		
72.2600000			meanleq	average value of Leq for a minute within a position	60.1000000		
97.0000000	27.1	20	meanco	average value of sct02 for a minute within a position	89.5000000		
149.0000000			meanhr	average value of heart rate for a minute within a position	133.0000000		
100.0000000			meanpo	average value of SpO2 for a minute within a position	99.5000000		

			meanleq	average value of Leq for a minute within a position	.	.
91.6296296	27.2	105	meanco	average value of sct02 for a minute within a position	63.6333333	
176.0500000			meanhr	average value of heart rate for a minute within a position	123.8666667	
100.0000000			meanpo	average value of SpO2 for a minute within a position	93.7000000	
64.3983333			meanleq	average value of Leq for a minute within a position	53.8166667	
80.2380952	27.3	35	meanco	average value of sct02 for a minute within a position	62.3333333	
149.8000000			meanhr	average value of heart rate for a minute within a position	123.7118644	
100.0000000			meanpo	average value of SpO2 for a minute within a position	99.8000000	
			meanleq	average value of Leq for a minute within a position	.	.
85.5000000	27.5	83	meanco	average value of sct02 for a minute within a position	62.5333333	

		N				
	PMA	Obs	Variable	Label	Minimum	Maximum
196.6666667		27.5	83	meanhr	average value of heart rate for a minute within a position	153.4333333
100.0000000				meanpo	average value of SpO2 for a minute within a position	86.0000000
58.3000000				meanleq	average value of Leq for a minute within a position	54.3000000
80.0000000	28.1	20	meanco	average value of sctO2 for a minute within a position	76.5000000	
131.5000000				meanhr	average value of heart rate for a minute within a position	124.5000000
98.5000000				meanpo	average value of SpO2 for a minute within a position	92.5000000
68.5000000				meanleq	average value of Leq for a minute within a position	67.6000000
73.0000000	28.2	42	meanco	average value of sctO2 for a minute within a position	58.0000000	
173.0000000				meanhr	average value of heart rate for a minute within a position	148.0000000
94.0000000				meanpo	average value of SpO2 for a minute within a position	84.0000000
64.7000000				meanleq	average value of Leq for a minute within a position	63.2000000
85.1000000	28.3	70	meanco	average value of sctO2 for a minute within a position	55.8571429	
176.9500000				meanhr	average value of heart rate for a minute within a position	115.0000000
100.0000000				meanpo	average value of SpO2 for a minute within a position	64.5000000
				meanleq	average value of Leq for a minute within a position	.
81.0833333	28.5	169	meanco	average value of sctO2 for a minute within a position	49.3666667	
187.0000000				meanhr	average value of heart rate for a minute within a position	138.0000000
100.0000000				meanpo	average value of SpO2 for a minute within a position	88.0000000
65.6200000				meanleq	average value of Leq for a minute within a position	54.4000000
85.0000000	29	85	meanco	average value of sctO2 for a minute within a position	65.8333333	
169.4000000				meanhr	average value of heart rate for a minute within a position	125.5000000
100.0000000				meanpo	average value of SpO2 for a minute within a position	75.2500000
67.9000000				meanleq	average value of Leq for a minute within a position	62.2100000

82.5000000	29.2	167	meanco	average value of sctO2 for a minute within a position	55.1052632
185.0000000			meanhr	average value of heart rate for a minute within a position	136.0000000
100.0000000			meanpo	average value of SpO2 for a minute within a position	74.0000000
70.0000000			meanleq	average value of Leq for a minute within a position	56.5000000
87.2166667	29.3	13	meanco	average value of sctO2 for a minute within a position	77.9666667
4					

		N				
	PMA	Obs	Variable	Label	Minimum	Maximum
<i>ff</i>						
		29.3	13	meanhr	average value of heart rate for a minute within a position	50.0000000
163.0000000				meanpo	average value of SpO2 for a minute within a position	99.0000000
100.0000000				meanleq	average value of Leq for a minute within a position	.
		29.4	42	meanco	average value of sct02 for a minute within a position	82.0333333
85.1000000				meanhr	average value of heart rate for a minute within a position	124.4833333
145.3500000				meanpo	average value of SpO2 for a minute within a position	94.1833333
97.3000000				meanleq	average value of Leq for a minute within a position	61.6000000
69.4000000						
		29.5	177	meanco	average value of sct02 for a minute within a position	53.3000000
82.2000000				meanhr	average value of heart rate for a minute within a position	120.7500000
205.5000000				meanpo	average value of SpO2 for a minute within a position	83.0500000
100.0000000				meanleq	average value of Leq for a minute within a position	54.1000000
77.0000000						
		29.6	85	meanco	average value of sct02 for a minute within a position	69.2372881
96.0833333				meanhr	average value of heart rate for a minute within a position	139.0833333
165.8135593				meanpo	average value of SpO2 for a minute within a position	91.1186441
100.0000000				meanleq	average value of Leq for a minute within a position	55.0066667
66.6000000						
		30	81	meanco	average value of sct02 for a minute within a position	69.5000000
93.6333333				meanhr	average value of heart rate for a minute within a position	120.4000000
167.5000000				meanpo	average value of SpO2 for a minute within a position	90.5000000
100.0000000				meanleq	average value of Leq for a minute within a position	55.4000000
62.5000000						
		30.1	23	meanco	average value of sct02 for a minute within a position	70.0000000
78.5000000				meanhr	average value of heart rate for a minute within a position	158.5000000
178.5000000				meanpo	average value of SpO2 for a minute within a position	96.5000000
100.0000000				meanleq	average value of Leq for a minute within a position	.

68.2372881	30.2	62	meanco	average value of sct02 for a minute within a position	48.7666667
175.5000000			meanhr	average value of heart rate for a minute within a position	152.0000000
97.6500000			meanpo	average value of SpO2 for a minute within a position	78.5000000
66.6000000			meanleq	average value of Leq for a minute within a position	59.1200000
96.7166667	30.3	85	meanco	average value of sct02 for a minute within a position	72.6333333
4					

		N				
	PMA	Obs	Variable	Label	Minimum	Maximum
<i>ff</i>						
<i>ffffffffffffffffffffffff</i>						
157.5000000	30.3	85	meanhr	average value of heart rate for a minute within a position	126.4000000	
100.0000000			meanpo	average value of SpO2 for a minute within a position	97.6166667	
73.4000000			meanleq	average value of Leq for a minute within a position	59.1133333	
78.5000000	30.4	43	meanco	average value of sctO2 for a minute within a position	70.1428571	
144.1428571			meanhr	average value of heart rate for a minute within a position	116.4814815	
99.8166667			meanpo	average value of SpO2 for a minute within a position	94.1000000	
75.1000000			meanleq	average value of Leq for a minute within a position	63.2000000	
95.4166667	30.5	139	meanco	average value of sctO2 for a minute within a position	54.0000000	
167.1428571			meanhr	average value of heart rate for a minute within a position	28.0000000	
188.0000000			meanpo	average value of SpO2 for a minute within a position	53.0000000	
65.2983333			meanleq	average value of Leq for a minute within a position	53.2000000	
84.0000000	30.6	83	meanco	average value of sctO2 for a minute within a position	63.7166667	
162.0000000			meanhr	average value of heart rate for a minute within a position	129.1166667	
100.0000000			meanpo	average value of SpO2 for a minute within a position	89.0000000	
64.6000000			meanleq	average value of Leq for a minute within a position	52.8000000	
99.0000000	31	63	meanco	average value of sctO2 for a minute within a position	77.3500000	
177.2333333			meanhr	average value of heart rate for a minute within a position	115.7000000	
100.0000000			meanpo	average value of SpO2 for a minute within a position	89.2500000	
			meanleq	average value of Leq for a minute within a position	.	.
84.0000000	31.1	74	meanco	average value of sctO2 for a minute within a position	65.0000000	
177.5000000			meanhr	average value of heart rate for a minute within a position	119.9166667	
100.0000000			meanpo	average value of SpO2 for a minute within a position	93.4833333	
68.1000000			meanleq	average value of Leq for a minute within a position	53.7000000	

98.5454545	31.2	126	meanco	average value of sct02 for a minute within a position	44.7777778
177.4500000			meanhr	average value of heart rate for a minute within a position	107.1666667
100.0000000			meanpo	average value of SpO2 for a minute within a position	63.8666667
66.7000000			meanleq	average value of Leq for a minute within a position	55.6000000
92.4666667	31.3	89	meanco	average value of sct02 for a minute within a position	73.8333333
4					

		N				
	PMA	Obs	Variable	Label	Minimum	Maximum
<i>ff</i>						
<i>ffffffffffffffff</i>						
153.5833333	31.3	89	meanhr	average value of heart rate for a minute within a position	118.3166667	
100.0000000			meanpo	average value of SpO2 for a minute within a position	96.3666667	
56.7166667			meanleq	average value of Leq for a minute within a position	54.9000000	
80.9333333	31.4	64	meanco	average value of sct02 for a minute within a position	65.9333333	
145.0000000			meanhr	average value of heart rate for a minute within a position	121.5833333	
99.9333333			meanpo	average value of SpO2 for a minute within a position	94.1833333	
62.9000000			meanleq	average value of Leq for a minute within a position	55.9000000	
98.0000000	31.5	145	meanco	average value of sct02 for a minute within a position	33.1500000	
187.5000000			meanhr	average value of heart rate for a minute within a position	76.0000000	
100.0000000			meanpo	average value of SpO2 for a minute within a position	74.0714286	
68.9000000			meanleq	average value of Leq for a minute within a position	53.9600000	
83.0333333	31.6	58	meanco	average value of sct02 for a minute within a position	62.0000000	
187.5000000			meanhr	average value of heart rate for a minute within a position	106.2500000	
100.0000000			meanpo	average value of SpO2 for a minute within a position	42.0000000	
67.9000000			meanleq	average value of Leq for a minute within a position	55.4500000	
85.2166667	32	131	meanco	average value of sct02 for a minute within a position	60.5000000	
205.0833333			meanhr	average value of heart rate for a minute within a position	95.3333333	
100.0000000			meanpo	average value of SpO2 for a minute within a position	79.8888889	
69.2000000			meanleq	average value of Leq for a minute within a position	56.5400000	
99.0000000	32.1	203	meanco	average value of sct02 for a minute within a position	68.5000000	
192.5000000			meanhr	average value of heart rate for a minute within a position	112.3333333	
100.0000000			meanpo	average value of SpO2 for a minute within a position	79.0000000	
62.6000000			meanleq	average value of Leq for a minute within a position	51.4416667	

81.0000000	32.2	126	meanco	average value of sct02 for a minute within a position	52.0333333
183.5000000			meanhr	average value of heart rate for a minute within a position	102.0000000
137.5000000			meanpo	average value of SpO2 for a minute within a position	89.0833333
59.9000000			meanleq	average value of Leq for a minute within a position	54.8000000
79.8166667	32.3	83	meanco	average value of sct02 for a minute within a position	70.3166667

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		N				
	PMA	Obs	Variable	Label	Minimum	Maximum
164.7500000		32.3	83	meanhr	average value of heart rate for a minute within a position	115.7666667
100.0000000				meanpo	average value of SpO2 for a minute within a position	83.0833333
67.4000000				meanleq	average value of Leq for a minute within a position	54.9000000
99.0000000	32.5	104	meanco	average value of sct02 for a minute within a position	15.0000000	
185.5000000			meanhr	average value of heart rate for a minute within a position	148.5500000	
100.0000000			meanpo	average value of SpO2 for a minute within a position	77.0000000	
69.6900000			meanleq	average value of Leq for a minute within a position	53.8200000	
88.8000000	32.6	143	meanco	average value of sct02 for a minute within a position	71.0000000	
173.5833333			meanhr	average value of heart rate for a minute within a position	119.9666667	
100.0000000			meanpo	average value of SpO2 for a minute within a position	95.1166667	
65.0000000			meanleq	average value of Leq for a minute within a position	49.1000000	

		N					
	PMA	Obs	Variable	Label	N	Mean	Std Dev
2.5568718		33	43	meanco	average value of sct02 for a minute within a position	43	81.3945095
12.0077293				meanhr	average value of heart rate for a minute within a position	43	166.1345340
0.0940277				meanpo	average value of SpO2 for a minute within a position	43	99.9655039

1.0448171			meanleq	average value of Leq for a minute within a position	36	57.0250000
5.0261288	33.1	79	meanco	average value of sct02 for a minute within a position	77	72.0255411
61.0312576			meanhr	average value of heart rate for a minute within a position	77	109.6233766
4.7583689			meanpo	average value of SpO2 for a minute within a position	77	97.2047619
4.4837409			meanleq	average value of Leq for a minute within a position	58	60.0310345
4.5094119	33.2	20	meanco	average value of sct02 for a minute within a position	19	53.6578947
9.9956131			meanhr	average value of heart rate for a minute within a position	19	157.6315789
1.6485861			meanpo	average value of SpO2 for a minute within a position	19	97.1315789
0.7844542			meanleq	average value of Leq for a minute within a position	20	54.8200000
3.7144791	33.3	43	meanco	average value of sct02 for a minute within a position	43	56.9980074
5.6828809			meanhr	average value of heart rate for a minute within a position	43	160.2535301

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		N				
PMA	Obs	Variable	Label	N	Mean	Std Dev
	33.3	43	meanpo	average value of SpO2 for a minute within a position	43	99.4201550
0.8604367			meanleq	average value of Leq for a minute within a position	37	55.1108108
0.9188712						
	33.5	170	meanco	average value of sct02 for a minute within a position	167	64.2514033
10.7019729			meanhr	average value of heart rate for a minute within a position	170	173.1432761
9.8866848			meanpo	average value of SpO2 for a minute within a position	170	96.9134499
3.0846289			meanleq	average value of Leq for a minute within a position	160	54.3596164
2.9924887						
	33.6	132	meanco	average value of sct02 for a minute within a position	127	74.8008096
4.1868767			meanhr	average value of heart rate for a minute within a position	132	173.7352421
13.2120431			meanpo	average value of SpO2 for a minute within a position	132	98.1211694
1.6821369			meanleq	average value of Leq for a minute within a position	99	58.0629098
4.8453590						
	34	75	meanco	average value of sct02 for a minute within a position	75	71.9761283
4.0002020			meanhr	average value of heart rate for a minute within a position	75	169.7299648
11.1134614			meanpo	average value of SpO2 for a minute within a position	75	95.5858355
4.4467701			meanleq	average value of Leq for a minute within a position	17	60.8882353
1.7269490						
	34.1	63	meanco	average value of sct02 for a minute within a position	63	76.1983488
4.1245180			meanhr	average value of heart rate for a minute within a position	63	154.6690848
11.6559096			meanpo	average value of SpO2 for a minute within a position	63	98.3839150
3.7933570			meanleq	average value of Leq for a minute within a position	41	59.3829268
4.6836899						
	34.2	50	meanco	average value of sct02 for a minute within a position	50	56.2696667
6.4541429			meanhr	average value of heart rate for a minute within a position	50	154.2110000
13.7000689			meanpo	average value of SpO2 for a minute within a position	50	95.2463333
9.8615842			meanleq	average value of Leq for a minute within a position	29	56.3034483
1.7779368						

1.9960904	34.6	21	meanco	average value of sct02 for a minute within a position	21	66.7404762
6.6785324			meanhr	average value of heart rate for a minute within a position	21	178.1801587
2.8636532			meanpo	average value of SpO2 for a minute within a position	21	97.3468721
			meanleq	average value of Leq for a minute within a position	0	.
5.2051943	35.1	42	meanco	average value of sct02 for a minute within a position	41	73.1938655
9.3288967			meanhr	average value of heart rate for a minute within a position	42	154.7670996
4						

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		N				
PMA	Obs	Variable	Label	N	Mean	Std Dev
<i>ff</i>						
<i>ffffffffffffffffffffffffffffffff</i>						
35.1	42	meanpo	average value of SpO2 for a minute within a position	42	94.8665945	3.6415795
		meanleq	average value of Leq for a minute within a position	26	55.0269231	1.0707223
35.2	42	meanco	average value of sct02 for a minute within a position	42	63.1190476	3.5865765
		meanhr	average value of heart rate for a minute within a position	42	155.3690476	10.2088314
		meanpo	average value of SpO2 for a minute within a position	42	98.4047619	1.9419568
		meanleq	average value of Leq for a minute within a position	0	.	.
35.3	40	meanco	average value of sct02 for a minute within a position	40	50.9750000	7.7508891
		meanhr	average value of heart rate for a minute within a position	40	179.8875000	6.0026570
		meanpo	average value of SpO2 for a minute within a position	40	91.7500000	7.1665176
		meanleq	average value of Leq for a minute within a position	40	56.5750000	2.4243159
36.1	20	meanco	average value of sct02 for a minute within a position	20	78.2309206	4.6889325
		meanhr	average value of heart rate for a minute within a position	20	155.1316667	14.5652142
		meanpo	average value of SpO2 for a minute within a position	20	96.0979167	8.0376944
		meanleq	average value of Leq for a minute within a position	0	.	.
36.2	83	meanco	average value of sct02 for a minute within a position	83	61.3413655	3.6414640
		meanhr	average value of heart rate for a minute within a position	83	160.8554217	12.0318047
		meanpo	average value of SpO2 for a minute within a position	83	96.9789157	3.7424912
		meanleq	average value of Leq for a minute within a position	0	.	.
37.1	20	meanco	average value of sct02 for a minute within a position	20	81.8250000	2.4455922
		meanhr	average value of heart rate for a minute within a position	20	145.2750000	10.5611939
		meanpo	average value of SpO2 for a minute within a position	20	98.1750000	0.6742442
		meanleq	average value of Leq for a minute within a position	20	60.9750000	0.5580747
37.2	59	meanco	average value of sct02 for a minute within a position	59	69.0142454	6.0072831
		meanhr	average value of heart rate for a minute within a position	59	142.2172720	16.0670350

1.7306931		meanpo	average value of SpO2 for a minute within a position	59	98.5652946	
3.4742786		meanleq	average value of Leq for a minute within a position	38	52.5421053	
4.1052086	38	44	meanco	average value of sctO2 for a minute within a position	44	78.6991790
6.2905999			meanhr	average value of heart rate for a minute within a position	44	146.0637054

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		N					
	PMA	Obs	Variable	Label	N	Mean	Std Dev
<i>ff</i>							
		38	44	meanpo	average value of SpO2 for a minute within a position	44	97.0879870
2.8083296				meanleq	average value of Leq for a minute within a position	0	.
<i>;</i>							
		39	42	meanco	average value of sctO2 for a minute within a position	42	76.0371872
4.5433735				meanhr	average value of heart rate for a minute within a position	42	146.8146220
13.5171850				meanpo	average value of SpO2 for a minute within a position	42	98.7645480
1.5372075				meanleq	average value of Leq for a minute within a position	0	.
<i>ff</i>							

		N				
	PMA	Obs	Variable	Label	Minimum	Maximum
<i>ff</i>						
		33	43	meanco	average value of sctO2 for a minute within a position	77.8333333
89.4000000				meanhr	average value of heart rate for a minute within a position	149.6833333
193.9833333				meanpo	average value of SpO2 for a minute within a position	99.5000000
100.0000000				meanleq	average value of Leq for a minute within a position	55.9000000
59.9000000						
	33.1	79	meanco	average value of sctO2 for a minute within a position	61.5000000	
85.5000000				meanhr	average value of heart rate for a minute within a position	21.0000000
195.0000000				meanpo	average value of SpO2 for a minute within a position	64.3166667
100.0000000				meanleq	average value of Leq for a minute within a position	56.5000000
67.1000000						
	33.2	20	meanco	average value of sctO2 for a minute within a position	40.0000000	
61.0000000				meanhr	average value of heart rate for a minute within a position	136.0000000
171.5000000				meanpo	average value of SpO2 for a minute within a position	94.5000000
100.0000000				meanleq	average value of Leq for a minute within a position	53.8000000
56.6000000						
	33.3	43	meanco	average value of sctO2 for a minute within a position	48.6333333	
67.3666667				meanhr	average value of heart rate for a minute within a position	141.6500000
179.0000000						

100.0000000			meanpo	average value of SpO2 for a minute within a position	96.1166667
57.7000000			meanleq	average value of Leq for a minute within a position	54.3000000
87.1333333	33.5	170	meanco	average value of sct02 for a minute within a position	24.5666667
205.9333333			meanhr	average value of heart rate for a minute within a position	150.9333333
100.0000000			meanpo	average value of SpO2 for a minute within a position	83.7833333

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		N				
	PMA	Obs	Variable	Label	Minimum	Maximum
61.4416667	33.5	170	meanleq	average value of Leq for a minute within a position	46.7000000	
94.8000000	33.6	132	meanco	average value of sct02 for a minute within a position	68.8000000	
209.2500000			meanhr	average value of heart rate for a minute within a position	145.9333333	
100.0000000			meanpo	average value of SpO2 for a minute within a position	92.0000000	
71.1183333			meanleq	average value of Leq for a minute within a position	50.4333333	
78.2666667	34	75	meanco	average value of sct02 for a minute within a position	60.1489362	
200.3500000			meanhr	average value of heart rate for a minute within a position	150.1500000	
100.0000000			meanpo	average value of SpO2 for a minute within a position	76.5319149	
65.2000000			meanleq	average value of Leq for a minute within a position	58.1000000	
84.1666667	34.1	63	meanco	average value of sct02 for a minute within a position	69.0000000	
180.4833333			meanhr	average value of heart rate for a minute within a position	93.0000000	
122.5000000			meanpo	average value of SpO2 for a minute within a position	88.0000000	
76.4000000			meanleq	average value of Leq for a minute within a position	55.2000000	
67.5000000	34.2	50	meanco	average value of sct02 for a minute within a position	31.0000000	
181.0000000			meanhr	average value of heart rate for a minute within a position	133.9000000	
100.0000000			meanpo	average value of SpO2 for a minute within a position	57.0000000	
60.8000000			meanleq	average value of Leq for a minute within a position	54.4000000	
71.0000000	34.6	21	meanco	average value of sct02 for a minute within a position	63.3000000	

189.7000000			meanhr	average value of heart rate for a minute within a position	167.0000000
100.0000000			meanpo	average value of SpO2 for a minute within a position	89.6500000
			meanleq	average value of Leq for a minute within a position	.
87.0000000	35.1	42	meanco	average value of sct02 for a minute within a position	62.1000000
176.9500000			meanhr	average value of heart rate for a minute within a position	141.0000000
99.0000000			meanpo	average value of SpO2 for a minute within a position	83.4500000
58.8500000			meanleq	average value of Leq for a minute within a position	54.1500000
72.0000000	35.2	42	meanco	average value of sct02 for a minute within a position	54.0000000
172.5000000			meanhr	average value of heart rate for a minute within a position	132.5000000
100.0000000			meanpo	average value of SpO2 for a minute within a position	92.0000000

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		N					
		PMA	Obs	Variable	Label	Minimum	Maximum
<i>ff</i>							
<i>ffffffffffffffff</i>							
		35.2	42	meanleq	average value of Leq for a minute within a position	.	.
77.5000000		35.3	40	meanco	average value of sct02 for a minute within a position	37.5000000	
193.5000000				meanhr	average value of heart rate for a minute within a position	167.0000000	
100.0000000				meanpo	average value of SpO2 for a minute within a position	72.0000000	
65.0000000				meanleq	average value of Leq for a minute within a position	53.8000000	
82.9500000		36.1	20	meanco	average value of sct02 for a minute within a position	61.7500000	
187.1666667				meanhr	average value of heart rate for a minute within a position	137.3666667	
100.0000000				meanpo	average value of SpO2 for a minute within a position	67.9833333	
				meanleq	average value of Leq for a minute within a position	.	.
71.5000000		36.2	83	meanco	average value of sct02 for a minute within a position	53.0000000	
182.6500000				meanhr	average value of heart rate for a minute within a position	120.0000000	
100.0000000				meanpo	average value of SpO2 for a minute within a position	79.1500000	
				meanleq	average value of Leq for a minute within a position	.	.
87.0000000		37.1	20	meanco	average value of sct02 for a minute within a position	76.0000000	
168.5000000				meanhr	average value of heart rate for a minute within a position	133.0000000	

99.0000000		meanpo	average value of SpO2 for a minute within a position	96.5000000	
62.2000000		meanleq	average value of Leq for a minute within a position	60.3000000	
78.8571429	37.2	59	meanco	average value of sctO2 for a minute within a position	57.5000000
198.4833333		meanhr	average value of heart rate for a minute within a position	117.0000000	
100.0000000		meanpo	average value of SpO2 for a minute within a position	93.0000000	
65.3000000		meanleq	average value of Leq for a minute within a position	48.5000000	
93.2857143	38	44	meanco	average value of sctO2 for a minute within a position	71.9333333
159.5000000		meanhr	average value of heart rate for a minute within a position	135.3000000	
99.5000000		meanpo	average value of SpO2 for a minute within a position	87.2833333	
87.9333333		meanleq	average value of Leq for a minute within a position	.	
192.1666667	39	42	meanco	average value of sctO2 for a minute within a position	69.2000000
100.0000000		meanhr	average value of heart rate for a minute within a position	128.7333333	
		meanpo	average value of SpO2 for a minute within a position	93.9000000	

means by pma
The MEANS Procedure

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		N			
PMA	Obs	Variable	Label	Minimum	Maximum
	39	42	meanleq	average value of Leq for a minute within a position	.

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

N	Mean	Std Dev	Minimum	Maximum
4742	72.7652666	9.8563568	15.0000000	99.0000000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
1	280	78.4660193	7.3315556	260	20	63.3000000	97.0000000
2	178	78.7593496	4.3308611	178	0	68.9122807	87.1000000
3	252	77.6041259	6.5952456	252	0	60.0333333	93.2500000
4	139	77.5171012	7.2798801	137	2	65.8666667	94.0000000
5	53	84.6426134	5.1809500	53	0	71.7826087	95.4166667
6	20	64.2833333	4.5182735	20	0	52.0333333	69.8333333
7	315	76.0676766	4.6367663	313	2	62.0000000	85.5000000
9	31	86.8764734	6.9032820	30	1	75.8666667	98.5454545
12	40	73.7354167	7.9461786	40	0	54.0833333	82.9833333
14	216	73.3254774	6.2677448	213	3	58.0000000	94.8000000
17	20	74.8250000	4.1715673	20	0	68.0000000	83.5000000
19	20	74.7343503	2.3557920	20	0	69.7000000	79.4000000
21	173	72.9843906	5.8632933	171	2	55.6666667	87.2166667
22	20	79.5847436	3.2239187	20	0	72.8000000	84.1666667
23	20	70.6433333	2.1843168	20	0	67.1000000	75.1333333
27	20	74.0466667	2.5568827	20	0	69.6833333	78.7500000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
28	144	67.2751313	7.5063020	142	2	52.0000000	84.5666667
33	20	76.0040113	2.8032699	20	0	67.2166667	78.2666667

35	129	68.7957774	7.0922998	127	2	44.7777778	85.5000000
36	16	68.4342803	2.9185626	16	0	62.1000000	71.5333333
42	150	64.5067163	8.0285136	147	3	37.9166667	98.0000000
48	20	78.2309206	4.6889325	20	0	61.7500000	82.9500000
49	120	58.6207827	13.6152116	115	5	25.3783784	82.8333333
56	107	62.1172947	9.9556400	107	0	24.5666667	78.4333333
61	20	76.5183333	2.4009373	20	0	71.9333333	80.1333333
63	40	71.7500000	10.6029749	40	0	54.0000000	87.0000000
64	20	46.4750000	6.2037234	20	0	37.5000000	67.5000000
68	20	73.4633333	3.3976755	20	0	69.2000000	80.5666667
70	40	60.3875000	3.1041071	40	0	53.0000000	64.7000000
77	20	64.6750000	2.7780862	20	0	57.5000000	69.0000000

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 fff*

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

GA	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
25.5	526	70.0014324	12.4109458	523	3	24.5666667	98.0000000
26.2	563	66.7902043	9.8672383	561	2	37.5000000	92.7166667
26.5	171	71.0295536	6.5262799	167	4	52.0000000	85.5000000
27	20	94.1500000	2.0969903	20	0	89.5000000	97.0000000
28	178	75.7327586	3.7573229	174	4	65.0000000	87.0000000
28.6	241	74.2440520	7.2461375	239	2	60.0333333	98.5454545
29.2	200	78.2712377	5.3539969	200	0	61.7500000	93.6333333
29.3	60	73.0586505	2.1926456	60	0	68.9122807	78.2166667
29.6	40	81.2269746	1.4474081	40	0	77.4333333	83.6333333
30	51	83.6340132	3.7946081	51	0	75.8666667	95.4166667
30.4	93	77.2831047	7.4544604	93	0	54.0833333	90.1833333
30.6	87	75.2925490	4.4741183	85	2	62.0000000	84.0000000
31	100	81.0997733	3.5550808	100	0	72.8000000	92.4666667
31.3	100	69.5000000	6.0269350	80	20	52.0333333	80.3000000
31.6	233	77.1953513	3.1209488	228	5	70.3166667	94.8000000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Caffeine	N Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
0	705	71.6986760	10.1086785	704	1	24.5666667	92.4666667
1	1958	73.3859378	9.3906086	1917	41	25.3783784	98.5454545

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	Caffeine	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
1	0	120	74.9381615	4.9741978	120	0	63.3000000	84.0000000
	1	160	81.4898975	7.6824038	140	20	65.5000000	97.0000000
2	0	58	79.3559727	1.6933324	58	0	74.1666667	82.2666667
	1	120	78.4709818	5.1251650	120	0	68.9122807	87.1000000
3	0	52	84.2852564	4.7098569	52	0	75.0000000	92.4666667
	1	200	75.8670319	5.8721057	200	0	60.0333333	93.2500000
4	1	139	77.5171012	7.2798801	137	2	65.8666667	94.0000000
5	1	53	84.6426134	5.1809500	53	0	71.7826087	95.4166667
6	1	20	64.2833333	4.5182735	20	0	52.0333333	69.8333333
7	0	40	78.5328341	1.6585451	40	0	75.7000000	83.6333333
	1	275	75.7064814	4.8210245	273	2	62.0000000	85.5000000
9	1	31	86.8764734	6.9032820	30	1	75.8666667	98.5454545
12	1	40	73.7354167	7.9461786	40	0	54.0833333	82.9833333
14	1	216	73.3254774	6.2677448	213	3	58.0000000	94.8000000
17	1	20	74.8250000	4.1715673	20	0	68.0000000	83.5000000
19	1	20	74.7343503	2.3557920	20	0	69.7000000	79.4000000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	Caffeine	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
21	1	173	72.9843906	5.8632933	171	2	55.6666667	87.2166667
22	0	20	79.5847436	3.2239187	20	0	72.8000000	84.1666667
23	0	20	70.6433333	2.1843168	20	0	67.1000000	75.1333333
27	1	20	74.0466667	2.5568827	20	0	69.6833333	78.7500000
28	0	12	66.1735225	2.9107648	12	0	60.1489362	69.3333333
	1	132	67.3768182	7.7935968	130	2	52.0000000	84.5666667
33	0	20	76.0040113	2.8032699	20	0	67.2166667	78.2666667
35	0	20	72.5404520	1.3909879	20	0	70.1333333	75.0833333
	1	109	68.0958383	7.5036190	107	2	44.7777778	85.5000000
36	0	16	68.4342803	2.9185626	16	0	62.1000000	71.5333333
42	0	40	69.1137500	3.1353419	40	0	63.3000000	75.0000000
	1	110	62.7844607	8.6116267	107	3	37.9166667	98.0000000
48	0	20	78.2309206	4.6889325	20	0	61.7500000	82.9500000
49	0	40	64.7948718	11.6640010	39	1	40.0000000	81.5000000
	1	80	55.4525001	13.5219480	76	4	25.3783784	82.8333333
56	0	67	61.6076435	11.5106157	67	0	24.5666667	78.4333333

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	Caffeine	N Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
<i>ff</i>								
56	1	40	62.9709605	6.6312987	40	0	52.6666667	76.1666667
61	0	20	76.5183333	2.4009373	20	0	71.9333333	80.1333333
63	0	40	71.7500000	10.6029749	40	0	54.0000000	87.0000000
64	0	20	46.4750000	6.2037234	20	0	37.5000000	67.5000000
68	0	20	73.4633333	3.3976755	20	0	69.2000000	80.5666667
70	0	40	60.3875000	3.1041071	40	0	53.0000000	64.7000000
77	0	20	64.6750000	2.7780862	20	0	57.5000000	69.0000000
<i>ff</i>								

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Probe	N Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum	
	0	1712	72.1967863	10.4293224	1692	20	24.5666667	98.5454545
	1	951	74.2731413	7.7504808	929	22	37.5000000	92.7166667

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Probe	N PA	Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
0	1	160	76.5798333	8.2198836	160	0	63.3000000	97.0000000
	2	118	78.7696946	4.5538672	118	0	68.9122807	86.5666667
	3	152	76.9903985	7.1717717	152	0	60.0333333	93.2500000
	4	99	78.2368385	8.5046239	97	2	65.8666667	94.0000000
	5	53	84.6426134	5.1809500	53	0	71.7826087	95.4166667
	6	20	64.2833333	4.5182735	20	0	52.0333333	69.8333333
	7	175	76.9107021	3.5358641	173	2	62.0000000	85.5000000
	9	31	86.8764734	6.9032820	30	1	75.8666667	98.5454545
	12	20	66.6691667	4.6567761	20	0	54.0833333	71.3000000
	14	156	73.2721411	5.8721339	153	3	58.0000000	94.8000000
	17	20	74.8250000	4.1715673	20	0	68.0000000	83.5000000
	21	93	71.7376606	7.0048709	91	2	55.6666667	87.2166667
	22	20	79.5847436	3.2239187	20	0	72.8000000	84.1666667
	28	101	68.3708637	8.5114550	100	1	52.0000000	84.5666667
	35	89	66.5648267	7.4875611	87	2	44.7777778	85.5000000
	42	118	63.7542008	8.7105444	116	2	37.9166667	98.0000000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Probe	N PA	Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
0	49	120	58.6207827	13.6152116	115	5	25.3783784	82.8333333
	56	87	58.8628414	8.0318889	87	0	24.5666667	76.1666667
	63	40	71.7500000	10.6029749	40	0	54.0000000	87.0000000
	68	20	73.4633333	3.3976755	20	0	69.2000000	80.5666667
	70	20	62.4250000	0.9904146	20	0	61.0000000	64.5000000
1	1	120	81.4839170	4.1421933	100	20	76.5000000	92.7166667
	2	60	78.7390046	3.8915951	60	0	69.9666667	87.1000000
	3	100	78.5369915	5.5111972	100	0	69.2372881	90.1833333
	4	40	75.7717384	1.5350358	40	0	72.0166667	77.9666667
	7	140	75.0259380	5.5506780	140	0	62.2500000	83.8833333
	12	20	80.8016667	1.6737472	20	0	77.3500000	82.9833333
	14	60	73.4614849	7.2316840	60	0	64.3333333	89.4000000
	19	20	74.7343503	2.3557920	20	0	69.7000000	79.4000000
	21	80	74.4025459	3.7750318	80	0	58.0000000	81.0833333
	23	20	70.6433333	2.1843168	20	0	67.1000000	75.1333333
	27	20	74.0466667	2.5568827	20	0	69.6833333	78.7500000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Probe	N PA	Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
1	28	43	64.6662445	2.9902906	42	1	54.5000000	69.3333333
	33	20	76.0040113	2.8032699	20	0	67.2166667	78.2666667
	35	40	73.6480952	1.9055407	40	0	70.7666667	78.3000000
	36	16	68.4342803	2.9185626	16	0	62.1000000	71.5333333
	42	32	67.3225806	3.5297507	31	1	61.5000000	73.5000000
	48	20	78.2309206	4.6889325	20	0	61.7500000	82.9500000
	56	20	76.2741667	1.2226119	20	0	72.9500000	78.4333333
	61	20	76.5183333	2.4009373	20	0	71.9333333	80.1333333
	64	20	46.4750000	6.2037234	20	0	37.5000000	67.5000000
	70	20	58.3500000	3.1713354	20	0	53.0000000	64.7000000
	77	20	64.6750000	2.7780862	20	0	57.5000000	69.0000000

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time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	4
Columns in X	21
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	231

Number of Observations

Number of Observations Read	2663
Number of Observations Used	2621

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time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Number of Observations

Number of Observations Not Used	42
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Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18052.41814761	
1	2	16415.59271817	0.00085291

2	1	16409.28798307	0.00032012
3	1	16406.99492923	0.00007839
4	1	16406.46532635	0.00000743
5	1	16406.41926629	0.00000009
6	1	16406.41872354	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm Subject Estimate

Intercept Infant 31.9740
 PA Infant 0.07145
 minute Infant 0.008266
 Residual 27.3764

Fit Statistics

-2 Res Log Likelihood 16406.4
 AIC (smaller is better) 16414.4
 AICC (smaller is better) 16414.4

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 time variable is pa
 covariates are ga, caffeine, probe with interactions
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The Mixed Procedure

Fit Statistics

BIC (smaller is better) 16419.1

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			90.1771	15.6971	23	5.74	<.0001
PA			-0.8804	0.1108	21	-7.95	<.0001
pa2			0.01876	0.003963	2540	4.73	<.0001
pa3			-0.00013	0.000047	2540	-2.82	0.0049
Caffeine	0		0.4938	0.8138	2540	0.61	0.5440
Caffeine	1		0	.	.	.	.
PA*Caffeine	0		0.01133	0.1406	2540	0.08	0.9358
PA*Caffeine	1		0	.	.	.	.
pa2*Caffeine	0		0.000616	0.005152	2540	0.12	0.9048
pa2*Caffeine	1		0	.	.	.	.
pa3*Caffeine	0		-0.00001	0.000054	2540	-0.19	0.8514
pa3*Caffeine	1		0	.	.	.	.
Probe		0	-4.9013	0.5887	2540	-8.33	<.0001
Probe		1	0	.	.	.	.
PA*Probe		0	1.1904	0.1045	2540	11.39	<.0001
PA*Probe		1	0	.	.	.	.
pa2*Probe		0	-0.04946	0.003953	2540	-12.51	<.0001
pa2*Probe		1	0	.	.	.	.
pa3*Probe		0	0.000483	0.000039	2540	12.53	<.0001
pa3*Probe		1	0	.	.	.	.

GA -0.2794 0.5444 2.540 -0.51 0.6077

4

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
PA	1	21	9.58	0.0055
pa2	1	2540	3.84	0.0501
pa3	1	2540	7.95	0.0049
Caffeine	1	2540	0.37	0.5440
PA*Caffeine	1	2540	0.01	0.9358
pa2*Caffeine	1	2540	0.01	0.9048
pa3*Caffeine	1	2540	0.04	0.8514
Probe	1	2540	69.32	<.0001
PA*Probe	1	2540	129.81	<.0001
pa2*Probe	1	2540	156.61	<.0001
pa3*Probe	1	2540	156.91	<.0001
GA	1	2540	0.26	0.6077

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 46
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	4
Columns in X	20
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	231

Number of Observations

Number of Observations Read	2663
Number of Observations Used	2621

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 47
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Number of Observations

Number of Observations Not Used	42
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Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18092.03634915	

1	2	16414.10841770	0.00066532
2	1	16409.22242903	0.00022940
3	1	16407.60109585	0.00004511
4	1	16407.30472382	0.00000249
5	1	16407.28967728	0.00000001

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	30.8377
PA	Infant	0.07244
minute	Infant	0.008110
Residual		27.3768

Fit Statistics

-2 Res Log Likelihood	16407.3
AIC (smaller is better)	16415.3
AICC (smaller is better)	16415.3
BIC (smaller is better)	16420.0

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are ga, caffeine, probe with interactions
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The Mixed Procedure
Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > t
Intercept			82.1464	1.2508	23	65.67	<.0001
PA			-0.8834	0.1109	21	-7.97	<.0001
pa2			0.01879	0.003962	2541	4.74	<.0001
pa3			-0.00013	0.000047	2541	-2.83	0.0047
Caffeine	0		0.4471	0.8099	2541	0.55	0.5810
Caffeine	1		0	.	.	.	.
PA*Caffeine	0		0.01565	0.1405	2541	0.11	0.9113
PA*Caffeine	1		0	.	.	.	.
pa2*Caffeine	0		0.000502	0.005149	2541	0.10	0.9223
pa2*Caffeine	1		0	.	.	.	.
pa3*Caffeine	0		-9.13E-6	0.000054	2541	-0.17	0.8653
pa3*Caffeine	1		0	.	.	.	.
Probe	0		-4.9068	0.5885	2541	-8.34	<.0001
Probe	1		0	.	.	.	.
PA*Probe	0		1.1912	0.1045	2541	11.40	<.0001
PA*Probe	1		0	.	.	.	.
pa2*Probe	0		-0.04949	0.003952	2541	-12.52	<.0001
pa2*Probe	1		0	.	.	.	.
pa3*Probe	0		0.000483	0.000039	2541	12.53	<.0001
pa3*Probe	1		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		

PA	1	21	9.55	0.0056
pa2	1	2541	3.90	0.0485
pa3	1	2541	8.00	0.0047
Caffeine	1	2541	0.30	0.5810

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 49
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA*Caffeine	1	2541	0.01	0.9113
pa2*Caffeine	1	2541	0.01	0.9223
pa3*Caffeine	1	2541	0.03	0.8653
Probe	1	2541	69.52	<.0001
PA*Probe	1	2541	130.04	<.0001
pa2*Probe	1	2541	156.83	<.0001
pa3*Probe	1	2541	157.11	<.0001

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 50
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	4
Columns in X	18
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	231

Number of Observations

Number of Observations Read	2663
Number of Observations Used	2621

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 51
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Number of Observations

Number of Observations Not Used 42

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18077.67627342	
1	2	16396.62430756	0.00068765
2	1	16391.57375912	0.00024318
3	1	16389.85160728	0.00005065
4	1	16389.51725366	0.00000322
5	1	16389.49774550	0.00000002
6	1	16389.49764298	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	30.8232
PA	Infant	0.07225
minute	Infant	0.008104
Residual		27.3671

Fit Statistics

-2 Res Log Likelihood	16389.5
AIC (smaller is better)	16397.5
AICC (smaller is better)	16397.5

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 52
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Fit Statistics

BIC (smaller is better)	16402.2
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Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > t
--------	----------	-------	-------------------	-------	----	---------	---------

Intercept		82.1758	1.2381	23	66.37	<.0001
PA		-0.8922	0.09784	21	-9.12	<.0001
pa2		0.01923	0.003001	2542	6.41	<.0001
pa3		-0.00014	0.000032	2542	-4.27	<.0001
Caffeine	0	0.3761	0.6928	2542	0.54	0.5873
Caffeine	1	0	.	.	.	.
PA*Caffeine	0	0.03600	0.07295	2542	0.49	0.6217
PA*Caffeine	1	0	.	.	.	.
pa2*Caffeine	0	-0.00034	0.001363	2542	-0.25	0.8030
pa2*Caffeine	1	0	.	.	.	.
Probe	0	-4.9045	0.5882	2542	-8.34	<.0001
Probe	1	0	.	.	.	.
PA*Probe	0	1.1917	0.1044	2542	11.41	<.0001
PA*Probe	1	0	.	.	.	.
pa2*Probe	0	-0.04952	0.003946	2542	-12.55	<.0001
pa2*Probe	1	0	.	.	.	.
pa3*Probe	0	0.000484	0.000038	2542	12.60	<.0001
pa3*Probe	1	0	.	.	.	.

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
PA	1	21	9.55	0.0055
pa2	1	2542	3.90	0.0485
pa3	1	2542	18.27	<.0001
Caffeine	1	2542	0.29	0.5873
PA*Caffeine	1	2542	0.24	0.6217
pa2*Caffeine	1	2542	0.06	0.8030
Probe	1	2542	69.51	<.0001
PA*Probe	1	2542	130.28	<.0001
pa2*Probe	1	2542	157.50	<.0001
pa3*Probe	1	2542	158.65	<.0001

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 54
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	4
Columns in X	16
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	231

Number of Observations

Number of Observations Read	2663
Number of Observations Used	2621

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 55
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Number of Observations

Number of Observations Not Used	42
---------------------------------	----

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18080.33634080	
1	2	16384.86319802	0.00065075

2	1	16380.09800394	0.00022484
3	1	16378.51228276	0.00004488
4	1	16378.21754250	0.00000265
5	1	16378.20155239	0.00000001
6	1	16378.20147624	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	30.8239
PA	Infant	0.07152
minute	Infant	0.008101
Residual		27.3589

Fit Statistics

-2 Res Log Likelihood	16378.2
AIC (smaller is better)	16386.2
AICC (smaller is better)	16386.2

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Fit Statistics

BIC (smaller is better)	16390.9
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Solution for Fixed Effects

Effect	Caffeine	Probe	Estimate	Standard Error	DF	t Value	Pr > t
Intercept		82.1616	1.2371	23	66.42	<.0001	
PA		-0.8921	0.09764	21	-9.14	<.0001	
pa2		0.01948	0.002823	2543	6.90	<.0001	
pa3		-0.00014	0.000027	2543	-5.33	<.0001	
Caffeine 0		0.4475	0.6313	2543	0.71	0.4784	
Caffeine 1		0	.	.	.	.
PA*Caffeine 0		0.01857	0.02097	2543	0.89	0.3758	
PA*Caffeine 1		0	.	.	.	.
Probe 0		-4.8878	0.5847	2543	-8.36	<.0001	
Probe 1		0	.	.	.	.
PA*Probe 0		1.1864	0.1023	2543	11.59	<.0001	
PA*Probe 1		0	.	.	.	.
pa2*Probe 0		-0.04930	0.003842	2543	-12.83	<.0001	
pa2*Probe 1		0	.	.	.	.
pa3*Probe 0		0.000482	0.000037	2543	12.90	<.0001	
pa3*Probe 1		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
--------	--------	--------	---------	--------

PA	1	21	13.98	0.0012
pa2	1	2543	7.15	0.0075
pa3	1	2543	28.42	<.0001

Dep var is averaged 1 minuted sct02 19:07 Friday, April 20, 2012 57
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Caffeine	1	2543	0.50	0.4784
PA*Caffeine	1	2543	0.78	0.3758
Probe	1	2543	69.88	<.0001
PA*Probe	1	2543	134.42	<.0001
pa2*Probe	1	2543	164.60	<.0001
pa3*Probe	1	2543	166.50	<.0001

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	4
Columns in X	14
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	231

Number of Observations

Number of Observations Read	2663
Number of Observations Used	2621

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Number of Observations

Number of Observations Not Used	42
---------------------------------	----

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18098.60688157	
1	2	16381.13741651	0.00076877

2	1	16375.49427212	0.00027642
3	1	16373.53289400	0.00006171
4	1	16373.12223275	0.00000477
5	1	16373.09309365	0.00000004
6	1	16373.09285326	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	31.1863
PA	Infant	0.07170
minute	Infant	0.008068
Residual		27.3539

Fit Statistics

-2 Res Log Likelihood	16373.1
AIC (smaller is better)	16381.1
AICC (smaller is better)	16381.1

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

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The Mixed Procedure
Fit Statistics

BIC (smaller is better)	16385.8
-------------------------	---------

Solution for Fixed Effects

Effect	Caffeine	Probe	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept			82.0908	1.2405	23	66.18	<.0001
PA			-0.8885	0.09759	21	-9.10	<.0001
pa2			0.01954	0.002822	2544	6.92	<.0001
pa3			-0.00014	0.000027	2544	-5.27	<.0001
Caffeine 0			0.8533	0.4350	2544	1.96	0.0499
Caffeine 1			0	.	.	.	.
Probe 0			-4.9564	0.5797	2544	-8.55	<.0001
Probe 1			0	.	.	.	.
PA*Probe 0			1.2004	0.1011	2544	11.87	<.0001
PA*Probe 1			0	.	.	.	.
pa2*Probe 0			-0.04991	0.003780	2544	-13.21	<.0001
pa2*Probe 1			0	.	.	.	.
pa3*Probe 0			0.000488	0.000037	2544	13.34	<.0001
pa3*Probe 1			0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	21	13.83	0.0013

pa2	1	2544	8.03	0.0046
pa3	1	2544	27.81	<.0001
Caffeine	1	2544	3.85	0.0499
Probe	1	2544	73.09	<.0001

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are ga, caffeine, probe with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA*Probe	1	2544	140.93	<.0001
pa2*Probe	1	2544	174.38	<.0001
pa3*Probe	1	2544	178.01	<.0001

Dep var is averaged 1 minuted sct02
time variable is pa
covariate is probe with interactions
All Data Collections March 30 2012
Final Overall Model

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The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	4
Columns in X	12
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	231

Number of Observations

Number of Observations Read	2663
Number of Observations Used	2621

Dep var is averaged 1 minuted sct02
time variable is pa
covariate is probe with interactions
All Data Collections March 30 2012
Final Overall Model

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The Mixed Procedure

Number of Observations

Number of Observations Not Used 42

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18134.48699713	
1	2	16385.34088000	0.00078525
2	1	16379.57358113	0.00028353
3	1	16377.56030841	0.00006405
4	1	16377.13325814	0.00000512
5	1	16377.10188316	0.00000005
6	1	16377.10160363	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	30.6529
PA	Infant	0.07529
minute	Infant	0.007914
Residual		27.3817

Fit Statistics

-2 Res Log Likelihood	16377.1
AIC (smaller is better)	16385.1

Dep var is averaged 1 minuted sct02
time variable is pa
covariate is probe with interactions
All Data Collections March 30 2012
Final Overall Model

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The Mixed Procedure

Fit Statistics

AICC (smaller is better)	16385.1
BIC (smaller is better)	16389.8

Solution for Fixed Effects

Effect	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
--------	-------	-------------------	-------	----	---------	---------

Intercept		82.3399	1.2255	23	67.19	<.0001
PA		-0.9149	0.09767	21	-9.37	<.0001
pa2		0.02053	0.002779	2545	7.39	<.0001
pa3		-0.00015	0.000026	2545	-5.61	<.0001
Probe	0	-4.8959	0.5793	2545	-8.45	<.0001
Probe	1	0	.	.	.	.
PA*Probe	0	1.1863	0.1009	2545	11.75	<.0001
PA*Probe	1	0	.	.	.	.
pa2*Probe	0	-0.04955	0.003778	2545	-13.12	<.0001
pa2*Probe	1	0	.	.	.	.
pa3*Probe	0	0.000486	0.000037	2545	13.27	<.0001
pa3*Probe	1	0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	21	17.54	0.0004
pa2	1	2545	5.46	0.0195
pa3	1	2545	31.49	<.0001
Probe	1	2545	71.43	<.0001
PA*Probe	1	2545	138.15	<.0001

Dep var is averaged 1 minuted sct02
time variable is pa
covariate is probe with interactions
All Data Collections March 30 2012
Final Overall Model

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The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
pa2*Probe	1	2545	172.03	<.0001
pa3*Probe	1	2545	176.08	<.0001

*****,
*****,

libname final 'C:\Users\Heather\Desktop';

data prep;
set final.aggtest;

```

*****
*****delete positions other than position 1*****
*****center pma to youngest infant at 1st data collection;*****
*****make time (postnatal age) quadratic and cubed*****
*****
    if position eq 1;
    if minute le 20;
    pa2= pa*pa;
    pa3= pa*pa*pa;

```

```

proc sort data=prep out=preps;
by newid minute;

```

```

*****
*****calculate means by position and minute*****
*****

```

```

proc means data=preps mean std n nmiss min max;
class pa;
var meanco;
Title1' means by postnatal age';
title2'prep for proc mixed chapter 3 Overall General Model-IVH NOT included';
run;

```

```

proc means data=preps mean std n nmiss min max;;
class ga;
var meanco;
Title1' means by gestational age';
title2'prep for proc mixed chapter 3 Overall General Model-IVH NOT included';

```

```

proc means data=preps mean std n nmiss min max;;
class caffeine;
var meanco;
Title1' means by caffeine';
title2'prep for proc mixed chapter 3 Overall General Model-IVH NOT included';

```

```

proc means data=preps mean std n nmiss min max;
class pa caffeine;
var meanco;
Title1' means by caffeine and age';
title2'prep for proc mixed chapter 3 Overall General Model-IVH NOT included';

```

```

proc means data=preps mean std n nmiss min max;
class probe;
var meanco;
Title1' means by probe';
title2'prep for proc mixed chapter 3 Overall General Model-IVH NOT included';

```

```

proc means data=preps mean std n nmiss min max;
class probe pa;
var meanco;
Title1' means by probe and age';
title2'prep for proc mixed chapter 3 Overall General Model-IVH NOT included';

```

```

*****
*****perform the proc mixed*****

```

```

*****;

proc mixed data=preps;
class caffeine probe infant;
model meanco = pa pa2 pa3 caffeine caffeine*pa caffeine*pa2 caffeine*pa3 probe probe*pa probe*pa2
probe*pa3 ga/s ;
random intercept pa minute /subject = infant type = vc;

title1' Dep var is averaged 1 minuted sct02 ' ;
title2' time variable is pa';
title3' covariates are ga, caffeine, probe with interactions';
title4' All Data Collections March 30 2012';
run;

*caffeine, caffeine*pa, caffeine*pa2, caffeine*pa3 and ga all non-significant- removed from model;
proc mixed data=preps;
class caffeine probe infant;
model meanco = pa pa2 pa3 caffeine caffeine*pa caffeine*pa2 caffeine*pa3 probe probe*pa probe*pa2
probe*pa3/s ;
random intercept pa minute /subject = infant type = vc;

title1' Dep var is averaged 1 minuted sct02 ' ;
title2' time variable is pa';
title3' covariates are ga, caffeine, probe with interactions';
title4' All Data Collections March 30 2012';
run;

proc mixed data=preps;
class caffeine probe infant;
model meanco = pa pa2 pa3 caffeine caffeine*pa caffeine*pa2 probe probe*pa probe*pa2 probe*pa3/s ;
random intercept pa minute /subject = infant type = vc;

title1' Dep var is averaged 1 minuted sct02 ' ;
title2' time variable is pa';
title3' covariates are ga, caffeine, probe with interactions';
title4' All Data Collections March 30 2012';
run;

proc mixed data=preps;
class caffeine probe infant;
model meanco = pa pa2 pa3 caffeine caffeine*pa probe probe*pa probe*pa2 probe*pa3/s ;
random intercept pa minute /subject = infant type = vc;

title1' Dep var is averaged 1 minuted sct02 ' ;
title2' time variable is pa';
title3' covariates are ga, caffeine, probe with interactions';
title4' All Data Collections March 30 2012';
run;

proc mixed data=preps;
class caffeine probe infant;
model meanco = pa pa2 pa3 caffeine probe probe*pa probe*pa2 probe*pa3/s ;
random intercept pa minute /subject = infant type = vc;

title1' Dep var is averaged 1 minuted sct02 ' ;

```

```

title2' time variable is pa';
title3' covariates are ga, caffeine, probe with interactions';
title4' All Data Collections March 30 2012';
run;

proc mixed data=preps;
class probe infant;
model meanco = pa pa2 pa3 probe probe*pa probe*pa2 probe*pa3/outpred = of s;
random intercept pa minute /subject = infant type = vc;

title1' Dep var is averaged 1 minuted sct02';
title2' time variable is pa';
title3' covariate is probe with interactions';
title4' All Data Collections March 30 2012';
title5' Final Overall Model';
run;

*****
*****examine*****
*****each interaction*****
*****and asking SAS for predicted means based on ONLY raw
data*****
/*data of2;
    set of;
    if ivh eq 1 and probe eq 1 and caffeine eq 1 then group = 1;
    else
    if ivh eq 1 and probe eq 1 and caffeine eq 0 then group = 2;
    else
    if ivh eq 1 and probe eq 0 and caffeine eq 0 then group = 3;
    else
    if ivh eq 1 and probe eq 1 and caffeine eq 1 then group = 4;
    else
    if ivh eq 0 and probe eq 1 and caffeine eq 1 then group = 5;
    else
    if ivh eq 0 and probe eq 0 and caffeine eq 0 then group = 6;
    else
    if ivh eq 0 and probe eq 1 and caffeine eq 0 then group = 7;
    else
    if ivh eq 0 and probe eq 0 and caffeine eq 1 then group = 8;

proc means data=of2;
class group pa;
var pred;

proc means data=of;
class probe pa;
var pred;
title1' means by pa and probe for all data collections- NO IVH taken into account';
title2' march 30 2012';
run;

proc means data=of;
class pa;
var pred;
title1' sct02 means by pa for all data collections- NO IVH taken into account';
title2' march 23 2012';
run;

```

```

proc gplot data=of2;

    symbol1 color = blue;
    symbol2 color = red;
    symbol3 color = green;
    symbol4 color = orange;
    axis1 label=none;
    axis2 label=none;
    *label abdtp = 'abdtp';
    plot pred*pa = group;

= 20 to 80 by 5;

    title1'predicted scto2 by age';
    title1' for ivh and probe group ';
        title4 'march 23 2012';

run;
ods rtf close;

```

* / vaxis

Appendix C Chapter 3 SAS Ouput: First Week Analysis of IVH vs. No IVH

1st Week analysis-IVH vs No IVH
The MEANS Procedure

Variable	Label	N	Mean	Std Dev	Minimum	Maximum
<i>.....</i>						
Caffeine	Caffeine	1237	0.7817300	0.4132387	0	1.0000000
Probe	Probe	1237	0.3718674	0.4834987	0	1.0000000
IVH	IVH	1237	0.3314470	0.4709238	0	1.0000000
<i>.....</i>						

full model
march 26 2012

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The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
IVH	2	0 1

Dimensions

Covariance Parameters	4
Columns in X	22
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	60

Number of Observations	
Number of Observations Read	1237
Number of Observations Used	1213

full model
march 26 2012

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The Mixed Procedure

Number of Observations

Number of Observations Not Used	24
---------------------------------	----

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	7789.70144623	
1	2	6121.10652480	0.02195283
2	1	6063.63569779	0.01530204

3	1	6024.28330172	0.01020591
4	1	5998.46309147	0.00632759
5	1	5982.69138383	0.00357538
6	1	5973.90714387	0.00177174
7	1	5969.64211036	0.00068891
8	1	5968.04204533	0.00016546
9	1	5967.68134480	0.00001445
10	1	5967.65248648	0.00000014
11	1	5967.65221259	0.00000000

Convergence criteria met.

4

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	56.9924
minute	Infant	0.01869
PA	Infant	2.8445
Residual		6.3731

full model
march 26 2012

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The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood 5967.7
AIC (smaller is better) 5975.7
AICC (smaller is better) 5975.7
BIC (smaller is better) 5980.4

Solution for Fixed Effects

Effect			Standard		Error	DF	t Value	Pr > |t|
	Caffeine	Probe	IVH	Estimate				
Intercept			121.40	21.2498	22	5.71	<.0001	
PA			-3.2174	0.8966	19	-3.59	0.0020	
pa2			0.1996	0.06811	1135	2.93	0.0034	
Caffeine 0			-2.3529	1.2736	1135	-1.85	0.0649	
Caffeine 1			0	.	.	.	.
Probe 0			-15.1807	1.3717	1135	-11.07	<.0001	
Probe 1			0	.	.	.	.
IVH 0			-1.2226	3.4943	1135	-0.35	0.7265	
IVH 1			0	.	.	.	.
PA*Caffeine 0			5.2707	0.6652	1135	7.92	<.0001	
PA*Caffeine 1			0	.	.	.	.
pa2*Caffeine 0			-1.0491	0.1013	1135	-10.35	<.0001	
pa2*Caffeine 1			0	.	.	.	.
PA*Probe 0			5.9935	0.7968	1135	7.52	<.0001	
PA*Probe 1			0	.	.	.	.
pa2*Probe 0			-0.4371	0.1015	1135	-4.31	<.0001	
pa2*Probe 1			0	.	.	.	.
PA*IVH 0			-0.1212	0.9119	1135	-0.13	0.8943	
PA*IVH 1			0	.	.	.	.
pa2*IVH 0			0.1110	0.06505	1135	1.71	0.0882	
pa2*IVH 1			0	
GA			-1.1815	0.7360	1135	-1.61	0.1087	

full model
march 26 2012

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The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	19	21.53	0.0002
pa2	1	1135	84.31	<.0001
Caffeine	1	1135	3.41	0.0649
Probe	1	1135	122.49	<.0001
IVH	1	1135	0.12	0.7265
PA*Caffeine	1	1135	62.78	<.0001
pa2*Caffeine	1	1135	107.22	<.0001
PA*Probe	1	1135	56.58	<.0001
pa2*Probe	1	1135	18.56	<.0001
PA*IVH	1	1135	0.02	0.8943
pa2*IVH	1	1135	2.91	0.0882
GA	1	1135	2.58	0.1087

Reduced model 1
march 26 2012

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The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
IVH	2	0 1

Dimensions

Covariance Parameters	4
Columns in X	21
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	60

Number of Observations

Number of Observations Read	1237
Number of Observations Used	1213

Reduced model 1
march 26 2012

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The Mixed Procedure

Number of Observations

Number of Observations Not Used 24

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	7795.57844595	
1	2	6141.68354990	0.02386399
2	1	6078.90915177	0.01668746
3	1	6035.81335006	0.01125672
4	1	6007.21680383	0.00711284
5	1	5989.41808309	0.00412064
6	1	5979.25078041	0.00212359
7	1	5974.10549770	0.00088928
8	1	5972.01689212	0.00024803
9	1	5971.46586350	0.00002980
10	1	5971.40505197	0.00000059
11	1	5971.40392805	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	61.0771
minute	Infant	0.01849
PA	Infant	2.8217
Residual		6.3757

Reduced model 1
march 26 2012

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The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood 5971.4
AIC (smaller is better) 5979.4
AICC (smaller is better) 5979.4
BIC (smaller is better) 5984.1

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard		Error	DF	t Value	Pr > |t|
			IVH	Estimate				
Intercept			87.6381	3.1867	22	27.50	<.0001	
PA			-3.3271	0.8932	19	-3.72	0.0014	
pa2			0.2068	0.06802	1136	3.04	0.0024	
Caffeine	0		-2.5261	1.2689	1136	-1.99	0.0467	
Caffeine	1		0	.	.	.	.
Probe		0	-15.2607	1.3723	1136	-11.12	<.0001	
Probe		1	0	.	.	.	.
IVH		0	-1.2689	3.6053	1136	-0.35	0.7249	
IVH		1	0	.	.	.	.
PA*Caffeine	0		5.2818	0.6654	1136	7.94	<.0001	
PA*Caffeine	1		0	.	.	.	.
pa2*Caffeine	0		-1.0412	0.1013	1136	-10.28	<.0001	
pa2*Caffeine	1		0	.	.	.	.
PA*Probe		0	6.0105	0.7973	1136	7.54	<.0001	
PA*Probe		1	0	.	.	.	.
pa2*Probe		0	-0.4370	0.1015	1136	-4.30	<.0001	
pa2*Probe		1	0	.	.	.	.
PA*IVH		0	-0.06574	0.9094	1136	-0.07	0.9424	
PA*IVH		1	0	.	.	.	.
pa2*IVH		0	0.1045	0.06494	1136	1.61	0.1079	
pa2*IVH		1	0	.	.	.	.

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	19	20.49	0.0002
pa2	1	1136	82.23	<.0001
Caffeine	1	1136	3.96	0.0467
Probe	1	1136	123.66	<.0001
IVH	1	1136	0.12	0.7249
PA*Caffeine	1	1136	63.01	<.0001
pa2*Caffeine	1	1136	105.74	<.0001
PA*Probe	1	1136	56.83	<.0001
pa2*Probe	1	1136	18.53	<.0001
PA*IVH	1	1136	0.01	0.9424
pa2*IVH	1	1136	2.59	0.1079

Reduced Model 2
march 26 2012

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The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
IVH	2	0 1

Dimensions

Covariance Parameters	4
Columns in X	19
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	60

Number of Observations

Number of Observations Read	1237
Number of Observations Used	1213

Reduced Model 2
march 26 2012

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The Mixed Procedure

Number of Observations

Number of Observations Not Used 24

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	7810.50928532	
1	2	6123.25247162	0.02259184
2	1	6064.20201465	0.01553227
3	1	6024.36405293	0.01014214
4	1	5998.79605671	0.00609498
5	1	5983.67582072	0.00329655
6	1	5975.62146796	0.00155207
7	1	5971.90697249	0.00056502
8	1	5970.60623975	0.00011990
9	1	5970.34859601	0.00000805
10	1	5970.33273933	0.00000005
11	1	5970.33265214	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	60.3599
minute	Infant	0.01846
PA	Infant	2.6728
Residual		6.3919

The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood	5970.3
AIC (smaller is better)	5978.3
AICC (smaller is better)	5978.4
BIC (smaller is better)	5983.0

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard		Error	DF	t Value	Pr > |t|
			IVH	Estimate				
Intercept			88.6898	3.0991	22	28.62	<.0001	
PA			-3.8291	0.8232	19	-4.65	0.0002	
pa2			0.2539	0.06119	1137	4.15	<.0001	
Caffeine	0		-2.7875	1.2586	1137	-2.21	0.0270	
Caffeine	1		0	.	.	.	.
Probe		0	-15.4470	1.3667	1137	-11.30	<.0001	
Probe		1	0	.	.	.	.
IVH		0	-2.4143	3.5104	1137	-0.69	0.4917	
IVH		1	0	.	.	.	.
PA*Caffeine	0		5.3045	0.6656	1137	7.97	<.0001	
PA*Caffeine	1		0	.	.	.	.
pa2*Caffeine	0		-0.9983	0.09824	1137	-10.16	<.0001	
pa2*Caffeine	1		0	.	.	.	.
PA*Probe		0	5.8819	0.7943	1137	7.41	<.0001	
PA*Probe		1	0	.	.	.	.
pa2*Probe		0	-0.3977	0.09871	1137	-4.03	<.0001	
pa2*Probe		1	0	.	.	.	.
PA*IVH		0	0.7032	0.7515	1137	0.94	0.3496	
PA*IVH		1	0	.	.	.	.

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	19	18.88	0.0003
pa2	1	1137	84.18	<.0001
Caffeine	1	1137	4.90	0.0270
Probe	1	1137	127.73	<.0001
IVH	1	1137	0.47	0.4917
PA*Caffeine	1	1137	63.52	<.0001
pa2*Caffeine	1	1137	103.25	<.0001
PA*Probe	1	1137	54.84	<.0001
pa2*Probe	1	1137	16.23	<.0001
PA*IVH	1	1137	0.88	0.3496

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
IVH	2	0 1

Dimensions

Covariance Parameters	4
Columns in X	17
Columns in Z Per Subject	3
Subjects	24
Max Obs Per Subject	60

Number of Observations

Number of Observations Read	1237
Number of Observations Used	1213

The Mixed Procedure

Number of Observations

Number of Observations Not Used 24

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	7808.96026174	
1	2	6125.57674781	0.02253585
2	1	6066.66835245	0.01550073
3	1	6026.88940021	0.01017250
4	1	6001.22416601	0.00615380
5	1	5985.94902758	0.00334047
6	1	5977.78703755	0.00156928
7	1	5974.03366816	0.00056559
8	1	5972.73362948	0.00011712
9	1	5972.48265191	0.00000744
10	1	5972.46802937	0.00000004
11	1	5972.46795775	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	60.7464
minute	Infant	0.01846
PA	Infant	2.6012
Residual		6.3935

The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood	5972.5
AIC (smaller is better)	5980.5
AICC (smaller is better)	5980.5
BIC (smaller is better)	5985.2

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard		DF	t Value	Pr > |t|
			IVH	Estimate			
Intercept			88.3963	3.0912	22	28.60	<.0001
PA			-3.3176	0.6150	20	-5.39	<.0001
pa2			0.2465	0.06071	1137	4.06	<.0001
Caffeine	0		-2.7994	1.2583	1137	-2.22	0.0263
Caffeine	1		0	.	.	.	.
PA*Caffeine	0		5.3199	0.6651	1137	8.00	<.0001
PA*Caffeine	1		0	.	.	.	.
pa2*Caffeine	0		-0.9933	0.09811	1137	-10.12	<.0001
pa2*Caffeine	1		0	.	.	.	.
Probe		0	-15.2994	1.3582	1137	-11.26	<.0001
Probe		1	0	.	.	.	.
PA*Probe		0	5.7887	0.7884	1137	7.34	<.0001
PA*Probe		1	0	.	.	.	.
pa2*Probe		0	-0.3854	0.09786	1137	-3.94	<.0001
pa2*Probe		1	0	.	.	.	.
IVH		0	-2.1275	3.5072	1137	-0.61	0.5442
IVH		1	0	.	.	.	.

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	20	23.13	0.0001
pa2	1	1137	83.91	<.0001
Caffeine	1	1137	4.95	0.0263
PA*Caffeine	1	1137	63.98	<.0001
pa2*Caffeine	1	1137	102.51	<.0001
Probe	1	1137	126.88	<.0001
PA*Probe	1	1137	53.91	<.0001
pa2*Probe	1	1137	15.51	<.0001
IVH	1	1137	0.37	0.5442

```
*****  
*****  
**Analysis looking at those with and without IVH diagnosis for 1st week of life  
*****;
```

```
*libname pos 'S:\SED\Elser-NIRS\Dissertation\Dis_Subject_folders';  
*ods rtf file = 'S:\SED\Elser-NIRS\Dissertation\output\firstweek\mixed_3dc_03262012';
```

```
data prep;  
set final.aggtest;
```

```
*****  
*****delete positions other than position 1*****  
*****Only include first 20 minutes in position 1,*****  
*****make time (postnatal age) quadratic*****  
*****  
if position eq 1;  
if minute le 20;  
if pa le 7;  
pa2 = pa*pa;
```

```
proc sort data=prep out=preps;  
by newid minute;
```

```
proc means data= preps;  
var caffeine probe ivh;  
run;
```

```
*****  
*****calculate means by position and minute*****  
*****  
/*  
proc means data=preps mean std n nmiss min max;  
class pa;  
var meanco;  
Title1' means by post natal age';  
title2'prep for proc mixed chapter 3';
```

```

proc means data=preps mean std n nmiss min max;;
class ga;
var meanco;
Title1' means by gestational age';
title2'prep for proc mixed chapter 3';

```

```

proc means data=preps mean std n nmiss min max;;
class caffeine;
var meanco;
Title1' means by caffeine age';
title2'prep for proc mixed chapter 3';

```

```

proc means data=preps mean std n nmiss min max;
class pa caffeine;
var meanco;
Title1' means by caffeine age';
title2'prep for proc mixed chapter 3';

```

```

proc means data=preps mean std n nmiss min max;
class probe;
var meanco;
Title1' means by caffeine age';
title2'prep for proc mixed chapter 3';

```

```

proc means data=preps mean std n nmiss min max;
class probe pa;
var meanco;
Title1' means by caffeine age';
title2'prep for proc mixed chapter 3';

```

```

proc means data=preps mean std n nmiss min max;
class ivh;
var meanco;
Title1' means by caffeine age';
title2'prep for proc mixed chapter 3';

```

```

proc means data=preps mean std n nmiss min max;
class ivh probe;
var meanco;
Title1' means by caffeine age';
title2'prep for proc mixed chapter 3';
*/

```

```

*****
*****perform the proc mixed*****
*****

```

```

proc mixed data=preps;
class caffeine probe infant ivh;
model meanco = pa pa2 caffeine probe ivh caffeine*pa caffeine*pa2 probe*pa probe*pa2 ivh*pa ivh*pa2 ga
/ s ;
random intercept minute pa /subject = infant type = vc;
title1' full model';
title2' march 26 2012';
run;

```

*removed ga for no significance;

```

proc mixed data=preps;
class caffeine probe infant ivh;
model meanco = pa pa2 caffeine probe ivh caffeine*pa caffeine*pa2 probe*pa probe*pa2 ivh*pa ivh*pa2 / s
;

random intercept minute pa /subject = infant type = vc;
title1' Reduced model 1';
title2' march 26 2012';
run;

```

*removed ivh*pa2 for no significance;

```

proc mixed data=preps;
class caffeine probe infant ivh;
model meanco = pa pa2 caffeine probe ivh caffeine*pa caffeine*pa2 probe*pa probe*pa2 ivh*pa / s ;
random intercept minute pa /subject = infant type = vc;
title1' Reduced Model 2';
title2' march 26 2012';
run;

```

```

proc mixed data=preps;
class caffeine probe infant ivh;
model meanco = pa pa2 caffeine caffeine*pa caffeine*pa2 probe probe*pa probe*pa2 ivh/ outpred = of s ;
random intercept minute pa /subject = infant type = vc;
title1' 1st Week analysis-IVH vs No IVH';
title2' Final Model';
title2' march 26 2012';
run;

```

*When looking at probe=0, probe=1 holding caffeine and ivh constant;

```

/*
proc sql;
select mean(caffeine) into: mcaffeine from preps;
select mean(ivh) into: mivh from preps;
quit;

```

```

data toscore;
do probe = 0 to 1;
caffeine = &mcaffeine;
ivh= &mivh;
output;
end;
run;

```

```

proc print data= toscore;
run;

```

```

proc mixed data=toscore;
score clm data = toscore out=pred;
run;

```

```

proc mixed data=preps;
class caffeine probe infant ivh;
model meanco = pa pa2 caffeine probe ivh caffeine*pa caffeine*pa2 probe*pa probe*pa2 / outp = of s ;
random intercept minute pa /subject = infant type = vc;
title1' 1st Week analysis-IVH vs No IVH';
title2' Final Model';
title2' march 26 2012';
run;

```

```

proc print data=of;

```

```

run;

/*
*****
*****plot predicted means across time*****
*****by each covariate*****
*****
proc means data=of;
class caffeine pa;
var pred;
title1' predicted means by caffeine and time';
title2' march 26 2012';

proc means data=of;
class probe pa;
var pred;
title1' predicted means by ivh and time';
title2' march 26 2012';
*****
*****plot predicted values over age*****
*****separately by caffeine grouping*****
*****

proc gplot data=of;

symbol1 color = blue;
symbol2 color = red;
symbol3 color = green;
symbol4 color = orange;
axis1 label=none;
axis2 label=none;
*label abdtpr = 'abdtpr';
plot pred*pa = caffeine;

= 20 to 80 by 5;

title1'predicted scto2 by age';
title1' for those on and off caffeine ';
title4 'march 26 2012';

*****
*****plot predicted values over age*****
*****separately by probe*****
*****

proc gplot data=of;

symbol1 color = blue;
symbol2 color = red;
symbol3 color = green;
symbol4 color = orange;
axis1 label=none;
axis2 label=none;
*label abdtpr = 'abdtpr';
plot pred*pa = probe;
* / vaxis = 20 to 80 by 5;

title1'predicted scto2 by age';
title1' by probe';

```

```
title4 'march 26 2012';
```

```
run;
```

```
;
```

Appendix D Chapter 3 SAS Output: All Data Collections for IVH vs. No IVH

means by postnatal age 16:39 Monday, April 2, 2012 2:56
 prep for proc mixed chapter 3 All Data Collections-IVH Included

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
1	300	78.4660193	7.3315556	260	40	63.3000000	97.0000000
2	178	78.7593496	4.3308611	178	0	68.9122807	87.1000000
3	252	77.6041259	6.5952456	252	0	60.0333333	93.2500000
4	139	77.5171012	7.2798801	137	2	65.8666667	94.0000000
5	53	84.6426134	5.1809500	53	0	71.7826087	95.4166667
6	20	64.2833333	4.5182735	20	0	52.0333333	69.8333333
7	315	76.0676766	4.6367663	313	2	62.0000000	85.5000000
9	31	86.8764734	6.9032820	30	1	75.8666667	98.5454545
12	40	73.7354167	7.9461786	40	0	54.0833333	82.9833333
14	216	73.3254774	6.2677448	213	3	58.0000000	94.8000000
17	20	74.8250000	4.1715673	20	0	68.0000000	83.5000000
19	20	74.7343503	2.3557920	20	0	69.7000000	79.4000000
21	173	72.9843906	5.8632933	171	2	55.6666667	87.2166667
22	20	79.5847436	3.2239187	20	0	72.8000000	84.1666667
23	20	70.6433333	2.1843168	20	0	67.1000000	75.1333333
27	20	74.0466667	2.5568827	20	0	69.6833333	78.7500000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

GA	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
25.5	526	70.0014324	12.4109458	523	3	24.5666667	98.0000000
26.2	563	66.7902043	9.8672383	561	2	37.5000000	92.7166667
26.5	171	71.0295536	6.5262799	167	4	52.0000000	85.5000000
27	20	94.1500000	2.0969903	20	0	89.5000000	97.0000000
28	178	75.7327586	3.7573229	174	4	65.0000000	87.0000000
28.6	241	74.2440520	7.2461375	239	2	60.0333333	98.5454545
29.2	200	78.2712377	5.3539969	200	0	61.7500000	93.6333333
29.3	60	73.0586505	2.1926456	60	0	68.9122807	78.2166667
29.6	40	81.2269746	1.4474081	40	0	77.4333333	83.6333333
30	51	83.6340132	3.7946081	51	0	75.8666667	95.4166667
30.4	93	77.2831047	7.4544604	93	0	54.0833333	90.1833333
30.6	87	75.2925490	4.4741183	85	2	62.0000000	84.0000000
31	100	81.0997733	3.5550808	100	0	72.8000000	92.4666667
31.3	120	69.5000000	6.0269350	80	40	52.0333333	80.3000000
31.6	233	77.1953513	3.1209488	228	5	70.3166667	94.8000000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Caffeine	N Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum	
	0	705	71.6986760	10.1086785	704	1	24.5666667	92.4666667
	1	1978	73.3859378	9.3906086	1917	61	25.3783784	98.5454545

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	Caffeine	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
	0	120	74.9381615	4.9741978	120	0	63.3000000	84.0000000
	1	180	81.4898975	7.6824038	140	40	65.5000000	97.0000000
2	0	58	79.3559727	1.6933324	58	0	74.1666667	82.2666667
	1	120	78.4709818	5.1251650	120	0	68.9122807	87.1000000
3	0	52	84.2852564	4.7098569	52	0	75.0000000	92.4666667
	1	200	75.8670319	5.8721057	200	0	60.0333333	93.2500000
4	1	139	77.5171012	7.2798801	137	2	65.8666667	94.0000000
5	1	53	84.6426134	5.1809500	53	0	71.7826087	95.4166667
6	1	20	64.2833333	4.5182735	20	0	52.0333333	69.8333333
7	0	40	78.5328341	1.6585451	40	0	75.7000000	83.6333333
	1	275	75.7064814	4.8210245	273	2	62.0000000	85.5000000
9	1	31	86.8764734	6.9032820	30	1	75.8666667	98.5454545
12	1	40	73.7354167	7.9461786	40	0	54.0833333	82.9833333
14	1	216	73.3254774	6.2677448	213	3	58.0000000	94.8000000
17	1	20	74.8250000	4.1715673	20	0	68.0000000	83.5000000
19	1	20	74.7343503	2.3557920	20	0	69.7000000	79.4000000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	Caffeine	N Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
21	1	173	72.9843906	5.8632933	171	2	55.6666667	87.2166667
22	0	20	79.5847436	3.2239187	20	0	72.8000000	84.1666667
23	0	20	70.6433333	2.1843168	20	0	67.1000000	75.1333333
27	1	20	74.0466667	2.5568827	20	0	69.6833333	78.7500000
28	0	12	66.1735225	2.9107648	12	0	60.1489362	69.3333333
	1	132	67.3768182	7.7935968	130	2	52.0000000	84.5666667
33	0	20	76.0040113	2.8032699	20	0	67.2166667	78.2666667
35	0	20	72.5404520	1.3909879	20	0	70.1333333	75.0833333
	1	109	68.0958383	7.5036190	107	2	44.7777778	85.5000000
36	0	16	68.4342803	2.9185626	16	0	62.1000000	71.5333333
42	0	40	69.1137500	3.1353419	40	0	63.3000000	75.0000000
	1	110	62.7844607	8.6116267	107	3	37.9166667	98.0000000
48	0	20	78.2309206	4.6889325	20	0	61.7500000	82.9500000
49	0	40	64.7948718	11.6640010	39	1	40.0000000	81.5000000
	1	80	55.4525001	13.5219480	76	4	25.3783784	82.8333333
56	0	67	61.6076435	11.5106157	67	0	24.5666667	78.4333333

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

PA	Caffeine	N Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
<i>ff</i>								
56	1	40	62.9709605	6.6312987	40	0	52.6666667	76.1666667
61	0	20	76.5183333	2.4009373	20	0	71.9333333	80.1333333
63	0	40	71.7500000	10.6029749	40	0	54.0000000	87.0000000
64	0	20	46.4750000	6.2037234	20	0	37.5000000	67.5000000
68	0	20	73.4633333	3.3976755	20	0	69.2000000	80.5666667
70	0	40	60.3875000	3.1041071	40	0	53.0000000	64.7000000
77	0	20	64.6750000	2.7780862	20	0	57.5000000	69.0000000
<i>ff</i>								

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Probe	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum	
	0	1732	72.1967863	10.4293224	1692	40	24.5666667	98.5454545
	1	951	74.2731413	7.7504808	929	22	37.5000000	92.7166667

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Probe	N PA	Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
0	1	180	76.5798333	8.2198836	160	20	63.3000000	97.0000000
2	118	78.7696946	4.5538672	118	0	68.9122807	86.5666667	
3	152	76.9903985	7.1717717	152	0	60.0333333	93.2500000	
4	99	78.2368385	8.5046239	97	2	65.8666667	94.0000000	
5	53	84.6426134	5.1809500	53	0	71.7826087	95.4166667	
6	20	64.2833333	4.5182735	20	0	52.0333333	69.8333333	
7	175	76.9107021	3.5358641	173	2	62.0000000	85.5000000	
9	31	86.8764734	6.9032820	30	1	75.8666667	98.5454545	
12	20	66.6691667	4.6567761	20	0	54.0833333	71.3000000	
14	156	73.2721411	5.8721339	153	3	58.0000000	94.8000000	
17	20	74.8250000	4.1715673	20	0	68.0000000	83.5000000	
21	93	71.7376606	7.0048709	91	2	55.6666667	87.2166667	
22	20	79.5847436	3.2239187	20	0	72.8000000	84.1666667	
28	101	68.3708637	8.5114550	100	1	52.0000000	84.5666667	
35	89	66.5648267	7.4875611	87	2	44.7777778	85.5000000	
42	118	63.7542008	8.7105444	116	2	37.9166667	98.0000000	

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Probe	N PA	Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
<i>ff</i>								
0	49	120	58.6207827	13.6152116	115	5	25.3783784	82.8333333
	56	87	58.8628414	8.0318889	87	0	24.5666667	76.1666667
	63	40	71.7500000	10.6029749	40	0	54.0000000	87.0000000
	68	20	73.4633333	3.3976755	20	0	69.2000000	80.5666667
	70	20	62.4250000	0.9904146	20	0	61.0000000	64.5000000
1	1	120	81.4839170	4.1421933	100	20	76.5000000	92.7166667
	2	60	78.7390046	3.8915951	60	0	69.9666667	87.1000000
	3	100	78.5369915	5.5111972	100	0	69.2372881	90.1833333
	4	40	75.7717384	1.5350358	40	0	72.0166667	77.9666667
	7	140	75.0259380	5.5506780	140	0	62.2500000	83.8833333
	12	20	80.8016667	1.6737472	20	0	77.3500000	82.9833333
	14	60	73.4614849	7.2316840	60	0	64.3333333	89.4000000
	19	20	74.7343503	2.3557920	20	0	69.7000000	79.4000000
	21	80	74.4025459	3.7750318	80	0	58.0000000	81.0833333
	23	20	70.6433333	2.1843168	20	0	67.1000000	75.1333333
	27	20	74.0466667	2.5568827	20	0	69.6833333	78.7500000
<i>ff</i>								

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

Probe	N PA	Obs	Mean	N Std Dev	N	Miss	Minimum	Maximum
1	28	43	64.6662445	2.9902906	42	1	54.5000000	69.3333333
	33	20	76.0040113	2.8032699	20	0	67.2166667	78.2666667
	35	40	73.6480952	1.9055407	40	0	70.7666667	78.3000000
	36	16	68.4342803	2.9185626	16	0	62.1000000	71.5333333
	42	32	67.3225806	3.5297507	31	1	61.5000000	73.5000000
	48	20	78.2309206	4.6889325	20	0	61.7500000	82.9500000
	56	20	76.2741667	1.2226119	20	0	72.9500000	78.4333333
	61	20	76.5183333	2.4009373	20	0	71.9333333	80.1333333
	64	20	46.4750000	6.2037234	20	0	37.5000000	67.5000000
	70	20	58.3500000	3.1713354	20	0	53.0000000	64.7000000
	77	20	64.6750000	2.7780862	20	0	57.5000000	69.0000000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N		N				
IVH	Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
	0	72.7725037	9.3298156	1701	56	37.5000000	98.5454545
	1	73.2290020	10.1222195	920	6	24.5666667	98.0000000

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

IVH	N PA	Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
0	1	240	79.3622085	7.6979124	200	40	65.5000000	97.0000000
	2	100	77.6856253	4.8455335	100	0	68.9122807	86.5666667
	3	212	76.6525458	6.5769154	212	0	60.0333333	93.2500000
	4	60	79.2852778	10.2365764	60	0	65.8666667	94.0000000
	5	20	84.4337952	2.8768170	20	0	82.1833333	95.4166667
	6	20	64.2833333	4.5182735	20	0	52.0333333	69.8333333
	7	195	76.8238888	4.2375442	193	2	62.0000000	85.5000000
	9	31	86.8764734	6.9032820	30	1	75.8666667	98.5454545
	14	119	70.7630991	5.9741766	117	2	58.0000000	94.8000000
	17	20	74.8250000	4.1715673	20	0	68.0000000	83.5000000
	21	120	73.6283683	4.1701245	118	2	58.0000000	81.0833333
	23	20	70.6433333	2.1843168	20	0	67.1000000	75.1333333
	28	116	67.8836431	8.0922541	114	2	52.0000000	84.5666667
	35	109	67.9963900	7.4417237	107	2	44.7777778	85.5000000
	36	16	68.4342803	2.9185626	16	0	62.1000000	71.5333333
	42	112	67.0684940	5.0818460	111	1	49.3320000	88.8833333

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

IVH	PA	N Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
0	49	80	64.3011243	11.5073963	76	4	40.0000000	82.8333333
	56	47	61.7837961	7.1914870	47	0	40.0000000	76.1666667
	63	40	71.7500000	10.6029749	40	0	54.0000000	87.0000000
	64	20	46.4750000	6.2037234	20	0	37.5000000	67.5000000
	70	40	60.3875000	3.1041071	40	0	53.0000000	64.7000000
	77	20	64.6750000	2.7780862	20	0	57.5000000	69.0000000
	1	1	60	75.4787222	4.9288351	60	0	63.3000000	82.2500000
2		78	80.1359193	3.0839782	78	0	74.1333333	87.1000000
3		40	82.6475000	3.8611948	40	0	76.0333333	92.4666667
4		79	76.1393013	3.0160191	77	2	70.3166667	83.8666667
5		33	84.7691700	6.2177934	33	0	71.7826087	93.6333333
7		120	74.8514354	4.9977273	120	0	62.2500000	82.9661017
12		40	73.7354167	7.9461786	40	0	54.0833333	82.9833333
14		97	76.4483759	5.1132162	96	1	62.5333333	89.4000000
19		20	74.7343503	2.3557920	20	0	69.7000000	79.4000000
21		53	71.5506289	8.3801352	53	0	55.6666667	87.2166667

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

IVH	N PA	Obs	Mean	Std Dev	N	Miss	Minimum	Maximum
1	22	20	79.5847436	3.2239187	20	0	72.8000000	84.1666667
	27	20	74.0466667	2.5568827	20	0	69.6833333	78.7500000
	28	28	64.7976190	3.4999928	28	0	57.7000000	75.4000000
	33	20	76.0040113	2.8032699	20	0	67.2166667	78.2666667
	35	20	73.0725000	1.3279857	20	0	70.7666667	75.9333333
	42	38	56.6079018	10.1353878	36	2	37.9166667	98.0000000
	48	20	78.2309206	4.6889325	20	0	61.7500000	82.9500000
	49	40	47.5513991	10.2214501	39	1	25.3783784	61.9333333
	56	60	62.3785352	11.7298973	60	0	24.5666667	78.4333333
	61	20	76.5183333	2.4009373	20	0	71.9333333	80.1333333
	68	20	73.4633333	3.3976755	20	0	69.2000000	80.5666667

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 271
time variable is pa
covariates are ga, caffeine, probe, & ivh with interactions
All Data Collections March 30 2012

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containmentment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
IVH	2	0 1
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26

Dimensions

Covariance Parameters	4
Columns in X	29
Columns in Z Per Subject	3
Subjects	25
Max Obs Per Subject	231

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 272
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covariates are ga, caffeine, probe, & ivh with interactions
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The Mixed Procedure

Number of Observations

Number of Observations Read	2683
Number of Observations Used	2621
Number of Observations Not Used	62

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18031.68110684	
1	2	16431.97356886	0.00077035
2	1	16426.28569689	0.00027497
3	1	16424.32871694	0.00005916
4	1	16423.93388754	0.00000431
5	1	16423.90745708	0.00000003
6	1	16423.90727391	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
minute	Infant	0.007824
Intercept	Infant	33.2846
PA	Infant	0.07941
Residual		27.2787

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The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood 16423.9
AIC (smaller is better) 16431.9
AICC (smaller is better) 16431.9
BIC (smaller is better) 16436.8

Solution for Fixed Effects

Effect	Caffeine	Probe	IVH	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept				89.9924	16.1270	22	5.58	<.0001
PA				-0.7989	0.1519	20	-5.26	<.0001
pa2				0.01144	0.004903	2538	2.33	0.0198
pa3				-0.00007	0.000057	2538	-1.14	0.2526
Caffeine	0			0.7704	0.8209	2538	0.94	0.3480
Caffeine	1			0	.	.	.	.
PA*Caffeine	0			-0.02318	0.1429	2538	-0.16	0.8712
PA*Caffeine	1			0	.	.	.	.
pa2*Caffeine	0			0.001423	0.005196	2538	0.27	0.7842
pa2*Caffeine	1			0	.	.	.	.
pa3*Caffeine	0			-0.00001	0.000054	2538	-0.23	0.8166
pa3*Caffeine	1			0	.	.	.	.
Probe		0		-4.8084	0.5915	2538	-8.13	<.0001
Probe		1		0	.	.	.	.
PA*Probe		0		1.1929	0.1051	2538	11.35	<.0001
PA*Probe		1		0	.	.	.	.
pa2*Probe		0		-0.04925	0.004012	2538	-12.28	<.0001
pa2*Probe		1		0	.	.	.	.
pa3*Probe		0		0.000477	0.000039	2538	12.20	<.0001
pa3*Probe		1		0
IVH			0	0.4228	2.5795	2538	0.16	0.8698
IVH			1	0

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The Mixed Procedure

Solution for Fixed Effects

Effect	Caffeine	Probe	IVH	Standard		DF	t Value	Pr > t
				Estimate	Error			
PA*IVH		0	-0.1162	0.1651	2538	-0.70	0.4816	
PA*IVH		1	0	.	.	.	.
pa2*IVH		0	0.01165	0.004470	2538	2.61	0.0092	
pa2*IVH		1	0	.	.	.	.
pa3*IVH		0	-0.00011	0.000048	2538	-2.19	0.0285	
pa3*IVH		1	0	.	.	.	.
GA			-0.2879	0.5550	2538	-0.52	0.6040	

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > |t|
		Estimate	Pred			
minute	1	-0.03128	0.05169	2538	-0.61	0.5450
Intercept	1	7.1499	2.4337	2538	2.94	0.0033
PA	1	-0.1676	0.09150	2538	-1.83	0.0671
minute	2	0.06853	0.05369	2538	1.28	0.2020
Intercept	2	-4.6546	2.8541	2538	-1.63	0.1031
PA	2	-0.02706	0.1098	2538	-0.25	0.8054
minute	3	-0.04008	0.05726	2538	-0.70	0.4840
Intercept	3	-0.03433	2.8582	2538	-0.01	0.9904
PA	3	0.01422	0.1093	2538	0.13	0.8965
minute	4	-0.00860	0.07004	2538	-0.12	0.9022
Intercept	4	2.0691	2.0790	2538	1.00	0.3197
PA	4	0.01992	0.2045	2538	0.10	0.9224
minute	5	-0.09684	0.05891	2538	-1.64	0.1003
Intercept	5	-5.3195	1.7154	2538	-3.10	0.0019
PA	5	0.2121	0.09163	2538	2.31	0.0207
minute	6	-0.02349	0.04938	2538	-0.48	0.6343

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The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > t
		Estimate	Pred			
Intercept	6	-1.2025	2.1588	2538	-0.56	0.5776
PA	6	-0.1241	0.09044	2538	-1.37	0.1702
minute	7	0.01176	0.06624	2538	0.18	0.8591
Intercept	7	-0.2697	2.7625	2538	-0.10	0.9222
PA	7	0.01614	0.1481	2538	0.11	0.9132
minute	8	0.007354	0.07018	2538	0.10	0.9166
Intercept	8	-1.4114	2.7499	2538	-0.51	0.6078
PA	8	0.1358	0.1538	2538	0.88	0.3771
minute	9	-0.00576	0.06687	2538	-0.09	0.9313
Intercept	9	0.9196	2.3851	2538	0.39	0.6999
PA	9	0.08924	0.1383	2538	0.65	0.5189
minute	10	-0.02579	0.07003	2538	-0.37	0.7127
Intercept	10	-6.3365	1.9250	2538	-3.29	0.0010
PA	10	0.3547	0.2120	2538	1.67	0.0944
minute	11	-0.08632	0.05048	2538	-1.71	0.0874
Intercept	11	-3.8265	2.1619	2538	-1.77	0.0768
PA	11	-0.2063	0.09114	2538	-2.26	0.0237
minute	12	-0.07398	0.05423	2538	-1.36	0.1726
Intercept	12	-3.7512	1.7631	2538	-2.13	0.0335
PA	12	0.2606	0.09146	2538	2.85	0.0044
minute	13	0.05619	0.05505	2538	1.02	0.3075
Intercept	13	-6.0825	2.0860	2538	-2.92	0.0036
PA	13	0.1243	0.09223	2538	1.35	0.1777
minute	14	-0.01628	0.08031	2538	-0.20	0.8393
Intercept	14	15.5608	2.2079	2538	7.05	<.0001
PA	14	0.03713	0.2815	2538	0.13	0.8951
minute	15	-0.05359	0.06368	2538	-0.84	0.4002
Intercept	15	2.0621	1.7470	2538	1.18	0.2380
PA	15	-0.1413	0.09631	2538	-1.47	0.1425
minute	16	0.04201	0.06692	2538	0.63	0.5302

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 276
time variable is pa
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The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > t
		Estimate	Pred			
Intercept	16	-0.2891	2.0447	2538	-0.14	0.8876
PA	16	-0.05321	0.1065	2538	-0.50	0.6173
minute	17	0.01164	0.07463	2538	0.16	0.8761
Intercept	17	1.2608	1.9376	2538	0.65	0.5153
PA	17	0.2360	0.2668	2538	0.88	0.3765
minute	18	-0.01808	0.05168	2538	-0.35	0.7265
Intercept	18	6.2750	2.2420	2538	2.80	0.0052
PA	18	0.1219	0.1094	2538	1.11	0.2653
minute	20	0.1113	0.06295	2538	1.77	0.0771
Intercept	20	2.3835	2.5581	2538	0.93	0.3516
PA	20	0.2422	0.1249	2538	1.94	0.0525
minute	21	0	0.08846	2538	0.00	1.0000
Intercept	21	0	5.7693	2538	0.00	1.0000
PA	21	0	0.2818	2538	0.00	1.0000
minute	22	0.02071	0.08035	2538	0.26	0.7967
Intercept	22	1.1537	2.5576	2538	0.45	0.6520
PA	22	0.01101	0.2774	2538	0.04	0.9683
minute	23	-0.05107	0.06160	2538	-0.83	0.4072
Intercept	23	-4.0064	2.6557	2538	-1.51	0.1315
PA	23	0.1928	0.1108	2538	1.74	0.0821
minute	24	0.1228	0.07296	2538	1.68	0.0924
Intercept	24	6.5138	2.1411	2538	3.04	0.0024
PA	24	-0.3536	0.2150	2538	-1.64	0.1001
minute	25	0.008884	0.07005	2538	0.13	0.8991
Intercept	25	-9.8820	2.3064	2538	-4.28	<.0001
PA	25	-0.2990	0.2224	2538	-1.34	0.1789
minute	26	-0.1298	0.07872	2538	-1.65	0.0993
Intercept	26	1.7179	2.8138	2538	0.61	0.5416
PA	26	-0.6960	0.1973	2538	-3.53	0.0004

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 277
time variable is pa
covariates are ga, caffeine, probe, & ivh with interactions
All Data Collections March 30 2012

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
PA	1	20	7.95	0.0106
pa2	1	2538	4.59	0.0323
pa3	1	2538	1.31	0.2526
Caffeine	1	2538	0.88	0.3480
PA*Caffeine	1	2538	0.03	0.8712
pa2*Caffeine	1	2538	0.08	0.7842
pa3*Caffeine	1	2538	0.05	0.8166
Probe	1	2538	66.07	<.0001
PA*Probe	1	2538	128.83	<.0001
pa2*Probe	1	2538	150.72	<.0001
pa3*Probe	1	2538	148.77	<.0001
IVH	1	2538	0.03	0.8698
PA*IVH	1	2538	0.50	0.4816
pa2*IVH	1	2538	6.79	0.0092
pa3*IVH	1	2538	4.80	0.0285
GA	1	2538	0.27	0.6040

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containmentment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
IVH	2	0 1
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26

Dimensions

Covariance Parameters	4
Columns in X	20
Columns in Z Per Subject	3
Subjects	25
Max Obs Per Subject	231

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Number of Observations

Number of Observations Read	2683
Number of Observations Used	2621
Number of Observations Not Used	62

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18099.85854218	
1	2	16404.21625164	0.00077304
2	1	16398.53058369	0.00027338
3	1	16396.59412225	0.00005722
4	1	16396.21512421	0.00000380
5	1	16396.19208399	0.00000002
6	1	16396.19196201	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
minute	Infant	0.007523
Intercept	Infant	31.7027
PA	Infant	0.08285
Residual		27.3021

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood 16396.2
AIC (smaller is better) 16404.2
AICC (smaller is better) 16404.2
BIC (smaller is better) 16409.1

Solution for Fixed Effects

Effect	Probe	IVH	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept			82.0473	2.1006	22	39.06	<.0001
PA			-0.8590	0.1440	20	-5.96	<.0001
pa2			0.01399	0.003968	2543	3.52	0.0004
pa3			-0.00009	0.000042	2543	-2.09	0.0366
Probe	0		-4.8289	0.5810	2543	-8.31	<.0001
Probe	1		0	.	.	.	.
PA*Probe	0		1.1945	0.1011	2543	11.82	<.0001
PA*Probe	1		0	.	.	.	.
pa2*Probe	0		-0.04962	0.003798	2543	-13.07	<.0001
pa2*Probe	1		0	.	.	.	.
pa3*Probe	0		0.000483	0.000037	2543	13.15	<.0001
pa3*Probe	1		0	.	.	.	.
IVH		0	0.3337	2.5206	2543	0.13	0.8947
IVH		1	0	.	.	.	.
PA*IVH		0	-0.08631	0.1665	2543	-0.52	0.6043
PA*IVH		1	0	.	.	.	.
pa2*IVH		0	0.01020	0.004418	2543	2.31	0.0210
pa2*IVH		1	0	.	.	.	.
pa3*IVH		0	-0.00009	0.000047	2543	-1.91	0.0561
pa3*IVH		1	0	.	.	.	.

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > t
		Estimate	Pred			
minute	1	-0.02971	0.05132	2543	-0.58	0.5627
Intercept	1	8.1030	1.6457	2543	4.92	<.0001
PA	1	-0.1786	0.09085	2543	-1.97	0.0494
minute	2	0.06891	0.05328	2543	1.29	0.1960
Intercept	2	-3.8024	2.1729	2543	-1.75	0.0803
PA	2	-0.02948	0.1113	2543	-0.26	0.7911
minute	3	-0.03785	0.05675	2543	-0.67	0.5048
Intercept	3	0.6462	2.1763	2543	0.30	0.7665
PA	3	0.01864	0.1108	2543	0.17	0.8664
minute	4	-0.00812	0.06915	2543	-0.12	0.9065
Intercept	4	2.1344	1.8277	2543	1.17	0.2430
PA	4	0.02691	0.2021	2543	0.13	0.8941
minute	5	-0.09226	0.05837	2543	-1.58	0.1141
Intercept	5	-5.3752	1.6767	2543	-3.21	0.0014
PA	5	0.2357	0.09246	2543	2.55	0.0109
minute	6	-0.02266	0.04906	2543	-0.46	0.6442
Intercept	6	-0.6362	1.6287	2543	-0.39	0.6961
PA	6	-0.1219	0.08994	2543	-1.36	0.1755
minute	7	0.01006	0.06547	2543	0.15	0.8779
Intercept	7	-1.2529	2.2814	2543	-0.55	0.5829
PA	7	0.03546	0.1490	2543	0.24	0.8119
minute	8	0.005948	0.06928	2543	0.09	0.9316
Intercept	8	-1.9835	2.2934	2543	-0.86	0.3872
PA	8	0.1204	0.1544	2543	0.78	0.4355
minute	9	-0.00578	0.06608	2543	-0.09	0.9303
Intercept	9	0.7473	1.7837	2543	0.42	0.6753
PA	9	0.05579	0.1367	2543	0.41	0.6833
minute	10	-0.02616	0.06915	2543	-0.38	0.7052
Intercept	10	-6.6717	1.8698	2543	-3.57	0.0004
PA	10	0.3698	0.2140	2543	1.73	0.0841

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > t
		Estimate	Pred			
minute	11	-0.08403	0.05015	2543	-1.68	0.0939
Intercept	11	-3.3313	1.6311	2543	-2.04	0.0412
PA	11	-0.1942	0.09036	2543	-2.15	0.0317
minute	12	-0.07281	0.05383	2543	-1.35	0.1763
Intercept	12	-3.7960	1.6809	2543	-2.26	0.0240
PA	12	0.2786	0.09072	2543	3.07	0.0022
minute	13	0.05549	0.05461	2543	1.02	0.3097
Intercept	13	-5.4536	1.6577	2543	-3.29	0.0010
PA	13	0.1170	0.09150	2543	1.28	0.2010
minute	14	-0.01366	0.07896	2543	-0.17	0.8626
Intercept	14	15.7958	1.9680	2543	8.03	<.0001
PA	14	0.04128	0.2875	2543	0.14	0.8858
minute	15	-0.05348	0.06301	2543	-0.85	0.3961
Intercept	15	1.8375	1.7076	2543	1.08	0.2820
PA	15	-0.1075	0.09636	2543	-1.12	0.2645
minute	16	0.04213	0.06612	2543	0.64	0.5240
Intercept	16	-0.4616	1.7476	2543	-0.26	0.7917
PA	16	-0.04974	0.1055	2543	-0.47	0.6374
minute	17	0.01064	0.07356	2543	0.14	0.8850
Intercept	17	0.8337	1.8477	2543	0.45	0.6519
PA	17	0.2471	0.2719	2543	0.91	0.3636
minute	18	-0.01775	0.05133	2543	-0.35	0.7295
Intercept	18	6.0573	2.1823	2543	2.78	0.0055
PA	18	0.1307	0.1112	2543	1.18	0.2400
minute	20	0.1088	0.06230	2543	1.75	0.0810
Intercept	20	2.0476	2.2265	2543	0.92	0.3579
PA	20	0.2549	0.1222	2543	2.08	0.0372
minute	21	0	0.08674	2543	0.00	1.0000
Intercept	21	0	5.6305	2543	0.00	1.0000
PA	21	0	0.2878	2543	0.00	1.0000

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > t
		Estimate	Pred			
minute	22	0.01851	0.07899	2543	0.23	0.8147
Intercept	22	0.3816	2.1940	2543	0.17	0.8619
PA	22	0.003989	0.2827	2543	0.01	0.9887
minute	23	-0.05086	0.06098	2543	-0.83	0.4044
Intercept	23	-3.0033	2.1864	2543	-1.37	0.1697
PA	23	0.1707	0.1122	2543	1.52	0.1283
minute	24	0.1186	0.07196	2543	1.65	0.0996
Intercept	24	6.1059	2.0152	2543	3.03	0.0025
PA	24	-0.3555	0.2171	2543	-1.64	0.1017
minute	25	0.007357	0.06915	2543	0.11	0.9153
Intercept	25	-10.2136	1.8573	2543	-5.50	<.0001
PA	25	-0.3688	0.2188	2543	-1.69	0.0920
minute	26	-0.1251	0.07750	2543	-1.61	0.1067
Intercept	26	1.2909	2.6706	2543	0.48	0.6289
PA	26	-0.7013	0.1991	2543	-3.52	0.0004

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
PA	1	20	13.90	0.0013
pa2	1	2543	8.53	0.0035
pa3	1	2543	4.37	0.0366
Probe	1	2543	69.08	<.0001
PA*Probe	1	2543	139.70	<.0001
pa2*Probe	1	2543	170.71	<.0001
pa3*Probe	1	2543	172.82	<.0001
IVH	1	2543	0.02	0.8947

Dep var is averaged 1 minuted sct02
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections March 30 2012

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The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
PA*IVH	1	2543	0.27	0.6043
pa2*IVH	1	2543	5.33	0.0210
pa3*IVH	1	2543	3.65	0.0561

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 285
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
IVH	2	0 1
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26

Dimensions

Covariance Parameters	3
Columns in X	18
Columns in Z Per Subject	2
Subjects	25
Max Obs Per Subject	231

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 286
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Number of Observations

Number of Observations Read 2683
Number of Observations Used 2621
Number of Observations Not Used 62

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18134.33575416	
1	2	16394.68691798	0.00066532
2	1	16389.77017188	0.00024873
3	1	16388.00657019	0.00005194
4	1	16387.66449298	0.00000312
5	1	16387.64565064	0.00000001
6	1	16387.64557115	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	32.6412
PA	Infant	0.09446
Residual		27.5299

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 287
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Fit Statistics

-2 Res Log Likelihood 16387.6
AIC (smaller is better) 16393.6
AICC (smaller is better) 16393.7
BIC (smaller is better) 16397.3

Solution for Fixed Effects

Effect	Probe	IVH	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept			82.5105	2.1081	22	39.14	<.0001
PA			-0.9729	0.1391	20	-6.99	<.0001
pa2			0.01932	0.002859	2568	6.76	<.0001
pa3			-0.00015	0.000026	2568	-5.66	<.0001
Probe	0		-4.8644	0.5836	2568	-8.34	<.0001
Probe	1		0	.	.	.	.
PA*Probe	0		1.1883	0.1015	2568	11.71	<.0001
PA*Probe	1		0	.	.	.	.
pa2*Probe	0		-0.04915	0.003806	2568	-12.92	<.0001
pa2*Probe	1		0	.	.	.	.
pa3*Probe	0		0.000481	0.000037	2568	13.04	<.0001
pa3*Probe	1		0	.	.	.	.
IVH	0		-0.3671	2.5256	2568	-0.15	0.8845
IVH	1		0	.	.	.	.
PA*IVH	0		0.08320	0.1517	2568	0.55	0.5836
PA*IVH	1		0	.	.	.	.
pa2*IVH	0		0.001946	0.000880	2568	2.21	0.0271
pa2*IVH	1		0	.	.	.	.

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 288
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > |t|
		Estimate	Pred			
Intercept	1	7.7828	1.5798	2568	4.93	<.0001
PA	1	-0.1666	0.09579	2568	-1.74	0.0822
Intercept	2	-2.9274	2.1360	2568	-1.37	0.1706
PA	2	-0.04559	0.1170	2568	-0.39	0.6969
Intercept	3	0.2534	2.1373	2568	0.12	0.9056
PA	3	0.008007	0.1168	2568	0.07	0.9454
Intercept	4	2.2219	1.7241	2568	1.29	0.1976
PA	4	0.01246	0.2095	2568	0.06	0.9526
Intercept	5	-6.2977	1.5919	2568	-3.96	<.0001
PA	5	0.2473	0.09738	2568	2.54	0.0112
Intercept	6	-0.7217	1.5708	2568	-0.46	0.6459
PA	6	-0.1199	0.09510	2568	-1.26	0.2076
Intercept	7	-1.3626	2.2267	2568	-0.61	0.5406
PA	7	0.07080	0.1542	2568	0.46	0.6462
Intercept	8	-2.1254	2.2441	2568	-0.95	0.3437
PA	8	0.1554	0.1598	2568	0.97	0.3309
Intercept	9	0.8342	1.6817	2568	0.50	0.6199
PA	9	0.04375	0.1411	2568	0.31	0.7565
Intercept	10	-6.8872	1.7748	2568	-3.88	0.0001
PA	10	0.3819	0.2225	2568	1.72	0.0863
Intercept	11	-4.2655	1.5664	2568	-2.72	0.0065
PA	11	-0.1777	0.09522	2568	-1.87	0.0621
Intercept	12	-4.4899	1.6101	2568	-2.79	0.0053
PA	12	0.2860	0.09579	2568	2.99	0.0029
Intercept	13	-4.8846	1.5821	2568	-3.09	0.0020
PA	13	0.1311	0.09633	2568	1.36	0.1736
Intercept	14	15.8842	1.8372	2568	8.65	<.0001
PA	14	0.04597	0.3070	2568	0.15	0.8810
Intercept	15	1.2899	1.6019	2568	0.81	0.4208
PA	15	-0.08793	0.1009	2568	-0.87	0.3834

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 289
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > |t|
		Estimate	Pred			
Intercept	16	0.04647	1.6826	2568	0.03	0.9780
PA	16	-0.04923	0.1100	2568	-0.45	0.6545
Intercept	17	1.0526	1.7306	2568	0.61	0.5431
PA	17	0.2742	0.2883	2568	0.95	0.3417
Intercept	18	5.6724	2.1522	2568	2.64	0.0084
PA	18	0.1419	0.1178	2568	1.20	0.2285
Intercept	20	3.0083	2.1753	2568	1.38	0.1668
PA	20	0.2748	0.1283	2568	2.14	0.0323
Intercept	21	0	5.7133	2568	0.00	1.0000
PA	21	0	0.3073	2568	0.00	1.0000
Intercept	22	0.6629	2.1211	2568	0.31	0.7547
PA	22	0.007674	0.3012	2568	0.03	0.9797
Intercept	23	-3.4170	2.1374	2568	-1.60	0.1100
PA	23	0.1552	0.1179	2568	1.32	0.1882
Intercept	24	7.6425	1.9134	2568	3.99	<.0001
PA	24	-0.4220	0.2252	2568	-1.87	0.0611
Intercept	25	-9.8708	1.7601	2568	-5.61	<.0001
PA	25	-0.4071	0.2277	2568	-1.79	0.0740
Intercept	26	0.8984	2.6843	2568	0.33	0.7379
PA	26	-0.7606	0.2053	2568	-3.70	0.0002

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
PA	1	20	16.00	0.0007
pa2	1	2568	5.51	0.0190
pa3	1	2568	32.00	<.0001

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 290
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
Probe	1	2568	69.47	<.0001
PA*Probe	1	2568	137.17	<.0001
pa2*Probe	1	2568	166.81	<.0001
pa3*Probe	1	2568	170.04	<.0001
IVH	1	2568	0.02	0.8845
PA*IVH	1	2568	0.30	0.5836
pa2*IVH	1	2568	4.89	0.0271

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 291
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Model Information

Data Set WORK.PREPS
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containmentment

Class Level Information

Class	Levels	Values
Caffeine	2	0 1
Probe	2	0 1
IVH	2	0 1
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26

Dimensions

Covariance Parameters	3
Columns in X	13
Columns in Z Per Subject	2
Subjects	25
Max Obs Per Subject	231

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 292
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Number of Observations

Number of Observations Read 2683
Number of Observations Used 2621
Number of Observations Not Used 62

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	18234.75916937	
1	2	16537.25707870	0.00056194
2	1	16533.09749632	0.00018316
3	1	16531.80609462	0.00002945
4	1	16531.61451036	0.00000106
5	1	16531.60816202	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	27.8309
PA	Infant	0.07891
Residual		29.7375

Fit Statistics

-2 Res Log Likelihood	16531.6
AIC (smaller is better)	16537.6

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 293
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Fit Statistics

AICC (smaller is better) 16537.6
BIC (smaller is better) 16541.3

Solution for Fixed Effects

Effect	Probe	IVH	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept			79.4347	1.9286	22	41.19	<.0001
PA			-0.3779	0.1098	20	-3.44	0.0026
pa2			0.001638	0.000741	2571	2.21	0.0272
Probe	0		0.2470	0.3527	2571	0.70	0.4838
Probe	1		0	.	.	.	.
PA*Probe	0		-0.04343	0.01380	2571	-3.15	0.0017
PA*Probe	1		0	.	.	.	.
IVH		0	0.4180	2.3416	2571	0.18	0.8583
IVH		1	0	.	.	.	.
PA*IVH		0	-0.01709	0.1414	2571	-0.12	0.9038
PA*IVH		1	0	.	.	.	.
pa2*IVH		0	0.003344	0.000905	2571	3.69	0.0002
pa2*IVH		1	0	.	.	.	.

Solution for Random Effects

Effect	Infant	Estimate	Std Err	Pred	DF	t Value	Pr > |t|
Intercept	1	7.8341	1.4852	2571	5.27	<.0001	
PA	1	-0.2730	0.08869	2571	-3.08	0.0021	
Intercept	2	-0.8420	1.9901	2571	-0.42	0.6723	
PA	2	-0.2173	0.1078	2571	-2.02	0.0440	

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 294
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > |t|
		Estimate	Pred			
Intercept	3	0.9655	1.9983	2571	0.48	0.6290
PA	3	-0.1246	0.1079	2571	-1.16	0.2481
Intercept	4	1.3688	1.6351	2571	0.84	0.4026
PA	4	0.2174	0.2022	2571	1.08	0.2824
Intercept	5	-5.3383	1.5034	2571	-3.55	0.0004
PA	5	0.1197	0.09058	2571	1.32	0.1864
Intercept	6	-0.3913	1.4796	2571	-0.26	0.7915
PA	6	-0.1892	0.08850	2571	-2.14	0.0326
Intercept	7	-1.8350	2.0947	2571	-0.88	0.3811
PA	7	0.1952	0.1484	2571	1.32	0.1885
Intercept	8	-2.9374	2.1122	2571	-1.39	0.1644
PA	8	0.2922	0.1540	2571	1.90	0.0579
Intercept	9	0.3954	1.6002	2571	0.25	0.8049
PA	9	0.1677	0.1375	2571	1.22	0.2227
Intercept	10	-7.0634	1.6835	2571	-4.20	<.0001
PA	10	0.4594	0.2138	2571	2.15	0.0317
Intercept	11	-3.0474	1.4724	2571	-2.07	0.0386
PA	11	-0.2586	0.08829	2571	-2.93	0.0034
Intercept	12	-2.2119	1.5070	2571	-1.47	0.1423
PA	12	0.1524	0.08875	2571	1.72	0.0861
Intercept	13	-4.7020	1.4900	2571	-3.16	0.0016
PA	13	0.04981	0.08943	2571	0.56	0.5776
Intercept	14	13.7123	1.7647	2571	7.77	<.0001
PA	14	0.03888	0.2806	2571	0.14	0.8898
Intercept	15	2.9007	1.5074	2571	1.92	0.0544
PA	15	-0.1821	0.09430	2571	-1.93	0.0535
Intercept	16	-0.7675	1.6037	2571	-0.48	0.6323
PA	16	-0.02926	0.1053	2571	-0.28	0.7810
Intercept	17	1.8452	1.6375	2571	1.13	0.2599
PA	17	0.09323	0.2664	2571	0.35	0.7264

Dep var is averaged 1 minuted sct02 16:39 Monday, April 2, 2012 295
time variable is pa
covariates are probe, & ivh with interactions
All Data Collections-IVH Final Analysis March 30 2012

The Mixed Procedure

Solution for Random Effects

Effect	Infant	Std Err		DF	t Value	Pr > |t|
		Estimate	Pred			
Intercept	18	4.0216	2.0103	2571	2.00	0.0456
PA	18	0.1484	0.1091	2571	1.36	0.1739
Intercept	20	2.3281	2.0394	2571	1.14	0.2537
PA	20	0.2884	0.1212	2571	2.38	0.0174
Intercept	21	0	5.2755	2571	0.00	1.0000
PA	21	0	0.2809	2571	0.00	1.0000
Intercept	22	0.3133	2.0127	2571	0.16	0.8763
PA	22	0.003553	0.2754	2571	0.01	0.9897
Intercept	23	-2.1736	1.9964	2571	-1.09	0.2764
PA	23	0.006232	0.1091	2571	0.06	0.9544
Intercept	24	6.5228	1.8191	2571	3.59	0.0003
PA	24	-0.2072	0.2157	2571	-0.96	0.3370
Intercept	25	-11.3708	1.6643	2571	-6.83	<.0001
PA	25	-0.1628	0.2179	2571	-0.75	0.4552
Intercept	26	0.4727	2.5524	2571	0.19	0.8531
PA	26	-0.5886	0.1970	2571	-2.99	0.0028

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
PA	1	20	33.68	<.0001
pa2	1	2571	63.25	<.0001
Probe	1	2571	0.49	0.4838
PA*Probe	1	2571	9.90	0.0017
IVH	1	2571	0.03	0.8583
PA*IVH	1	2571	0.01	0.9038
pa2*IVH	1	2571	13.64	0.0002

means by pa and probe for all data collections- NO IVH taken into account

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The MEANS Procedure

Analysis Variable : Pred Predicted

Probe	N PA	Obs	N	Mean	Std Dev	Minimum	Maximum
0	1	180	180	78.0767497	6.7370319	67.2945777	93.4637508
2	118	118	118	78.8186999	4.7515323	71.7054736	84.9341613
3	152	152	152	77.3404908	4.2443742	72.3048063	84.3170564
4	99	99	99	76.3790080	6.0133658	66.5567923	84.9583016
5	53	53	53	81.9291639	4.0813237	74.8902722	84.7812674
6	20	20	20	65.8118513	0	65.8118513	65.8118513
7	175	175	175	76.8398247	3.3548110	72.5640412	82.6647917
9	31	31	31	79.6417019	1.6000780	78.4743487	81.7641622
12	20	20	20	68.4320857	0	68.4320857	68.4320857
14	156	156	156	74.4917201	2.4127762	70.2609320	78.2557131
17	20	20	20	75.0676009	0	75.0676009	75.0676009
21	93	93	93	70.5433498	3.4782125	66.5041128	76.0510017
22	20	20	20	80.5712198	0	80.5712198	80.5712198
28	101	101	101	69.6976896	4.8514005	61.9889640	74.8031737
35	89	89	89	66.4754737	5.7808353	57.4108660	73.4923965
42	118	118	118	63.3902894	6.6521397	53.4783160	72.8140505

means by pa and probe for all data collections- NO IVH taken into account

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The MEANS Procedure

Analysis Variable : Pred Predicted

Probe	N PA	Obs	N	Mean	Std Dev	Minimum	Maximum
<i>ff</i>							
0	49	120	120	60.5410072	8.1126332	50.4551997	73.4635160
	56	87	87	55.8481027	4.9151822	49.4552752	62.9086843
	63	40	40	70.7150408	10.9501048	59.9026786	81.5274030
	68	20	20	74.4355419	0	74.4355419	74.4355419
	70	20	20	65.8974014	0	65.8974014	65.8974014
1	1	120	120	79.8757445	2.9353601	75.1232130	82.6682049
	2	60	60	78.3461585	2.3825302	75.6523513	81.4048788
	3	100	100	78.5525358	3.0839772	73.9896203	81.9657620
	4	40	40	77.0340891	0.7962889	76.2478168	77.8203613
	7	140	140	76.5573255	3.1357162	73.4520120	83.4735713
	12	20	20	80.7001720	0	80.7001720	80.7001720
	14	60	60	76.3641874	3.9197642	70.8674530	79.1588769
	19	20	20	77.9741677	0	77.9741677	77.9741677
	21	80	80	70.9043875	3.0211673	68.6202462	76.0663124
	23	20	20	70.0381210	0	70.0381210	70.0381210
	27	20	20	76.2970338	0	76.2970338	76.2970338
<i>ff</i>							

means by pa and probe for all data collections- NO IVH taken into account

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The MEANS Procedure

Analysis Variable : Pred Predicted

Probe	N PA	Obs	N	Mean	Std Dev	Minimum	Maximum
1	28	43	43	66.3951478	3.5102136	62.6758993	69.7445994
33	20	20		75.7840847	0	75.7840847	75.7840847
35	40	40		69.5901349	3.5206412	66.1137803	73.0664896
36	16	16		68.7583860	0	68.7583860	68.7583860
42	32	32		67.5325542	5.9520796	59.9694696	72.0704050
48	20	20		75.9387804	0	75.9387804	75.9387804
56	20	20		76.0684572	0	76.0684572	76.0684572
61	20	20		75.8959464	0	75.8959464	75.8959464
64	20	20		57.5666195	0	57.5666195	57.5666195
70	20	20		55.9815645	0	55.9815645	55.9815645
77	20	20		61.5956509	0	61.5956509	61.5956509

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The MEANS Procedure

Analysis Variable : Pred Predicted

IVH	N PA	Obs	N	Mean	Std Dev	Minimum	Maximum
0	1	240	240	78.9712946	6.1177681	67.2945777	93.4637508
	2	100	100	78.4766578	4.5868383	71.7054736	84.9341613
	3	212	212	77.2150170	3.9146103	72.3048063	84.3170564
	4	60	60	76.7517277	7.7073187	66.5567923	84.9583016
	5	20	20	83.6523402	0	83.6523402	83.6523402
	6	20	20	65.8118513	0	65.8118513	65.8118513
	7	195	195	76.7671862	3.3745460	72.5640412	83.4735713
	9	31	31	79.6417019	1.6000780	78.4743487	81.7641622
	14	119	119	74.7937344	3.4290471	70.2609320	79.0662325
	17	20	20	75.0676009	0	75.0676009	75.0676009
	21	120	120	71.3590122	3.6267376	66.5041128	76.0663124
	23	20	20	70.0381210	0	70.0381210	70.0381210
	28	116	116	69.8391893	4.4830411	61.9889640	74.8031737
	35	109	109	67.6848344	5.8136178	57.4108660	73.4923965
	36	16	16	68.7583860	0	68.7583860	68.7583860
	42	112	112	67.0652054	5.1852873	59.6207047	72.8140505

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means by ivh and probe for first week of life 16:39 Monday, April 2, 2012

march 23 2012

The MEANS Procedure

Analysis Variable : Pred Predicted

IVH	N		N	Mean	Std Dev	Minimum	Maximum
	PA	Obs					
<i>ff</i>							
0	49	80	80	63.1954454	8.1350548	50.8473437	73.4635160
	56	47	47	58.6463961	4.4025897	50.2526802	62.9086843
	63	40	40	70.7150408	10.9501048	59.9026786	81.5274030
	64	20	20	57.5666195	0	57.5666195	57.5666195
	70	40	40	60.9394830	5.0210792	55.9815645	65.8974014
	77	20	20	61.5956509	0	61.5956509	61.5956509
1	1	60	60	78.0965600	2.6068446	74.8068066	81.1222731
	2	78	78	78.8937220	3.4089578	76.0954091	84.5446155
	3	40	40	81.0356147	0.8135321	80.2323161	81.8389132
	4	79	79	76.4276163	0.9630688	75.1468555	77.8203613
	5	33	33	80.8848147	4.9078887	74.8902722	84.7812674
	7	120	120	76.6282798	3.0687667	73.4520120	82.6647917
	12	40	40	74.5661289	6.2121870	68.4320857	80.7001720
	14	97	97	75.2794350	2.4166914	71.8950930	79.1588769
	19	20	20	77.9741677	0	77.9741677	77.9741677
	21	53	53	69.2415297	1.4519059	67.7330128	71.4606384

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means by ivh and probe for first week of life 16:39 Monday, April 2, 2012

march 23 2012

The MEANS Procedure

Analysis Variable : Pred Predicted

IVH	N		N	Mean	Std Dev	Minimum	Maximum
	PA	Obs					
<i>ff</i>							
1	22	20	20	80.5712198	0	80.5712198	80.5712198


```

var meanco;
Title1' means by gestational age';
title2'prep for proc mixed chapter 3 All Data Collections-IVH Included';

proc means data=preps mean std n nmiss min max;;
class caffeine;
var meanco;
Title1' means by caffeine';
title2'prep for proc mixed chapter 3 All Data Collections-IVH Included';

proc means data=preps mean std n nmiss min max;
class pa caffeine;
var meanco;
Title1' means by caffeine and age';
title2'prep for proc mixed chapter 3 All Data Collections-IVH Included';

proc means data=preps mean std n nmiss min max;
class probe;
var meanco;
Title1' means by probe';
title2'prep for proc mixed chapter 3 All Data Collections-IVH Included';

proc means data=preps mean std n nmiss min max;
class probe pa;
var meanco;
Title1' means by probe and age';
title2'prep for proc mixed chapter 3 All Data Collections-IVH Included';

proc means data=preps mean std n nmiss min max;
class ivh;
var meanco;
Title1' means by ivh';
title2'prep for proc mixed chapter 3 All Data Collections-IVH Included';

proc means data=preps mean std n nmiss min max;
class ivh pa;
var meanco;
Title1' means by probe and age';
title2'prep for proc mixed chapter 3 Overall General Model-IVH NOT included';
*****
*****perform the proc mixed*****
*****
*****

proc mixed data=preps;
class caffeine probe ivh infant;
model meanco = pa pa2 pa3 caffeine caffeine*pa caffeine*pa2 caffeine*pa3 probe probe*pa probe*pa2
probe*pa3 ivh ivh*pa ivh*pa2 ivh*pa3 ga/ s ;
random minute intercept pa /subject = infant type = vc solution;

title1' Dep var is averaged 1 minuted sct02 ';
title2' time variable is pa';
title3' covariates are ga, caffeine, probe, & ivh with interactions';
title4' All Data Collections March 30 2012';
run;

*caffeine and all interactions with time and ga not significant- removed from next model;

proc mixed data=preps;
class caffeine probe ivh infant;
model meanco = pa pa2 pa3 probe probe*pa probe*pa2 probe*pa3 ivh ivh*pa ivh*pa2 ivh*pa3 / s ;

```

```

random minute intercept pa /subject = infant type = vc solution;

title1' Dep var is averaged 1 minuted sct02 ';
title2' time variable is pa';
title3' covariates are probe, & ivh with interactions';
title4' All Data Collections March 30 2012';
run;

* ivh*pa3 not significant- removed from next model;

proc mixed data=preps;
class caffeine probe ivh infant;
model meanco = pa pa2 pa3 probe probe*pa probe*pa2 probe*pa3 ivh ivh*pa ivh*pa2 / s ;
random intercept pa /subject = infant type = vc solution;

title1' Dep var is averaged 1 minuted sct02 ';
title2' time variable is pa';
title3' covariates are probe, & ivh with interactions';
title4' All Data Collections-IVH Final Analysis March 30 2012';

* pa3 and probe*pa3 not significant- removed from model;

proc mixed data=preps;
class caffeine probe ivh infant;
model meanco = pa pa2 probe probe*pa probe*pa ivh ivh*pa ivh*pa2 / s ;
random intercept pa /subject = infant type = vc solution;

title1' Dep var is averaged 1 minuted sct02 ';
title2' time variable is pa';
title3' covariates are probe, & ivh with interactions';
title4' All Data Collections-IVH Final Analysis March 30 2012';
run;
*****
*****examine*****
*****each interaction*****
*****
/*data of2;
    set of;
    if ivh eq 1 and probe eq 1 and caffeine eq 1 then group = 1;
    else
    if ivh eq 1 and probe eq 1 and caffeine eq 0 then group = 2;
    else
    if ivh eq 1 and probe eq 0 and caffeine eq 0 then group = 3;
    else
    if ivh eq 1 and probe eq 1 and caffeine eq 1 then group = 4;
    else
    if ivh eq 0 and probe eq 1 and caffeine eq 1 then group = 5;
    else
    if ivh eq 0 and probe eq 0 and caffeine eq 0 then group = 6;
    else
    if ivh eq 0 and probe eq 1 and caffeine eq 0 then group = 7;
    else
    if ivh eq 0 and probe eq 0 and caffeine eq 1 then group = 8;

proc means data=of2;
class group pa;
var pred;
*/
proc means data= of;
class probe pa;

```

```

var pred;
title1' means by pa and probe for all data collections- NO IVH taken into account';
title2' march 30 2012';
run;

proc means data=of;
class ivh pa;
var pred;
title1' means by ivh and probe for first week of life';
title2' march 23 2012';
run;
/*
4 proc gplot data=of2;

symbol1 color = blue;
symbol2 color = red;
symbol3 color = green;
symbol4 color = orange;
axis1 label=none;
axis2 label=none;
*label abdtp = 'abdtp';
plot pred*pa = group;

= 20 to 80 by 5;

title1'predicted scto2 by age';
title1' for ivh and probe group ';
title4 'march 23 2012';
*/
run;
ods rtf close;
* / vaxis

```

Appendix E Chapter 4 SAS Output: Effect of Sound on Cerebral Oxygenation

file containing data to be averaged 81
 by the gping variable 22:33 Monday, April 9, 2012
 april 4 2012

The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N	gping	Obs	N	Mean	Std Dev	Minimum
<i>ff</i>								
<i>ffffffffffffffffffffffffffffffff</i>								
1	2	1	30	30	89.33333333	1.4700066	88.0000000	
		2	31	31	88.9032258	0.8308565	86.0000000	
		3	30	30	83.4666667	1.3321834	82.0000000	
		4	30	30	83.9000000	0.8448628	82.0000000	
		5	29	29	86.3793103	0.8200084	85.0000000	
2	9	1	30	0	.	.	.	
		2	31	22	38.4090909	5.2703943	34.0000000	
		3	30	30	54.3000000	1.4419814	53.0000000	
		4	30	30	56.2000000	1.3746473	54.0000000	
		5	29	29	55.1379310	2.2476041	51.0000000	
	10	1	30	30	52.3000000	1.8411016	50.0000000	
		2	31	31	52.3225806	0.6525385	51.0000000	
		3	28	28	52.7500000	1.2056964	51.0000000	
3	8	1	30	30	38.83333333	1.2058288	37.0000000	
		2	31	31	44.2580645	1.9827211	41.0000000	
		3	15	15	43.2000000	0.8618916	42.0000000	
	10	1	30	30	49.0666667	0.8683450	48.0000000	
		2	31	31	49.4193548	2.7419481	46.0000000	
		3	30	30	44.0666667	1.5070715	43.0000000	
		4	30	30	55.2000000	10.1519490	43.0000000	
		5	29	29	57.5862069	3.7939542	54.0000000	
4	1	1	30	30	76.7000000	0.4660916	76.0000000	

*ff
ffffffffffffffff*

4

file containing data to be averaged 82
by the gping variable 22:33 Monday, April 9, 2012
april 4 2012

The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N	gping	Obs	Maximum
<i>ff</i>					
1	2	1	30	91.0000000	
		2	31	90.0000000	
		3	30	86.0000000	
		4	30	87.0000000	
		5	29	88.0000000	
2	9	1	30	.	
		2	31	54.0000000	
		3	30	57.0000000	
		4	30	58.0000000	
		5	29	58.0000000	
	10	1	30	55.0000000	
		2	31	53.0000000	
		3	28	55.0000000	
3	8	1	30	41.0000000	
		2	31	48.0000000	
		3	15	44.0000000	
	10	1	30	51.0000000	
		2	31	54.0000000	
		3	30	47.0000000	
		4	30	64.0000000	
		5	29	62.0000000	
4	1	1	30	77.0000000	
<i>ff</i>					

file containing data to be averaged 83
 by the gping variable 22:33 Monday, April 9, 2012
 april 4 2012

The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N gping	Obs	N	Mean	Std Dev	Minimum
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
4	1	2	31	31	71.2903226	2.0362310	69.0000000
		3	30	30	70.3000000	1.3933339	69.0000000
		4	30	30	74.3666667	0.6149479	73.0000000
		5	29	29	76.1379310	0.7427814	75.0000000
6	13	1	1	1	66.0000000	.	66.0000000
		2	1	1	59.0000000	.	59.0000000
		3	1	1	57.0000000	.	57.0000000
		4	1	1	64.0000000	.	64.0000000
		5	1	1	63.0000000	.	63.0000000
7	3	1	30	30	78.5000000	0.5085476	78.0000000
		2	31	31	75.1935484	1.3017771	73.0000000
		3	30	30	78.4000000	0.7701321	77.0000000
		4	30	30	80.0000000	0.6948083	79.0000000
		5	29	29	81.0000000	0	81.0000000
	4	1	30	30	74.4000000	1.1017228	73.0000000
		2	31	31	75.0322581	1.2243058	73.0000000
		3	30	30	74.6666667	0.8840866	74.0000000
		4	30	30	75.8666667	0.3457459	75.0000000
		5	29	29	76.4137931	0.5012300	76.0000000
8	1	1	30	30	79.0666667	0.2537081	79.0000000
		2	31	31	79.4193548	1.2048290	76.0000000
		3	30	30	79.5333333	1.9953970	76.0000000
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

file containing data to be averaged 84
by the gping variable 22:33 Monday, April 9, 2012
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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N	gping	Obs	Maximum
<i>ff</i>					
4	1	2	31	75.0000000	
		3	30	73.0000000	
		4	30	76.0000000	
		5	29	77.0000000	
6	13	1	1	66.0000000	
		2	1	59.0000000	
		3	1	57.0000000	
		4	1	64.0000000	
		5	1	63.0000000	
7	3	1	30	79.0000000	
		2	31	77.0000000	
		3	30	79.0000000	
		4	30	81.0000000	
		5	29	81.0000000	
	4	1	30	76.0000000	
		2	31	77.0000000	
		3	30	76.0000000	
		4	30	76.0000000	
		5	29	77.0000000	
8	1	1	30	80.0000000	
		2	31	81.0000000	
		3	30	83.0000000	
<i>ff</i>					

file containing data to be averaged 85
 by the gping variable 22:33 Monday, April 9, 2012
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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N gping	Obs	N	Mean	Std Dev	Minimum
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
8	1	4	30	30	80.0666667	0.4497764	79.0000000
		5	29	29	80.1034483	0.3099340	80.0000000
3	1	30	30	30	75.3333333	0.5466723	74.0000000
	2	31	31	31	76.0000000	0	76.0000000
	3	30	30	30	75.0333333	0.5560534	74.0000000
	4	30	30	30	75.0000000	0	75.0000000
	5	29	29	29	75.0000000	0	75.0000000
4	1	30	30	30	74.8666667	0.5074163	74.0000000
	2	31	31	31	75.8387097	1.3440430	74.0000000
	3	30	30	30	78.3333333	1.9710549	75.0000000
	4	30	30	30	75.1000000	1.0618786	73.0000000
	5	29	29	29	76.6206897	2.1449907	73.0000000
11	10	1	1	1	51.0000000	.	51.0000000
	11	1	1	1	67.0000000	.	67.0000000
	2	1	1	1	44.0000000	.	44.0000000
	3	1	1	1	48.0000000	.	48.0000000
	4	1	1	1	45.0000000	.	45.0000000
	5	1	1	1	46.0000000	.	46.0000000
13	5	2	1	1	69.0000000	.	69.0000000
	3	1	1	1	59.0000000	.	59.0000000
	4	1	1	1	57.0000000	.	57.0000000
	5	1	1	1	59.0000000	.	59.0000000
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

file containing data to be averaged 86
 by the gping variable 22:33 Monday, April 9, 2012
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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N	gping	Obs	Maximum
<i>ff</i>					
8	1	4	30	81.0000000	
		5	29	81.0000000	
	3	1	30	76.0000000	
		2	31	76.0000000	
		3	30	76.0000000	
		4	30	75.0000000	
		5	29	75.0000000	
	4	1	30	76.0000000	
		2	31	78.0000000	
		3	30	81.0000000	
		4	30	77.0000000	
		5	29	79.0000000	
11	10	1	1	51.0000000	
	11	1	1	67.0000000	
		2	1	44.0000000	
		3	1	48.0000000	
		4	1	45.0000000	
		5	1	46.0000000	
13	5	2	1	69.0000000	
		3	1	59.0000000	
		4	1	57.0000000	
		5	1	59.0000000	
<i>ff</i>					

file containing data to be averaged 87
by the gping variable 22:33 Monday, April 9, 2012
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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N gping	Obs	N	Mean	Std Dev	Minimum
<i>ff</i>							
13	8	1	1	1	66.0000000	.	66.0000000
		2	1	1	67.0000000	.	67.0000000
		3	1	1	67.0000000	.	67.0000000
		4	1	1	67.0000000	.	67.0000000
		5	1	1	66.0000000	.	66.0000000
	9	1	30	30	70.4000000	1.0372377	69.0000000
		2	31	31	70.0645161	1.3149267	68.0000000
		3	30	30	73.0666667	1.5070715	71.0000000
		4	30	30	76.0666667	0.9444332	74.0000000
		5	29	29	76.2068966	1.2357563	74.0000000
16	1	1	1	1	78.0000000	.	78.0000000
		2	1	1	80.0000000	.	80.0000000
		3	1	1	84.0000000	.	84.0000000
		4	1	1	84.0000000	.	84.0000000
		5	1	1	82.0000000	.	82.0000000
	3	1	1	1	71.0000000	.	71.0000000
		2	1	0	.	.	.
		3	1	0	.	.	.
		4	1	1	67.0000000	.	67.0000000
		5	1	1	65.0000000	.	65.0000000
17	1	1	30	30	80.5333333	1.0080139	79.0000000
		2	31	31	80.0322581	0.6046415	79.0000000
<i>ff</i>							

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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N	gping	Obs	Maximum
<i>ff</i>					
13	8	1	1	66.0000000	
		2	1	67.0000000	
		3	1	67.0000000	
		4	1	67.0000000	
		5	1	66.0000000	
	9	1	30	72.0000000	
		2	31	72.0000000	
		3	30	75.0000000	
		4	30	77.0000000	
		5	29	78.0000000	
16	1	1	1	78.0000000	
		2	1	80.0000000	
		3	1	84.0000000	
		4	1	84.0000000	
		5	1	82.0000000	
	3	1	1	71.0000000	
		2	1	.	
		3	1	.	
		4	1	67.0000000	
		5	1	65.0000000	
17	1	1	30	82.0000000	
		2	31	81.0000000	
<i>ff</i>					

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by the gping variable 22:33 Monday, April 9, 2012
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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N gping	Obs	N	Mean	Std Dev	Minimum
<i>ff</i>							
17	1	3	30	30	80.6666667	0.6608946	79.0000000
		4	30	30	77.8333333	0.7466400	77.0000000
		5	29	29	77.3103448	0.4708236	77.0000000
18	1	1	30	30	82.8666667	0.3457459	82.0000000
		2	31	31	83.0645161	0.2497310	83.0000000
		3	30	30	83.0000000	0	83.0000000
		4	30	30	83.7333333	0.4497764	83.0000000
		5	29	29	84.0000000	0	84.0000000
	4	1	30	30	74.8000000	0.4068381	74.0000000
		2	31	31	75.3225806	0.5992827	74.0000000
		3	30	30	75.4000000	0.4982729	75.0000000
		4	30	30	73.8666667	0.6288102	73.0000000
		5	29	29	72.8965517	1.2633523	71.0000000
20	3	1	30	30	78.6666667	0.7111590	78.0000000
		2	31	31	76.8064516	0.9099214	76.0000000
		3	30	30	77.8666667	1.0416609	76.0000000
		4	30	30	78.0000000	0.6432675	77.0000000
		5	29	29	79.7931034	0.4122508	79.0000000
	5	1	30	30	80.6000000	0.8136762	80.0000000
		2	31	31	80.1612903	1.0983859	78.0000000
		3	30	30	79.5333333	1.2242755	78.0000000
		4	30	30	80.1333333	1.1665846	78.0000000
<i>ff</i>							

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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N	gping	Obs	Maximum
<i>ff</i>					
17	1	3	30	81.0000000	
		4	30	81.0000000	
		5	29	78.0000000	
18	1	1	30	83.0000000	
		2	31	84.0000000	
		3	30	83.0000000	
		4	30	84.0000000	
		5	29	84.0000000	
	4	1	30	75.0000000	
		2	31	76.0000000	
		3	30	76.0000000	
		4	30	75.0000000	
		5	29	74.0000000	
20	3	1	30	80.0000000	
		2	31	78.0000000	
		3	30	79.0000000	
		4	30	79.0000000	
		5	29	80.0000000	
	5	1	30	82.0000000	
		2	31	81.0000000	
		3	30	82.0000000	
		4	30	81.0000000	
<i>ff</i>					

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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N		Mean	Std Dev	Minimum
		gping	Obs			
	20	5	29	81.1724138	0.8480636	80.0000000
	24	1	30	83.1333333	0.5713465	82.0000000
		2	31	84.0000000	0	84.0000000
		3	30	84.1333333	1.0416609	83.0000000
		4	30	83.2333333	0.4301831	83.0000000
		5	29	83.6896552	0.4708236	83.0000000
	3	1	30	78.6666667	1.0283342	77.0000000
		2	31	76.4516129	0.6752140	76.0000000
		3	30	76.2000000	0.5508614	75.0000000
		4	30	75.7333333	0.4497764	75.0000000
		5	29	76.1034483	0.3099340	76.0000000
	25	1	30	68.0000000	0	68.0000000
		2	31	68.2580645	0.4448027	68.0000000
		3	30	68.9000000	0.3051286	68.0000000
		4	30	69.0000000	0	69.0000000
		5	29	69.8275862	0.3844259	69.0000000

Analysis Variable : SctO2 SctO2

Infant	DC	N		Maximum
		gping	Obs	
	20	5	29	82.0000000
	24	1	30	84.0000000
		2	31	84.0000000

ff

4

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The MEANS Procedure

Analysis Variable : SctO2 SctO2

Infant	DC	N	gping	Obs	Maximum
<i>ff</i>					
24	1	3	30	86.0000000	
		4	30	84.0000000	
		5	29	84.0000000	
	3	1	30	80.0000000	
		2	31	78.0000000	
		3	30	77.0000000	
		4	30	76.0000000	
		5	29	77.0000000	
25	1	1	30	68.0000000	
		2	31	69.0000000	
		3	30	69.0000000	
		4	30	69.0000000	
		5	29	70.0000000	
<i>ff</i>					

file containing data to be averaged 93
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The CONTENTS Procedure

Data Set Name	WORK.MNS	Observations	309
Member Type	DATA	Variables	11
Engine	V9	Indexes	0
Created	Monday, April 09, 2012 10:45:59 PM	Observation Length	88
Last Modified	Monday, April 09, 2012 10:45:59 PM	Deleted Observations	0
Protection		Compressed	NO
Data Set Type		Sorted	NO
Label			
Data Representation	WINDOWS_64		
Encoding	wlatin1 Western (Windows)		

Engine/Host Dependent Information

Data Set Page Size	8192
Number of Data Set Pages	4
First Data Page	1
Max Obs per Page	92
Obs in First Data Page	68
Number of Data Set Repairs	0
Filename	C:\Users\Heather\AppData\Local\Temp\SAS Temporary Files\TD1768_HEATHER-THINK_\mns.sas7bdat
Release Created	9.0301M0
Host Created	X64_7PRO

Alphabetic List of Variables and Attributes

#	Variable	Type	Len	Label
5	Caffeine	Num	8	Caffeine
2	DC	Num	8	DC
7	GA	Num	8	GA
6	IVH	Num	8	IVH
1	Infant	Num	8	Infant
4	PA	Num	8	PA
8	Probe	Num	8	Probe
10	_FREQ_	Num	8	
9	_TYPE_	Num	8	
3	gping	Num	8	
11	scto2mn	Num	8	SctO2

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Obs	Infant	DC	gping	PA	Caffeine	IVH	GA	Probe	_TYPE_	_FREQ_	scto2mn
184	1	2	1	4	1	0	25.5	0	7	30	89.3333
185	1	2	2	4	1	0	25.5	0	7	31	88.9032
186	1	2	3	4	1	0	25.5	0	7	30	83.4667
187	1	2	4	4	1	0	25.5	0	7	30	83.9000
188	1	2	5	4	1	0	25.5	0	7	29	86.3793
189	2	9	1	49	1	1	25.5	0	7	30	.
190	2	9	2	49	1	1	25.5	0	7	31	38.4091
191	2	9	3	49	1	1	25.5	0	7	30	54.3000
192	2	9	4	49	1	1	25.5	0	7	30	56.2000
193	2	9	5	49	1	1	25.5	0	7	29	55.1379
194	2	10	1	56	0	1	25.5	0	7	30	52.3000
195	2	10	2	56	0	1	25.5	0	7	31	52.3226
196	2	10	3	56	0	1	25.5	0	7	28	52.7500
197	3	8	1	42	1	1	25.5	0	7	30	38.8333
198	3	8	2	42	1	1	25.5	0	7	31	44.2581
199	3	8	3	42	1	1	25.5	0	7	15	43.2000
200	3	10	1	56	0	1	25.5	0	7	30	49.0667
201	3	10	2	56	0	1	25.5	0	7	31	49.4194
202	3	10	3	56	0	1	25.5	0	7	30	44.0667
203	3	10	4	56	0	1	25.5	0	7	30	55.2000
204	3	10	5	56	0	1	25.5	0	7	29	57.5862
205	4	1	1	1	0	0	30.4	0	7	30	76.7000
206	4	1	2	1	0	0	30.4	0	7	31	71.2903
207	4	1	3	1	0	0	30.4	0	7	30	70.3000
208	4	1	4	1	0	0	30.4	0	7	30	74.3667
209	4	1	5	1	0	0	30.4	0	7	29	76.1379
210	6	13	1	77	0	0	26.2	1	7	1	66.0000
211	6	13	2	77	0	0	26.2	1	7	1	59.0000
212	6	13	3	77	0	0	26.2	1	7	1	57.0000
213	6	13	4	77	0	0	26.2	1	7	1	64.0000
214	6	13	5	77	0	0	26.2	1	7	1	63.0000
215	7	3	1	7	1	1	31.6	1	7	30	78.5000
216	7	3	2	7	1	1	31.6	1	7	31	75.1935
217	7	3	3	7	1	1	31.6	1	7	30	78.4000
218	7	3	4	7	1	1	31.6	1	7	30	80.0000
219	7	3	5	7	1	1	31.6	1	7	29	81.0000
220	7	4	1	14	1	1	31.6	0	7	30	74.4000
221	7	4	2	14	1	1	31.6	0	7	31	75.0323
222	7	4	3	14	1	1	31.6	0	7	30	74.6667
223	7	4	4	14	1	1	31.6	0	7	30	75.8667
224	7	4	5	14	1	1	31.6	0	7	29	76.4138
225	8	1	1	2	0	1	31.6	0	7	30	79.0667
226	8	1	2	2	0	1	31.6	0	7	31	79.4194
227	8	1	3	2	0	1	31.6	0	7	30	79.5333
228	8	1	4	2	0	1	31.6	0	7	30	80.0667
229	8	1	5	2	0	1	31.6	0	7	29	80.1034
230	8	3	1	7	1	1	31.6	1	7	30	75.3333
231	8	3	2	7	1	1	31.6	1	7	31	76.0000
232	8	3	3	7	1	1	31.6	1	7	30	75.0333

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Obs	Infant	DC	gping	PA	Caffeine	IVH	GA	Probe	_TYPE_	_FREQ_	scto2mn
233	8	3	4	7	1	1	31.6	1	7	30	75.0000
234	8	3	5	7	1	1	31.6	1	7	29	75.0000
235	8	4	1	14	1	1	31.6	0	7	30	74.8667
236	8	4	2	14	1	1	31.6	0	7	31	75.8387
237	8	4	3	14	1	1	31.6	0	7	30	78.3333
238	8	4	4	14	1	1	31.6	0	7	30	75.1000
239	8	4	5	14	1	1	31.6	0	7	29	76.6207
240	11	10	1	56	0	0	26.2	0	7	1	51.0000
241	11	11	1	64	0	0	26.2	1	7	1	67.0000
242	11	11	2	64	0	0	26.2	1	7	1	44.0000
243	11	11	3	64	0	0	26.2	1	7	1	48.0000
244	11	11	4	64	0	0	26.2	1	7	1	45.0000
245	11	11	5	64	0	0	26.2	1	7	1	46.0000
246	13	5	2	21	1	0	26.5	1	7	1	69.0000
247	13	5	3	21	1	0	26.5	1	7	1	59.0000
248	13	5	4	21	1	0	26.5	1	7	1	57.0000
249	13	5	5	21	1	0	26.5	1	7	1	59.0000
250	13	8	1	42	1	0	26.5	1	7	1	66.0000
251	13	8	2	42	1	0	26.5	1	7	1	67.0000
252	13	8	3	42	1	0	26.5	1	7	1	67.0000
253	13	8	4	42	1	0	26.5	1	7	1	67.0000
254	13	8	5	42	1	0	26.5	1	7	1	66.0000
255	13	9	1	49	1	0	26.5	0	7	30	70.4000
256	13	9	2	49	1	0	26.5	0	7	31	70.0645
257	13	9	3	49	1	0	26.5	0	7	30	73.0667
258	13	9	4	49	1	0	26.5	0	7	30	76.0667
259	13	9	5	49	1	0	26.5	0	7	29	76.2069
260	16	1	1	1	0	0	30.6	0	7	1	78.0000
261	16	1	2	1	0	0	30.6	0	7	1	80.0000
262	16	1	3	1	0	0	30.6	0	7	1	84.0000
263	16	1	4	1	0	0	30.6	0	7	1	84.0000
264	16	1	5	1	0	0	30.6	0	7	1	82.0000
265	16	3	1	7	1	0	30.6	0	7	1	71.0000
266	16	3	2	7	1	0	30.6	0	7	1	.
267	16	3	3	7	1	0	30.6	0	7	1	.
268	16	3	4	7	1	0	30.6	0	7	1	67.0000
269	16	3	5	7	1	0	30.6	0	7	1	65.0000
270	17	1	1	1	1	0	29.6	1	7	30	80.5333
271	17	1	2	1	1	0	29.6	1	7	31	80.0323
272	17	1	3	1	1	0	29.6	1	7	30	80.6667
273	17	1	4	1	1	0	29.6	1	7	30	77.8333
274	17	1	5	1	1	0	29.6	1	7	29	77.3103
275	18	1	1	2	1	1	29.2	0	7	30	82.8667
276	18	1	2	2	1	1	29.2	0	7	31	83.0645
277	18	1	3	2	1	1	29.2	0	7	30	83.0000
278	18	1	4	2	1	1	29.2	0	7	30	83.7333
279	18	1	5	2	1	1	29.2	0	7	29	84.0000
280	18	4	1	19	1	1	29.2	1	7	30	74.8000
281	18	4	2	19	1	1	29.2	1	7	31	75.3226

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Obs	Infant	DC	gping	PA	Caffeine	IVH	GA	Probe	_TYPE_	_FREQ_	scto2mn
282	18	4	3	19	1	1	29.2	1	7	30	75.4000
283	18	4	4	19	1	1	29.2	1	7	30	73.8667
284	18	4	5	19	1	1	29.2	1	7	29	72.8966
285	20	3	1	7	1	1	31.0	0	7	30	78.6667
286	20	3	2	7	1	1	31.0	0	7	31	76.8065
287	20	3	3	7	1	1	31.0	0	7	30	77.8667
288	20	3	4	7	1	1	31.0	0	7	30	78.0000
289	20	3	5	7	1	1	31.0	0	7	29	79.7931
290	20	5	1	22	0	1	31.0	0	7	30	80.6000
291	20	5	2	22	0	1	31.0	0	7	31	80.1613
292	20	5	3	22	0	1	31.0	0	7	30	79.5333
293	20	5	4	22	0	1	31.0	0	7	30	80.1333
294	20	5	5	22	0	1	31.0	0	7	29	81.1724
295	24	1	1	3	1	0	30.0	0	7	30	83.1333
296	24	1	2	3	1	0	30.0	0	7	31	84.0000
297	24	1	3	3	1	0	30.0	0	7	30	84.1333
298	24	1	4	3	1	0	30.0	0	7	30	83.2333
299	24	1	5	3	1	0	30.0	0	7	29	83.6897
300	24	3	1	9	1	0	30.0	0	7	30	78.6667
301	24	3	2	9	1	0	30.0	0	7	31	76.4516
302	24	3	3	9	1	0	30.0	0	7	30	76.2000
303	24	3	4	9	1	0	30.0	0	7	30	75.7333
304	24	3	5	9	1	0	30.0	0	7	29	76.1034
305	25	1	1	1	0	0	31.3	0	7	30	68.0000
306	25	1	2	1	0	0	31.3	0	7	31	68.2581
307	25	1	3	1	0	0	31.3	0	7	30	68.9000
308	25	1	4	1	0	0	31.3	0	7	30	69.0000
309	25	1	5	1	0	0	31.3	0	7	29	69.8276

Dep var is averaged 30 second scto2 means 97
time before and after peak sound is defined by
the dummy variables 22:33 Monday, April 9, 2012
Full Model with ga, caffeine, and probe as covariates

The Mixed Procedure

Model Information

Data Set WORK.MNS2
Dependent Variable scto2mn
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Infant	15	1 2 3 4 6 7 8 11 13 16 17 18 20 24 25
d2	2	0 1
d3	2	0 1
d4	2	0 1
d5	2	0 1
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	3
Columns in X	14
Columns in Z Per Subject	2
Subjects	15
Max Obs Per Subject	15

Number of Observations

Number of Observations Read	126
Number of Observations Used	123
Number of Observations Not Used	3

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	858.45655783	

Dep var is averaged 30 second scto2 means 98
time before and after peak sound is defined by
the dummy variables 22:33 Monday, April 9, 2012
Full Model with ga, caffeine, and probe as covariates

The Mixed Procedure

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
1	2	748.14298030	0.03269677
2	1	736.31971938	0.02548902
3	1	727.27417370	0.01961950
4	1	720.53273181	0.01236531
5	1	716.44812579	0.00573949
6	1	714.63065678	0.00171189
7	1	714.11978209	0.00022197
8	1	714.05900349	0.00000501
9	1	714.05772320	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	168.73
DC	Infant	4.7223
Residual		11.5269

Fit Statistics

-2 Res Log Likelihood	714.1
AIC (smaller is better)	720.1
AICC (smaller is better)	720.3
BIC (smaller is better)	722.2

Solution for Fixed Effects

Effect	d2	d3	d4	d5	Caffeine	Probe	Estimate	Error	DF	t Value	Pr > |t|
Intercept					-27.4550	51.9226	14	-0.53	0.6052		
d2	0				1.4726	0.9693	91	1.52	0.1322		
d2	1				0	.	.	.	.
d3		0			1.1298	0.9693	91	1.17	0.2468		
d3		1			0	.	.	.	.
d4			0		0.3457	0.9786	91	0.35	0.7247		
d4			1		0	.	.	.	.
d5				0	-0.03257	0.9786	91	-0.03	0.9735		

Dep var is averaged 30 second scto2 means 99
time before and after peak sound is defined by
the dummy variables 22:33 Monday, April 9, 2012
Full Model with ga, caffeine, and probe as covariates

The Mixed Procedure

Solution for Fixed Effects

Effect	d2	d3	d4	d5	Standard		Error	DF	t Value	Pr > |t|
					Caffeine	Probe				
d5		1			0	.	.	.	.
Caffeine			0		5.1387	1.7682	91	2.91	0.0046	
Caffeine			1		0	.	.	.	.
Probe				0	1.2330	1.2504	91	0.99	0.3267	
Probe				1	0	.	.	.	.
GA					3.2965	1.7654	91	1.87	0.0651	

Type 3 Tests of Fixed Effects

Effect	Num		Den		F Value	Pr > F
	DF	DF	DF	DF		
d2	1	91	2.31	0.1322		
d3	1	91	1.36	0.2468		
d4	1	91	0.12	0.7247		
d5	1	91	0.00	0.9735		
Caffeine	1	91	8.45	0.0046		
Probe	1	91	0.97	0.3267		
GA	1	91	3.49	0.0651		

Dep var is averaged 30 second scto2 means 100
time before and after peak sound is defined by
the dummy variables 22:33 Monday, April 9, 2012
Final model with caffeine as covariate

The Mixed Procedure

Model Information

Data Set WORK.MNS2
Dependent Variable scto2mn
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Infant	15	1 2 3 4 6 7 8 11 13 16 17 18 20 24 25
d2	2	0 1
d3	2	0 1
d4	2	0 1
d5	2	0 1
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	3
Columns in X	11
Columns in Z Per Subject	2
Subjects	15
Max Obs Per Subject	15

Number of Observations

Number of Observations Read	126
Number of Observations Used	123
Number of Observations Not Used	3

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	926.23146727	

Dep var is averaged 30 second scto2 means 101
time before and after peak sound is defined by
the dummy variables 22:33 Monday, April 9, 2012
Final model with caffeine as covariate

The Mixed Procedure

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
1	2	745.39796088	0.02782186
2	1	735.52284173	0.01904742
3	1	728.99181565	0.01079082
4	1	725.41790667	0.00468637
5	1	723.92518723	0.00134362
6	1	723.51982133	0.00017999
7	1	723.46964920	0.00000493
8	1	723.46837235	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Intercept	Infant	185.50
DC	Infant	5.0100
Residual		11.5997

Fit Statistics

-2 Res Log Likelihood	723.5
AIC (smaller is better)	729.5
AICC (smaller is better)	729.7
BIC (smaller is better)	731.6

Solution for Fixed Effects

Effect	Standard					Error	DF	t Value	Pr > |t|
	d2	d3	d4	d5	Caffeine Estimate				
Intercept					69.6587	4.6550	14	14.96	<.0001
d2	0				1.4979	0.9720	93	1.54	0.1267
d2	1				0	.	.	.	.
d3		0			1.1551	0.9720	93	1.19	0.2377
d3		1			0	.	.	.	.
d4			0		0.3488	0.9814	93	0.36	0.7231
d4			1		0	.	.	.	.
d5				0	-0.02949	0.9814	93	-0.03	0.9761
d5				1	0	.	.	.	.

Dep var is averaged 30 second scto2 means 102
time before and after peak sound is defined by
the dummy variables 22:33 Monday, April 9, 2012
Final model with caffeine as covariate

The Mixed Procedure

Solution for Fixed Effects

Effect	d2	d3	d4	d5	Standard		Error	DF	t Value	Pr > |t|
					Caffeine	Estimate				
Caffeine				0	6.3378	1.6934	93	3.74	0.0003	
Caffeine				1	0	.	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num		Den		F Value	Pr > F
	DF	DF	DF	DF		
d2	1	93	2.37	0.1267		
d3	1	93	1.41	0.2377		
d4	1	93	0.13	0.7231		
d5	1	93	0.00	0.9761		
Caffeine	1	93	14.01	0.0003		

```
*****
*****
```

```
*libname pos 'S:\SED\Elser-NIRS\Dissertation\Dis_Subject_folders';
*ods rtf file = 'S:\SED\Elser-NIRS\Dissertation\output\Chapter 4\soundmixed_04042012';
*****
*****compute means for sound analysis*****
*****
```

```
proc means data=work.soundcat_04042012;
class infant dc gping;
var scto2;
id pa caffeine ivh ga probe;
output out = mns mean=scto2mn; /*scto2mn is dependent variable for proc mixed*/
```

/*main

independent variables willbe the dummy codes created below*/

```
title1' file containing data to be averaged';
title2' by the gping variable';
```

```

title3' april 4 2012';

proc contents data=mns;

proc print data=mns;
where _type_ eq 7;
*****
*****create dummy codes for *****
*****proc mixed*****
*****
data mns2;
    set mns;
    if _type_ eq 7;

    if gping eq 2 then d2 = 1;    /* if d2 = 1 mnscto2 is over 30 seconds right after peak sound*/
    else d2 = 0;

    if gping eq 3 then d3 = 1;    /* if d3 = 1 mnscto2 is over seconds from 30 to 60 second after
peak*/
    else d3 = 0;

    if gping eq 4 then d4 = 1;    /* if d4 = 1 mnscto2 is over seconds from 60 to 90 seconds after
peak*/
    else d4 = 0;

    if gping eq 5 then d5 = 1;    /* if d5 = 1 mnscto2 is over seconds from 90 to 120 seconds after
peak*/
    else d5 = 0;

proc means data=mns2;
class gping;
var scto2mn;
run;
*****
*****proc mixed*****
*****
proc mixed data=mns2;
class infant d2 d3 d4 d5 caffeine probe;
model scto2mn = d2 d3 d4 d5 caffeine probe ga/ s ;
random intercept dc /subject = infant type = vc ;

title1' Dep var is averaged 30 second scto2 means ';
title2' time before and after peak sound is defined by';
title3' the dummy variables';
title4' Full Model with ga, caffeine, and probe as covariates';
run;

proc mixed data=mns2;
class infant d2 d3 d4 d5 caffeine;
model scto2mn = d2 d3 d4 d5 caffeine/ s ;
random intercept dc /subject = infant type = vc ;

title1' Dep var is averaged 30 second scto2 means ';
title2' time before and after peak sound is defined by';
title3' the dummy variables';
title4' Final model with caffeine as covariate';
run;

```

4

Appendix F Chapter 4 SAS Output: Effect of Position on Cerebral Oxygenation

Means by position within data collection 16:37 Sunday, April 22, 2012 855
 prep for proc mixed on march 8 2012

-----newid=101-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N		Mean	Std Dev	Minimum	Maximum
Position	Obs	N				
1	20	20	83.6675000	1.8678918	80.9000000	86.5666667
6	14	3	83.6317251	3.6558013	80.0701754	87.3750000

-----newid=102-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N		Mean	Std Dev	Minimum	Maximum
Position	Obs	N				
1	20	20	91.8058333	2.5906731	85.2166667	94.0000000
4	19	19	86.4591038	1.3538237	83.6500000	88.4833333

-----newid=103-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	82.5975000	0.7796625	81.3000000	83.8833333	
5	20	20	78.3150000	7.2466728	66.9166667	88.0833333	

-----newid=104-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	71.2462766	3.8498714	65.6500000	78.6333333	

-----newid=105-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	77.5479237	2.0337648	72.5084746	81.0833333	
2	20	20	74.1417857	1.4365733	70.0000000	77.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

-----newid=106-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	76.8063842	2.0486082	73.3666667	80.5500000	
3	20	20	79.1678906	2.6175804	69.7272727	82.2000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

-----newid=107-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	74.2236905	2.2343321	71.1000000	78.3000000	
5	20	20	74.9477778	2.7599424	70.8888889	80.7666667	

-----newid=108-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	67.5801417	7.7755380	49.3320000	88.8833333	
4	19	17	67.8091368	5.6513463	54.0303030	74.4500000	

-----newid=109-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	53.9725000	3.9839821	44.6000000	59.9833333	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=110-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	20	69.0177542	3.3146070	64.1833333	76.1666667	
3	19	19	81.2116040	4.9381238	68.8888889	87.1333333	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=201-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	82.1048810	1.8030943	78.9000000	87.1000000	
4	20	20	80.3766882	1.8884853	76.9000000	83.3333333	

-----newid=202-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	79.5866667	2.6005488	73.8333333	83.8666667	
6	20	20	82.5869414	3.1744809	77.0333333	88.0000000	

-----newid=203-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	66.1716667	2.8169604	62.2500000	71.5333333	
2	19	18	60.6404321	13.0543932	32.4166667	77.0000000	
<i>ff</i>							

-----newid=204-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	71.1300000	6.0338218	62.5333333	82.8666667	
<i>ff</i>							

-----newid=205-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	62.7991667	4.0289830	55.6666667	67.6833333	
3	19	19	64.2652357	6.7104529	49.3666667	71.6500000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=206-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	20	65.0450000	2.0904471	59.1166667	68.5166667	
5	20	20	61.8667771	2.8954646	55.0000000	64.9333333	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=208-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	18	62.8586420	9.7702499	49.5555556	98.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=209-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	19	38.5107665	6.2317051	25.3783784	55.5000000	
4	20	19	40.5255733	10.7284460	15.0000000	54.0357143	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=210-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	54.3098274	9.6894698	24.5666667	69.0250000	
3	20	20	55.0191539	3.8172048	47.6666667	59.8833333	
<i>ff</i>							

-----newid=301-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	77.3353333	2.7171748	72.1433333	80.5300000	
4	20	20	75.4695000	2.1072227	73.2866667	79.5866667	
<i>ff</i>							

-----newid=302-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	80.4283333	2.1915381	76.0333333	84.2666667	
2	20	20	76.5650000	2.1342508	72.3333333	80.7666667	
<i>ff</i>							

-----newid=303-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	76.4308475	3.1254323	71.0000000	81.6166667	
6	20	20	70.6285714	3.8217273	64.7666667	75.8333333	
<i>ff</i>							

-----newid=305-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	72.9550000	1.3179940	70.6833333	75.3166667	
5	20	20	73.1876418	2.1607105	69.7666667	76.7500000	

-----newid=306-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	8	8	64.1791667	5.8971593	57.7000000	75.4000000	

-----newid=307-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	73.0725000	1.3279857	70.7666667	75.9333333	
2	20	20	72.3563438	1.3015276	69.6000000	74.9166667	

-----newid=308-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	18	18	50.3571615	5.7703481	37.9166667	58.3333333	
3	20	20	54.6839094	11.3781538	33.1500000	67.9523810	

-----newid=310-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	56.5516116	4.9348079	46.1500000	63.4666667	
6	20	20	58.5512276	4.6141321	48.6333333	65.1166667	
<i>ff</i>							

-----newid=401-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	76.0108333	1.8557109	70.8166667	78.4166667	
3	20	20	74.2639947	2.4952404	70.1428571	78.5000000	
<i>ff</i>							

-----newid=402-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	87.7000000	1.4193628	84.6166667	90.1833333	
5	20	20	95.5665476	1.7770526	91.4166667	97.8166667	
<i>ff</i>							
<i>ff</i>							

-----newid=403-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	78.5139732	1.4113744	75.7000000	80.5932203	
4	20	20	78.1623164	1.0055206	76.4333333	80.9333333	
<i>ff</i>							
<i>ff</i>							

-----newid=501-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	77.9756356	0.6761966	76.7500000	79.1500000	
5	20	20	77.3265164	4.3773893	65.8333333	82.2333333	
<i>ff</i>							

-----newid=502-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	70.4661950	3.5663882	60.0333333	73.7500000	
4	2	2	73.1833333	0.2592725	73.0000000	73.3666667	
<i>ff</i>							

-----newid=503-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	73.1236299	1.8272578	69.3666667	75.6779661	
6	20	20	84.2187625	7.4598921	75.0333333	96.0833333	
<i>ff</i>							

-----newid=504-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	67.0081780	2.8713906	64.3333333	74.0333333	
2	19	19	66.2525253	1.2994317	63.7166667	67.6666667	
<i>ff</i>							

-----newid=506-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	13	12	77.1622589	5.0769842	71.0000000	84.5666667	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=507-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	20	72.5404520	1.3909879	70.1333333	75.0833333	
3	20	20	70.1936111	0.7466087	68.8000000	71.2666667	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=508-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	66.5275000	1.7864522	63.3000000	70.0333333	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

-----newid=601-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	88.6233333	2.9564005	80.8000000	92.7166667	
5	19	19	80.5868421	7.1752889	59.0000000	88.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

-----newid=602-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	74.5725000	5.0622767	62.9000000	79.8000000	
4	20	20	72.4719792	3.2053452	64.4833333	76.6333333	

-----newid=603-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	70.5345621	1.4420698	67.1166667	72.5666667	
2	20	20	72.4981596	2.6679978	63.6333333	74.7166667	

-----newid=604-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	72.7822599	2.2558154	66.6779661	76.9830508	
3	20	20	70.3776667	1.8645301	67.0500000	73.4166667	
<i>ff</i>							

-----newid=605-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	69.1521893	3.6989198	63.4067797	75.3000000	
3	20	20	69.0384240	4.5985127	55.1052632	75.3666667	
<i>ff</i>							

-----newid=606-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	59.1539124	3.9106495	53.0833333	68.2372881	
6	20	20	58.0348844	6.0670246	48.7666667	67.2666667	
<i>ff</i>							

-----newid=607-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	11	11	64.5300805	9.6353156	44.7777778	71.8666667	
<i>ff</i>							

-----newid=608-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	62.0725000	3.7072407	54.6333333	68.3333333	
3	20	20	61.1941667	2.5421147	56.9666667	64.4500000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

-----newid=610-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	56.9241667	1.5165122	52.6666667	59.7500000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

-----newid=611-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	61.6750000	3.3295922	54.0000000	68.0000000	
6	20	20	63.6750000	2.4185413	59.5000000	68.0000000	
<i>ff</i>							

-----newid=612-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	62.4250000	0.9904146	61.0000000	64.5000000	
4	20	20	64.4250000	3.4499237	59.5000000	71.5000000	
<i>ff</i>							

-----newid=613-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	64.6750000	2.7780862	57.5000000	69.0000000	
2	16	16	64.9687500	2.6737536	61.0000000	70.0000000	
<i>ff</i>							

-----newid=701-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	76.8027542	1.6532745	74.1333333	79.4166667	
6	20	20	78.3950000	0.6992916	77.1666667	80.2666667	
<i>ff</i>							

-----newid=702-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	76.0329944	0.9721934	74.5000000	77.9666667	
5	20	20	76.0460358	2.2185555	71.9333333	79.8166667	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

-----newid=703-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	77.9376130	2.2267715	73.8833333	81.6000000	
5	20	20	79.4949753	1.8457560	76.8333333	82.7666667	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

-----newid=704-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	74.8292655	1.7145908	71.9166667	77.2666667	
3	10	10	76.0465006	2.7436791	72.5833333	82.1333333	
<i>ff</i>							

-----newid=801-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	18	18	78.2002089	1.7416392	74.1666667	80.6551724	
6	20	20	82.5330036	6.4005036	76.8333333	98.5757576	
<i>ff</i>							

-----newid=802-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	19	17	72.9484314	1.8499024	70.3166667	77.4400000	
4	20	19	75.3036119	1.1165223	73.5000000	77.0689655	

-----newid=803-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	76.2566384	2.3629434	73.8666667	82.9661017	
2	20	20	74.2056123	1.3447492	71.6333333	76.7166667	

-----newid=804-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	17	16	76.3036019	1.3993469	74.4500000	79.1166667	
3	17	15	78.7496936	3.5313438	74.6333333	87.5957447	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=901-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	20	79.6333333	1.6206634	75.3000000	81.9000000	
6	20	20	80.7095596	1.4597936	78.4000000	82.9000000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

-----newid=902-----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	80.1187994	1.1413010	77.0508475	82.2666667	
6	15	15	80.5328161	1.0457995	78.8666667	81.9833333	

-----newid=903-----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	78.5516949	1.9114379	75.8000000	83.6333333	
5	20	20	84.9365315	2.2096214	81.2972973	88.8000000	

----- newid=904 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	19	17	78.1584412	6.8676978	73.4500000	94.8000000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

----- newid=1001 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	20	71.0151606	1.0021085	68.9122807	72.8500000	
6	20	20	73.3293152	1.1249473	71.7333333	75.2857143	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

----- newid=1002 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	72.8066243	1.4618290	69.2372881	74.5423729	
2	20	20	78.6252778	0.9976686	76.8888889	80.0000000	
<i>ff</i>							

----- newid=1003 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	75.3541667	1.3337047	72.6333333	78.2166667	
4	20	20	77.2343627	1.4517846	75.0833333	80.4500000	
<i>ff</i>							

----- newid=1101 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	73.9933333	2.1995042	69.9666667	78.1666667	
5	20	20	71.8591667	2.0334015	68.6333333	76.1166667	
<i>ff</i>							
<i>ff</i>							

----- newid=1102 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	66.6441667	2.8474893	60.9166667	71.5333333	
4	20	20	53.4556110	4.9058154	43.9090909	60.0166667	
<i>ff</i>							
<i>ff</i>							

----- newid=1103 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	78.5000000	2.8745709	73.0000000	83.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1104 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	64.1250000	2.4595410	58.0000000	68.0000000	
6	20	20	66.8500000	3.6277440	59.0000000	73.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1105 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	73.6250000	1.9592896	70.5000000	77.0000000	

----- newid=1106 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	60.4250000	3.5216436	52.0000000	66.0000000	

----- newid=1107 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	58.3250000	2.4455922	53.5000000	62.5000000	
3	19	19	63.6052632	3.8534939	56.0000000	69.0000000	

----- newid=1108 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	12	11	70.6818182	2.4522717	67.0000000	73.5000000	
2	20	20	75.1750000	4.9024027	65.0000000	81.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1109 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	19	53.6578947	4.5094119	40.0000000	61.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1110 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	7	7	55.0000000	6.8980674	40.0000000	59.5000000	
6	20	20	57.8500000	6.5696671	42.0000000	67.5000000	
<i>ff</i>							
<i>ff</i>							

----- newid=1111 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	46.4750000	6.2037234	37.5000000	67.5000000	
2	19	19	55.4210526	6.6692977	47.0000000	77.5000000	
<i>ff</i>							
<i>ff</i>							

----- newid=1112 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	58.3500000	3.1713354	53.0000000	64.7000000	
5	20	20	59.7666667	3.0954220	54.3333333	64.2000000	
<i>ff</i>							

----- newid=1201 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	79.1000000	1.0208356	76.5000000	80.0000000	
<i>ff</i>							

----- newid=1202 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	75.0500000	1.7083387	72.5000000	79.0000000	
2	6	5	77.4000000	4.1743263	73.0000000	83.0000000	
<i>ff</i>							

----- newid=1204 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	76.2000000	1.5844640	72.5000000	78.5000000	
6	2	2	72.0000000	2.8284271	70.0000000	74.0000000	
<i>ff</i>							

----- newid=1205 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	18	74.4166667	3.0498312	65.0000000	78.5000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1206 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	73.5000000	1.7770466	71.0000000	77.0000000	
6	17	15	73.9333333	7.2107724	68.5000000	99.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1207 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	18	16	73.9375000	3.9237525	67.5000000	85.5000000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

----- newid=1208 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	20	71.7000000	1.7044833	69.0000000	75.0000000	
<i>ff</i>							
<i>ffffffffffffffff</i>							

----- newid=1209 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffff</i>							
1	20	20	75.3750000	3.3121586	69.5000000	81.5000000	
4	5	4	80.8750000	4.1104542	78.5000000	87.0000000	
<i>ff</i>							
<i>ffffffff</i>							

----- newid=1211 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	81.8250000	2.4455922	76.0000000	87.0000000	

----- newid=1301 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	69.5000000	2.4170447	65.5000000	73.0000000	

----- newid=1302 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	74.9250000	1.0166379	73.0000000	76.5000000	

----- newid=1303 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	80.8000000	2.8395700	76.0000000	85.5000000	
6	19	19	77.1315789	1.8092517	75.0000000	80.5000000	
<i>ff</i>							

----- newid=1304 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	68.9500000	1.2555142	66.5000000	71.0000000	
4	19	19	66.4473684	3.2184138	60.5000000	72.0000000	
<i>ff</i>							

----- newid=1305 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	74.3250000	5.7360242	58.0000000	80.0000000	
5	19	19	72.1052632	2.5362864	67.5000000	76.5000000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

----- newid=1306 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	11	10	62.1000000	3.2386554	54.5000000	65.0000000	
2	20	20	64.9500000	5.1347628	54.0000000	70.5000000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

----- newid=1307 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	64.0500000	4.5765420	52.0000000	70.0000000	
3	19	19	64.5789474	2.2623928	59.5000000	69.5000000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

----- newid=1308 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	20	65.4750000	2.5260485	61.5000000	71.0000000	
5	19	18	70.3055556	7.9096718	64.0000000	99.0000000	
<i>ff</i>							
<i>ffffffffffffffff</i>							

----- newid=1309 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	17	75.3197321	3.9765022	68.0000000	82.8333333	
3	20	20	68.7963889	2.2401196	65.1333333	75.1111111	

----- newid=1401 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	94.1500000	2.0969903	89.5000000	97.0000000	

----- newid=1501 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	81.0500000	1.7983911	78.5000000	85.0000000	
5	20	19	81.2368421	1.7667329	78.0000000	83.5000000	
<i>ff</i>							
<i>ff</i>							

----- newid=1502 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	76.7000000	1.8238190	74.0000000	79.5000000	
2	19	19	78.7105263	2.0636792	74.5000000	82.5000000	
<i>ff</i>							
<i>ff</i>							

----- newid=1503 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	74.3000000	1.9560971	70.0000000	78.0000000	
6	19	19	71.8684211	1.7387903	69.5000000	74.5000000	
<i>ff</i>							
<i>ff</i>							

----- newid=1504 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	19	91.3430928	4.1871218	82.7333333	98.5454545	
4	6	6	74.1498316	2.2548153	71.4444444	77.0000000	
<i>ff</i>							
<i>ff</i>							

----- newid=1507 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	12	12	66.1735225	2.9107648	60.1489362	69.3333333	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1508 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	16	16	68.4342803	2.9185626	62.1000000	71.5333333	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1601 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	78.8750000	2.0318193	75.0000000	84.0000000	
<i>ffffffffffffffffffffffffffffffff</i>							
6	19	19	73.3684211	3.0588765	69.0000000	78.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1602 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	12	12	77.6250000	1.5829346	75.0000000	80.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1603 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	15	13	75.5000000	5.7373048	62.0000000	82.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1604 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	74.8250000	4.1715673	68.0000000	83.5000000	
<i>ffffffffffffffffffffffffffffffff</i>							
4	19	19	65.5263158	2.6377267	61.5000000	69.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1605 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	70.6433333	2.1843168	67.1000000	75.1333333	
5	20	20	72.2623563	1.6414759	70.2333333	76.1666667	
<i>ff</i>							

----- newid=1701 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	80.6706159	1.5622727	77.4333333	83.1333333	
2	18	18	86.8748612	7.3572045	78.7333333	99.0000000	
<i>ff</i>							

----- newid=1702 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	81.7833333	1.0990426	79.7000000	83.6333333	
4	20	19	82.6173489	4.4592299	78.6000000	91.6296296	
<i>ff</i>							
<i>ff</i>							

----- newid=1801 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	83.2422619	0.6026733	82.3333333	84.1666667	
6	20	20	83.2109809	0.8917128	82.0333333	85.1000000	
<i>ff</i>							
<i>ff</i>							

----- newid=1802 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	89.3966667	2.0390601	86.2666667	93.6333333	
4	20	20	85.3626695	5.8072865	77.7000000	92.9666667	
<i>ff</i>							

----- newid=1803 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	80.8016667	1.6737472	77.3500000	82.9833333	
<i>ff</i>							

----- newid=1804 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	74.7343503	2.3557920	69.7000000	79.4000000	
2	20	20	75.8288333	1.3896006	72.1600000	78.4000000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1805 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	74.0466667	2.5568827	69.6833333	78.7500000	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=1806 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	76.0040113	2.8032699	67.2166667	78.2666667	

----- newid=1808 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	78.2309206	4.6889325	61.7500000	82.9500000	

----- newid=1809 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	76.2741667	1.2226119	72.9500000	78.4333333	

----- newid=1810 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	76.5183333	2.4009373	71.9333333	80.1333333	
5	20	20	79.5772414	2.9845536	75.4000000	88.0000000	
<i>ff</i>							

----- newid=1811 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	73.4633333	3.3976755	69.2000000	80.5666667	
3	20	20	78.4647599	4.4000950	73.0000000	87.9333333	
<i>ff</i>							

----- newid=2001 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	79.7375000	1.5067380	77.4666667	82.2500000	
4	19	19	81.0592112	2.0707594	75.9333333	84.0000000	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

----- newid=2002 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							
1	20	20	84.8666667	3.9283197	79.6666667	92.4666667	
6	20	20	75.7212147	1.0967244	73.8333333	78.4576271	
<i>ff</i>							
<i>ffffffffffffffffffffffff</i>							

----- newid=2003 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	79.1799561	1.4918153	76.5000000	82.5166667	
4	20	20	80.0183974	2.7066460	74.3846154	85.2166667	
<i>ff</i>							
<i>ff</i>							

----- newid=2004 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	82.1300000	3.3510957	77.8333333	89.4000000	
5	20	20	80.7971429	1.2783675	78.1428571	82.5833333	
<i>ff</i>							
<i>ff</i>							

----- newid=2005 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	79.5847436	3.2239187	72.8000000	84.1666667	
3	20	20	76.8507018	2.5858365	72.9333333	83.1333333	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=2201 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	0	
2	18	2	81.2804878	0.3966697	81.0000000	81.5609756	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=2202 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	78.7700000	0.9932462	76.5666667	80.3000000	
6	20	20	80.3841228	1.6642904	76.0526316	83.0333333	

----- newid=2301 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	69.3633333	1.9229272	63.3000000	71.7000000	
6	20	20	59.4863842	3.4861558	56.4666667	70.6610169	

----- newid=2302 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	75.5104825	1.9359321	72.0166667	77.8166667	
5	20	20	74.3943421	3.6811086	67.2500000	79.2500000	
<i>ff</i>							

----- newid=2303 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	73.1318906	3.0161499	69.1166667	80.2380952	
2	11	11	66.6906095	2.8018979	62.3333333	71.5666667	
<i>ff</i>							

----- newid=2304 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	77.8200575	3.1766281	73.6000000	85.1000000	
3	19	19	67.0937876	1.6369344	62.4782609	70.0666667	
<i>ff</i>							

----- newid=2305 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	13	13	82.8538462	2.5533942	77.9666667	87.2166667	
<i>ff</i>							

----- newid=2309 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	56.1400000	3.5758097	48.6333333	61.9333333	
4	20	20	57.8691667	3.9222908	52.8500000	67.3666667	
<i>ff</i>							

----- newid=2401 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
1	20	20	85.2941667	3.5697981	80.4000000	93.2500000	
6	20	19	87.2060606	3.1829741	83.7272727	96.7166667	
<i>ff</i>							

----- newid=2402 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	84.4337952	2.8768170	82.1833333	95.4166667	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=2403 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	11	11	79.1614035	1.8060880	75.8666667	81.2333333	
4	20	20	79.5240351	1.7935881	74.7666667	82.2666667	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=2501 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	67.6666667	1.0557694	65.9333333	69.4166667	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=2502 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							
1	20	20	67.2800000	0.8293166	65.8666667	68.7000000	
4	20	20	62.6585632	1.4534196	60.5000000	66.1379310	
<i>ff</i>							
<i>ffffffffffffffffffffffffffffffff</i>							

----- newid=2503 -----

The MEANS Procedure

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	64.2833333	4.5182735	52.0333333	69.8333333	

----- newid=2601 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	13	13	77.6499443	2.4323277	71.7826087	80.8166667	

----- newid=2602 -----

Analysis Variable : meanco average value of sct02 for a minute within a position

	N						
Position	Obs	N	Mean	Std Dev	Minimum	Maximum	
1	20	20	66.6691667	4.6567761	54.0833333	71.9000000	
4	6	6	61.3488095	1.0080636	60.2857143	63.0000000	

means by position within data collection
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	Obs	newid	Position	Infant	c_pma	c_pma2	c_pma3	Caffeine	Probe	_TYPE_	_FREQ_	gmeanco	mean1	diff	pmacat	d2	d3	d4	d5	d6
	1	101	6	1	0.5	0.25	0.125	1	0	1	14	83.6317	83.6675	0.0358	0	0	0	0	0	1
	2	102	4	1	0.7	0.49	0.343	1	0	1	19	86.4591	91.8058	5.3467	0	0	0	1	0	0
	3	103	5	1	1.0	1.00	1.000	1	1	1	20	78.3150	82.5975	4.2825	0	0	0	0	1	0
	4	105	2	1	3.0	9.00	27.000	1	1	1	20	74.1418	77.5479	3.4061	1	1	0	0	0	0
	5	106	3	1	4.0	16.00	64.000	1	0	1	20	79.1679	76.8064	-2.3615	2	0	1	0	0	0
	6	107	5	1	5.0	25.00	125.000	1	1	1	20	74.9478	74.2237	-0.7241	2	0	0	0	1	0
	7	108	4	1	6.0	36.00	216.000	1	0	1	19	67.8091	67.5801	-0.2290	3	0	0	1	0	0
	8	110	3	1	8.0	64.00	512.000	1	0	1	19	81.2116	69.0178	-12.1938	4	0	1	0	0	0
	9	201	4	2	0.5	0.25	0.125	1	1	1	20	80.3767	82.1049	1.7282	0	0	0	1	0	0
	10	202	6	2	0.7	0.49	0.343	1	0	1	20	82.5869	79.5867	-3.0003	0	0	0	0	0	1
	11	203	2	2	1.0	1.00	1.000	1	1	1	19	60.6404	66.1717	5.5312	0	1	0	0	0	0
	12	205	3	2	3.0	9.00	27.000	1	0	1	19	64.2652	62.7992	-1.4661	1	0	1	0	0	0
	13	206	5	2	4.0	16.00	64.000	1	1	1	20	61.8668	65.0450	3.1782	2	0	0	0	1	0
	14	209	4	2	7.0	49.00	343.000	1	0	1	20	40.5256	38.5108	-2.0148	3	0	0	1	0	0
	15	210	3	2	8.0	64.00	512.000	0	0	1	20	55.0192	54.3098	-0.7093	4	0	1	0	0	0
	16	301	4	3	0.1	0.01	0.001	1	0	1	20	75.4695	77.3353	1.8658	0	0	0	1	0	0
	17	302	2	3	0.6	0.36	0.216	1	1	1	20	76.5650	80.4283	3.8633	0	1	0	0	0	0
	18	303	6	3	1.0	1.00	1.000	1	0	1	20	70.6286	76.4308	5.8023	0	0	0	0	0	1
	19	305	5	3	3.0	9.00	27.000	1	1	1	20	73.1876	72.9550	-0.2326	1	0	0	0	1	0
	20	307	2	3	5.0	25.00	125.000	1	1	1	20	72.3563	73.0725	0.7162	2	1	0	0	0	0
	21	308	3	3	6.0	36.00	216.000	1	0	1	20	54.6839	50.3572	-4.3267	3	0	1	0	0	0
	22	310	6	3	8.0	64.00	512.000	0	0	1	20	58.5512	56.5516	-1.9996	4	0	0	0	0	1
	23	401	3	4	4.9	24.01	117.649	0	0	1	20	74.2640	76.0108	1.7468	2	0	1	0	0	0
	24	402	5	4	5.5	30.25	166.375	0	1	1	20	95.5665	87.7000	-7.8665	2	0	0	0	1	0
	25	403	4	4	5.9	34.81	205.379	0	0	1	20	78.1623	78.5140	0.3517	2	0	0	1	0	0
	26	501	5	5	3.5	12.25	42.875	0	1	1	20	77.3265	77.9756	0.6491	1	0	0	0	1	0
	27	502	4	5	3.7	13.69	50.653	1	0	1	2	73.1833	70.4662	-2.7171	1	0	0	1	0	0
	28	503	6	5	4.1	16.81	68.921	1	0	1	20	84.2188	73.1236	-11.0951	2	0	0	0	0	1
	29	504	2	5	5.1	26.01	132.651	1	1	1	19	66.2525	67.0082	0.7557	2	1	0	0	0	0
	30	507	3	5	8.1	65.61	531.441	0	0	1	20	70.1936	72.5405	2.3468	4	0	1	0	0	0
	31	601	5	6	0.8	0.64	0.512	1	1	1	19	80.5868	88.6233	8.0365	0	0	0	0	1	0
	32	602	4	6	0.9	0.81	0.729	1	0	1	20	72.4720	74.5725	2.1005	0	0	0	1	0	0
	33	603	2	6	1.7	2.89	4.913	1	1	1	20	72.4982	70.5346	-1.9636	0	1	0	0	0	0
	34	604	3	6	3.7	13.69	50.653	1	1	1	20	70.3777	72.7823	2.4046	1	0	1	0	0	0
	35	605	3	6	3.7	13.69	50.653	1	0	1	20	69.0384	69.1522	0.1138	1	0	1	0	0	0
	36	606	6	6	4.7	22.09	103.823	1	0	1	20	58.0349	59.1539	1.1190	2	0	0	0	0	1
	37	608	3	6	6.7	44.89	300.763	1	0	1	20	61.1942	62.0725	0.8783	3	0	1	0	0	0

means by position within data collection
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	Obs	newid	Position	Infant	c_pma	c_pma2	c_pma3	Caffeine	Probe	_TYPE_	_FREQ_	gmeanco	mean1							
diff	pmacat	d2	d3	d4	d5	d6														
	38	611	6	6	9.7	94.09	912.67	0	0	1	20	63.6750	61.6750	-2.0000	4	0	0	0	0	1
	39	612	4	6	10.7	114.49	1225.04	0	0	1	20	64.4250	62.4250	-2.0000	5	0	0	1	0	0
	40	613	2	6	11.7	136.89	1601.61	0	1	1	16	64.9688	64.6750	-0.2938	5	1	0	0	0	0
	41	701	6	7	6.6	43.56	287.50	1	0	1	20	78.3950	76.8028	-1.5922	3	0	0	0	0	1
	42	702	5	7	6.8	46.24	314.43	1	1	1	20	76.0460	76.0330	-0.0130	3	0	0	0	1	0
	43	703	5	7	7.1	50.41	357.91	1	1	1	20	79.4950	77.9376	-1.5574	3	0	0	0	1	0
	44	704	3	7	8.1	65.61	531.44	1	0	1	10	76.0465	74.8293	-1.2172	4	0	1	0	0	0
	45	801	6	8	6.6	43.56	287.50	0	0	1	20	82.5330	78.2002	-4.3328	3	0	0	0	0	1
	46	802	4	8	6.8	46.24	314.43	1	0	1	20	75.3036	72.9484	-2.3552	3	0	0	1	0	0
	47	803	2	8	7.1	50.41	357.91	1	1	1	20	74.2056	76.2566	2.0510	3	1	0	0	0	0
	48	804	3	8	8.1	65.61	531.44	1	0	1	17	78.7497	76.3036	-2.4461	4	0	1	0	0	0
	49	901	6	9	6.6	43.56	287.50	0	0	1	20	80.7096	79.6333	-1.0762	3	0	0	0	0	1
	50	902	6	9	6.6	43.56	287.50	0	1	1	15	80.5328	80.1188	-0.4140	3	0	0	0	0	1
	51	903	5	9	7.1	50.41	357.91	0	1	1	20	84.9365	78.5517	-6.3848	3	0	0	0	1	0
	52	1001	6	10	4.0	16.00	64.00	1	0	1	20	73.3293	71.0152	-2.3142	2	0	0	0	0	1
	53	1002	2	10	4.1	16.81	68.92	1	1	1	20	78.6253	72.8066	-5.8187	2	1	0	0	0	0
	54	1003	4	10	4.8	23.04	110.59	1	0	1	20	77.2344	75.3542	-1.8802	2	0	0	1	0	0
	55	1101	5	11	0.9	0.81	0.73	1	1	1	20	71.8592	73.9933	2.1342	0	0	0	0	1	0
	56	1102	4	11	1.0	1.00	1.00	1	0	1	20	53.4556	66.6442	13.1886	0	0	0	1	0	0
	57	1104	6	11	2.7	7.29	19.68	1	0	1	20	66.8500	64.1250	-2.7250	1	0	0	0	0	1
	58	1107	3	11	5.7	32.49	185.19	1	0	1	19	63.6053	58.3250	-5.2803	2	0	1	0	0	0
	59	1108	2	11	6.7	44.89	300.76	1	1	1	20	75.1750	70.6818	-4.4932	3	1	0	0	0	0
	60	1110	6	11	8.7	75.69	658.50	0	0	1	20	57.8500	55.0000	-2.8500	4	0	0	0	0	1
	61	1111	2	11	9.8	96.04	941.19	0	1	1	19	55.4211	46.4750	-8.9461	4	1	0	0	0	0
	62	1112	5	11	10.7	114.49	1225.04	0	1	1	20	59.7667	58.3500	-1.4167	5	0	0	0	1	0
	63	1202	2	12	2.8	7.84	21.95	1	1	1	6	77.4000	75.0500	-2.3500	1	1	0	0	0	0
	64	1204	6	12	4.6	21.16	97.34	1	0	1	2	72.0000	76.2000	4.2000	2	0	0	0	0	1
	65	1206	6	12	6.6	43.56	287.50	1	0	1	17	73.9333	73.5000	-0.4333	3	0	0	0	0	1
	66	1209	4	12	9.6	92.16	884.74	0	0	1	5	80.8750	75.3750	-5.5000	4	0	0	1	0	0
	67	1303	6	13	2.0	4.00	8.00	1	0	1	19	77.1316	80.8000	3.6684	1	0	0	0	0	1
	68	1304	4	13	3.0	9.00	27.00	1	0	1	19	66.4474	68.9500	2.5026	1	0	0	1	0	0
	69	1305	5	13	4.0	16.00	64.00	1	1	1	19	72.1053	74.3250	2.2197	2	0	0	0	1	0
	70	1306	2	13	5.0	25.00	125.00	1	1	1	20	64.9500	62.1000	-2.8500	2	1	0	0	0	0
	71	1307	3	13	6.0	36.00	216.00	1	0	1	19	64.5789	64.0500	-0.5289	3	0	1	0	0	0
	72	1308	5	13	7.0	49.00	343.00	1	1	1	19	70.3056	65.4750	-4.8306	3	0	0	0	1	0
	73	1309	3	13	8.0	64.00	512.00	1	0	1	20	68.7964	75.3197	6.5233	4	0	1	0	0	0
	74	1401	1	14	1.6	2.56	4.10	1	0	1	20	94.1500	94.1500	0.0000	0	0	0	0	0	0

means by position within data collection
 prep for proc mixed on march 8 2012

16:37 Sunday, April 22, 2012 923

Obs	newid	Position	Infant	c_pma	c_pma2	c_pma3	Caffeine	Probe	_TYPE_	_FREQ_	gmeanco	mean1							
diff	pmacat	d2	d3	d4	d5	d6													
75	1501	5	15	3.5	12.25	42.88	1	1	1	20	81.2368	81.0500	-0.1868	1	0	0	0	1	0
76	1502	2	15	3.7	13.69	50.65	1	1	1	19	78.7105	76.7000	-2.0105	1	1	0	0	0	0
77	1503	6	15	4.5	20.25	91.13	1	0	1	19	71.8684	74.3000	2.4316	2	0	0	0	0	1
78	1504	4	15	5.7	32.49	185.19	1	0	1	6	74.1498	91.3431	17.1933	2	0	0	1	0	0
79	1601	6	16	5.1	26.01	132.65	0	0	1	19	73.3684	78.8750	5.5066	2	0	0	0	0	1
80	1604	4	16	7.6	57.76	438.98	1	0	1	19	65.5263	74.8250	9.2987	3	0	0	1	0	0
81	1605	5	16	8.5	72.25	614.13	0	1	1	20	72.2624	70.6433	-1.6190	4	0	0	0	1	0
82	1701	2	17	1.5	2.25	3.38	1	1	1	18	86.8749	80.6706	-6.2042	0	1	0	0	0	0
83	1702	4	17	1.7	2.89	4.91	1	0	1	20	82.6173	81.7833	-0.8340	0	0	0	1	0	0
84	1801	6	18	3.9	15.21	59.32	1	0	1	20	83.2110	83.2423	0.0313	1	0	0	0	0	1
85	1802	4	18	4.5	20.25	91.13	1	0	1	20	85.3627	89.3967	4.0340	2	0	0	1	0	0
86	1804	2	18	6.5	42.25	274.63	1	1	1	20	75.8288	74.7344	-1.0945	3	1	0	0	0	0
87	1810	5	18	12.5	156.25	1953.13	0	1	1	20	79.5772	76.5183	-3.0589	6	0	0	0	1	0
88	1811	3	18	13.5	182.25	2460.38	0	0	1	20	78.4648	73.4633	-5.0014	6	0	1	0	0	0
89	2001	4	20	5.6	31.36	175.62	0	0	1	19	81.0592	79.7375	-1.3217	2	0	0	1	0	0
90	2002	6	20	5.8	33.64	195.11	0	0	1	20	75.7212	84.8667	9.1455	2	0	0	0	0	1
91	2003	4	20	6.5	42.25	274.63	1	0	1	20	80.0184	79.1800	-0.8384	3	0	0	1	0	0
92	2004	5	20	7.5	56.25	421.88	1	1	1	20	80.7971	82.1300	1.3329	3	0	0	0	1	0
93	2005	3	20	8.6	73.96	636.06	0	0	1	20	76.8507	79.5847	2.7340	4	0	1	0	0	0
94	2202	6	22	6.1	37.21	226.98	1	0	1	20	80.3841	78.7700	-1.6141	3	0	0	0	0	1
95	2301	6	23	0.8	0.64	0.51	0	0	1	20	59.4864	69.3633	9.8769	0	0	0	0	0	1
96	2302	5	23	1.0	1.00	1.00	1	1	1	20	74.3943	75.5105	1.1161	0	0	0	0	1	0
97	2303	2	23	1.8	3.24	5.83	1	1	1	11	66.6906	73.1319	6.4413	0	1	0	0	0	0
98	2304	3	23	2.8	7.84	21.95	1	0	1	19	67.0938	77.8201	10.7263	1	0	1	0	0	0
99	2309	4	23	7.8	60.84	474.55	1	0	1	20	57.8692	56.1400	-1.7292	3	0	0	1	0	0
100	2401	6	24	4.8	23.04	110.59	1	0	1	20	87.2061	85.2942	-1.9119	2	0	0	0	0	1
101	2403	4	24	5.7	32.49	185.19	1	0	1	20	79.5240	79.1614	-0.3626	2	0	0	1	0	0
102	2502	4	25	6.5	42.25	274.63	1	0	1	20	62.6586	67.2800	4.6214	3	0	0	1	0	0
103	2602	4	26	6.7	44.89	300.76	1	0	1	6	61.3488	66.6692	5.3204	3	0	0	1	0	0

Dep var is difference between average cerebral oxygenation 924
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 2 is ref group
march 8 2012

The Mixed Procedure

Model Information

Data Set WORK.MN3
Dependent Variable diff
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containmentment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
d3	2	0 1
d4	2	0 1
d5	2	0 1
d6	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	10
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	10

Dep var is difference between average cerebral oxygenation 925
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 2 is ref group
march 8 2012

The Mixed Procedure

Number of Observations

Number of Observations Read 103
Number of Observations Used 103
Number of Observations Not Used 0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	580.47060403	
1	2	580.39868314	0.00000039
2	1	580.39860350	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	0.4595
Residual		18.1336

Fit Statistics

-2 Res Log Likelihood	580.4
AIC (smaller is better)	584.4
AICC (smaller is better)	584.5
BIC (smaller is better)	586.8

Dep var is difference between average cerebral oxygenation
time is centered post menstrual age
difference between position 1 and 2 is ref group
march 8 2012

926

16:37 Sunday, April 22, 2012

The Mixed Procedure

Solution for Fixed Effects

Effect	d3	d4	d5	d6	Standard		DF	t Value	Pr > |t|
					Estimate	Error			
Intercept					8.2512	3.7713	23	2.19	0.0391
c_pma					-0.5704	0.1505	74	-3.79	0.0003
d3	0				-1.4739	1.4611	74	-1.01	0.3164
d3	1				0	.	.	.	.
d4		0			-2.9463	1.3356	74	-2.21	0.0305
d4		1			0	.	.	.	.
d5			0		-0.9232	1.4135	74	-0.65	0.5157
d5			1		0	.	.	.	.
d6				0	-1.1268	1.3331	74	-0.85	0.4007
d6				1	0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num		Den		F Value	Pr > F
	DF	DF	DF	DF		
c_pma	1	74	14.36	0.0003		
d3	1	74	1.02	0.3164		
d4	1	74	4.87	0.0305		
d5	1	74	0.43	0.5157		
d6	1	74	0.71	0.4007		

Dep var is difference between average cerebral oxygenation 927
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 3 is ref group
Final Model
march 8 2012

The Mixed Procedure

Model Information

Data Set WORK.MN3
Dependent Variable diff
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
d2	2	0 1
d4	2	0 1
d5	2	0 1
d6	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	10
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	10

Dep var is difference between average cerebral oxygenation 928
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 3 is ref group
Final Model
march 8 2012

The Mixed Procedure

Number of Observations

Number of Observations Read 103
Number of Observations Used 103
Number of Observations Not Used 0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	580.71384290	
1	2	580.64557443	0.00000038
2	1	580.64549799	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	0.4500
Residual		18.1863

Fit Statistics

-2 Res Log Likelihood	580.6
AIC (smaller is better)	584.6
AICC (smaller is better)	584.8
BIC (smaller is better)	587.0

Dep var is difference between average cerebral oxygenation
time is centered post menstrual age
difference between position 1 and 3 is ref group
Final Model
march 8 2012

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16:37 Sunday, April 22, 2012

The Mixed Procedure

Solution for Fixed Effects

Effect	d2	d4	d5	d6	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept					2.7614	3.5043	23	0.79	0.4387
c_pma					-0.5602	0.1493	74	-3.75	0.0003
d2	0				1.2855	1.4521	74	0.89	0.3789
d2	1				0	.	.	.	.
d4		0			-1.6075	1.3288	74	-1.21	0.2302
d4		1			0	.	.	.	.
d5			0		0.4185	1.3970	74	0.30	0.7654
d5			1		0	.	.	.	.
d6				0	0.2095	1.3364	74	0.16	0.8759
d6				1	0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
c_pma	1	74	14.07	0.0003
d2	1	74	0.78	0.3789
d4	1	74	1.46	0.2302
d5	1	74	0.09	0.7654
d6	1	74	0.02	0.8759

Dep var is difference between average cerebral oxygenation 930
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 4 is ref group
Final Model
march 8 2012

The Mixed Procedure

Model Information

Data Set WORK.MN3
Dependent Variable diff
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
d2	2	0 1
d3	2	0 1
d5	2	0 1
d6	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	10
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	10

Dep var is difference between average cerebral oxygenation 931
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 4 is ref group
Final Model
march 8 2012

The Mixed Procedure

Number of Observations

Number of Observations Read	103
Number of Observations Used	103
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	581.15625809	
1	2	581.08516802	0.00000045
2	1	581.08507767	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	0.4658
Residual		18.2623

Fit Statistics

-2 Res Log Likelihood	581.1
AIC (smaller is better)	585.1
AICC (smaller is better)	585.2
BIC (smaller is better)	587.4

Dep var is difference between average cerebral oxygenation
time is centered post menstrual age
difference between position 1 and 4 is ref group
Final Model
march 8 2012

932

16:37 Sunday, April 22, 2012

The Mixed Procedure

Solution for Fixed Effects

Effect	d2	d3	d5	d6	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept					-3.1170	3.3925	23	-0.92	0.3677
c_pma					-0.5585	0.1508	74	-3.70	0.0004
d2	0				2.7434	1.3493	74	2.03	0.0456
d2	1				0	.	.	.	.
d3		0			1.3436	1.3507	74	0.99	0.3231
d3		1			0	.	.	.	.
d5			0		1.8783	1.3084	74	1.44	0.1553
d5			1		0	.	.	.	.
d6				0	1.6686	1.2263	74	1.36	0.1778
d6				1	0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
c_pma	1	74	13.71	0.0004
d2	1	74	4.13	0.0456
d3	1	74	0.99	0.3231
d5	1	74	2.06	0.1553
d6	1	74	1.85	0.1778

Dep var is difference between average cerebral oxygenation 933
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 5 is ref group
Final Model
march 8 2012

The Mixed Procedure

Model Information

Data Set WORK.MN3
Dependent Variable diff
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
d2	2	0 1
d3	2	0 1
d4	2	0 1
d6	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	10
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	10

Dep var is difference between average cerebral oxygenation 934
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 5 is ref group
Final Model
march 8 2012

The Mixed Procedure

Number of Observations

Number of Observations Read	103
Number of Observations Used	103
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	580.59347816	
1	2	580.51820681	0.00000046
2	1	580.51811432	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	0.4738
Residual		18.1441

Fit Statistics

-2 Res Log Likelihood	580.5
AIC (smaller is better)	584.5
AICC (smaller is better)	584.6
BIC (smaller is better)	586.9

Dep var is difference between average cerebral oxygenation 935
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 5 is ref group
Final Model
march 8 2012

The Mixed Procedure

Solution for Fixed Effects

Effect	d2	d3	d4	d6	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept					4.8504	3.5530	23	1.37	0.1854
c_pma					-0.5662	0.1502	74	-3.77	0.0003
d2	0				0.7814	1.4146	74	0.55	0.5824
d2	1				0	.	.	.	.
d3		0			-0.6329	1.4067	74	-0.45	0.6541
d3		1			0	.	.	.	.
d4			0		-2.1122	1.2961	74	-1.63	0.1074
d4			1		0	.	.	.	.
d6				0	-0.2937	1.2960	74	-0.23	0.8213
d6				1	0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
c_pma	1	74	14.20	0.0003
d2	1	74	0.31	0.5824
d3	1	74	0.20	0.6541
d4	1	74	2.66	0.1074
d6	1	74	0.05	0.8213

Dep var is difference between average cerebral oxygenation 936
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 6 is ref group
Final Model
march 8 2012

The Mixed Procedure

Model Information

Data Set WORK.MN3
Dependent Variable diff
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26
d2	2	0 1
d3	2	0 1
d4	2	0 1
d5	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	10
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	10

Dep var is difference between average cerebral oxygenation 937
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 6 is ref group
Final Model
march 8 2012

The Mixed Procedure

Number of Observations

Number of Observations Read	103
Number of Observations Used	103
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	580.61846337	
1	2	580.54564246	0.00000042
2	1	580.54555791	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	0.4647
Residual		18.1600

Fit Statistics

-2 Res Log Likelihood	580.5
AIC (smaller is better)	584.5
AICC (smaller is better)	584.7
BIC (smaller is better)	586.9

Dep var is difference between average cerebral oxygenation 938
time is centered post menstrual age 16:37 Sunday, April 22, 2012
difference between position 1 and 6 is ref group
Final Model
march 8 2012

The Mixed Procedure

Solution for Fixed Effects

Effect	d2	d3	d4	d5	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept					3.9966	3.4232	23	1.17	0.2550
c_pma					-0.5662	0.1505	74	-3.76	0.0003
d2	0				0.9981	1.3441	74	0.74	0.4601
d2	1				0	.	.	.	.
d3		0			-0.4175	1.3558	74	-0.31	0.7590
d3		1			0	.	.	.	.
d4			0		-1.8964	1.2239	74	-1.55	0.1255
d4			1		0	.	.	.	.
d5				0	0.1282	1.3057	74	0.10	0.9221
d5				1	0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
c_pma	1	74	14.15	0.0003
d2	1	74	0.55	0.4601
d3	1	74	0.09	0.7590
d4	1	74	2.40	0.1255
d5	1	74	0.01	0.9221


```
*libname pos 'S:\SED\Elser-NIRS\Dissertation\Dis_Subject_folders';
*ods rtf file = 'S:\SED\Elser-NIRS\Dissertation\output\Chapter 4\soundmixed_04042012';
*****
*****compute means for sound analysis*****
*****
```

```
proc means data=work.soundcat_04042012;
class infant dc gping;
var scto2;
id pa caffeine ivh ga probe;
output out = mns mean=scto2mn; /*scto2mn is dependent variable for proc mixed*/
```

/*main

independent variables will be the dummy codes created below*/

```
title1' file containing data to be averaged';
title2' by the gping variable';
title3' april 4 2012';

proc contents data=mns;

proc print data=mns;
where _type_ eq 7;
*****
*****create dummy codes for *****;
*****proc mixed*****;
*****;
data mns2;
set mns;
if _type_ eq 7;

if gping eq 2 then d2 = 1; /* if d2 = 1 mnscto2 is over 30 seconds right after peak sound*/
else d2 = 0;

peak*/
if gping eq 3 then d3 = 1; /* if d3 = 1 mnscto2 is over seconds from 30 to 60 second after
else d3 = 0;

peak*/
if gping eq 4 then d4 = 1; /* if d4 = 1 mnscto2 is over seconds from 60 to 90 seconds after
else d4 = 0;

peak*/
if gping eq 5 then d5 = 1; /* if d5 = 1 mnscto2 is over seconds from 90 to 120 seconds after
else d5 = 0;

proc means data=mns2;
class gping;
var scto2mn;
run;
*****;
*****proc mixed*****;
*****;
proc mixed data=mns2;
class infant d2 d3 d4 d5 caffeine probe;
model scto2mn = d2 d3 d4 d5 caffeine probe ga/ s ;
random intercept dc /subject = infant type = vc ;

title1' Dep var is averaged 30 second scto2 means ';
title2' time before and after peak sound is defined by';
title3' the dummy variables';
title4' Full Model with ga, caffeine, and probe as covariates';
run;

proc mixed data=mns2;
class infant d2 d3 d4 d5 caffeine;
model scto2mn = d2 d3 d4 d5 caffeine/ s ;
random intercept dc /subject = infant type = vc ;

title1' Dep var is averaged 30 second scto2 means ';
```

`title2'` time before and after peak sound is defined by';
`title3'` the dummy variables';
`title4'` Final model with caffeine as covariate';
run;

4

Appendix G Chapter 5 SAS Output: General Linear Mixed Model Using SPTSA Coefficients

Dep variable is reg1 (Y= SpO2, X= SctO2) multiplied by 10
independent variable is caffeine, probe, and pa

The Mixed Procedure

Model Information

Data Set WORK.TEMP2
Dependent Variable reg1by10
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containment

Class Level Information

Class	Levels	Values
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	7
Columns in Z Per Subject	25
Subjects	25
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	140
Number of Observations Used	127
Number of Observations Not Used	13

Dep variable is reg1 (Y= SpO2, X= SctO2) multiplied by 10
independent variable is caffeine, probe, and pa

2012

march 20, 2012

The Mixed Procedure

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	719.93675621	
1	3	705.26917850	0.00058893
2	1	705.11068393	0.00002565
3	1	705.10432785	0.00000006
4	1	705.10431371	0.00000000

Convergence criteria met.
Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	3.4174
Residual		11.8051

Fit Statistics

-2 Res Log Likelihood	705.1
AIC (smaller is better)	709.1
AICC (smaller is better)	709.2
BIC (smaller is better)	711.5

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept			0.5840	0.8286	22	0.70	0.4883
PA			0.1035	0.05456	100	1.90	0.0606
pa2			-0.00112	0.000900	100	-1.25	0.2143
Caffeine	0		0.4975	0.8860	100	0.56	0.5757
Caffeine	1		0	.	.	.	.
Probe		0	-0.4028	0.6641	100	-0.61	0.5455
Probe		1	0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	100	3.60	0.0606
pa2	1	100	1.56	0.2143
Caffeine	1	100	0.32	0.5757
Probe	1	100	0.37	0.5455

17, 2012 106

Dep variable is reg1 (Y= SpO2, X= SctO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine, probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Model Information

Data Set	WORK.TEMP2
Dependent Variable	reg1by10
Covariance Structure	Variance Components
Subject Effect	Infant
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	6
Columns in Z Per Subject	25
Subjects	25
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	140
Number of Observations Used	127

17, 2012 107

Dep variable is reg1 (Y= SpO2, X= SctO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine, probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Number of Observations

Number of Observations Not Used 13

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
-----------	-------------	-----------------	-----------

0	1	709.35507710	
1	3	694.67454963	0.00071801
2	1	694.48499680	0.00003631
3	1	694.47618848	0.00000011
4	1	694.47616179	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm Subject Estimate

Infant	Infant	3.4386
Residual		11.8570

Fit Statistics

-2 Res Log Likelihood	694.5
AIC (smaller is better)	698.5
AICC (smaller is better)	698.6
BIC (smaller is better)	700.9

Dep variable is reg1 (Y= SpO2, X= SctO2) multiplied by 10 11:47 Tuesday, April

17, 2012 108

independent variable is caffeine, probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept		1.0731	0.7322	22	1.47	0.1569	
PA		0.03943	0.01867	101	2.11	0.0372	
Caffeine 0		0.09291	0.8266	101	0.11	0.9107	
Caffeine 1		0	.	.	.	.
Probe 0		-0.3868	0.6654	101	-0.58	0.5623	
Probe 1		0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	101	4.46	0.0372
Caffeine	1	101	0.01	0.9107
Probe	1	101	0.34	0.5623

17, 2012 109

Dep variable is reg1 (Y= SctO2, X= HR) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine, probe, and pa
march 20, 2012

The Mixed Procedure

Model Information

Data Set	WORK.TEMP2
Dependent Variable	reg2by10
Covariance Structure	Variance Components
Subject Effect	Infant
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	7
Columns in Z Per Subject	25
Subjects	25
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	140
Number of Observations Used	129
Number of Observations Not Used	11

17, 2012 110

Dep variable is reg1 (Y= SctO2, X= HR) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine, probe, and pa
march 20, 2012

The Mixed Procedure

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	266.12120981	
1	1	266.12120981	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	0
Residual		0.3661

Fit Statistics

-2 Res Log Likelihood	266.1
AIC (smaller is better)	268.1
AICC (smaller is better)	268.2
BIC (smaller is better)	269.3

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept		0.08496	0.1237	23	0.69	0.4991	
PA		0.005505	0.009264	101	0.59	0.5537	
pa2		-0.00017	0.000153	101	-1.09	0.2764	
Caffeine	0	0.04748	0.1378	101	0.34	0.7311	
Caffeine	1	0	.	.	.	.

Dep variable is reg1 (Y= SctO2, X= HR) multiplied by 10 11:47 Tuesday, April

17, 2012 111

independent variable is caffeine, probe, and pa
march 20, 2012

The Mixed Procedure

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
Probe	0	-0.07305	0.1108	101	-0.66	0.5112	
Probe	1	0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	101	0.35	0.5537
pa2	1	101	1.20	0.2764
Caffeine	1	101	0.12	0.7311
Probe	1	101	0.43	0.5112

17, 2012 112

Dep variable is reg1 (Y= SctO2, X= HR) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine,probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Model Information

Data Set	WORK.TEMP2
Dependent Variable	reg2by10
Covariance Structure	Variance Components
Subject Effect	Infant
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	6
Columns in Z Per Subject	25
Subjects	25
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	140
Number of Observations Used	129

17, 2012 113

Dep variable is reg1 (Y= SctO2, X= HR) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine,probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Number of Observations

Number of Observations Not Used 11

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
-----------	-------------	-----------------	-----------

0	1	251.58065908	
1	1	251.58065908	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
----------	---------	----------

Infant	Infant	0
Residual		0.3667

Fit Statistics

-2 Res Log Likelihood	251.6
AIC (smaller is better)	253.6
AICC (smaller is better)	253.6
BIC (smaller is better)	254.8

17, 2012 114

Dep variable is reg1 (Y= SctO2, X= HR) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine,probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept			0.1581	0.1042	23	1.52	0.1426
PA			-0.00416	0.002807	102	-1.48	0.1418
Caffeine 0			-0.00990	0.1275	102	-0.08	0.9383
Caffeine 1			0	.	.	.	.
Probe 0			-0.06937	0.1108	102	-0.63	0.5328
Probe 1			0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	102	2.19	0.1418
Caffeine	1	102	0.01	0.9383
Probe	1	102	0.39	0.5328

17, 2012 115

Dep variable is reg3 (Y=HR, X= SctO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine, probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Model Information

Data Set	WORK.TEMP2
Dependent Variable	reg3by10
Covariance Structure	Variance Components
Subject Effect	Infant
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	7
Columns in Z Per Subject	25
Subjects	25
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	140
Number of Observations Used	127

17, 2012 116

Dep variable is reg3 (Y=HR, X= SctO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine, probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Number of Observations

Number of Observations Not Used	13
---------------------------------	----

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
-----------	-------------	-----------------	-----------

0	1	717.15765848	
1	3	713.91676679	0.00016447
2	1	713.87335327	0.00000275
3	1	713.87267211	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

4

Cov Parm	Subject	Estimate
----------	---------	----------

Infant	Infant	1.4037
Residual		13.7723

Fit Statistics

-2 Res Log Likelihood	713.9
AIC (smaller is better)	717.9
AICC (smaller is better)	718.0
BIC (smaller is better)	720.3

17, 2012 117

Dep variable is reg3 (Y=HR, X= SctO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine, probe, and pa
march 20, 2012
Final Model

The Mixed Procedure

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept			-1.8367	0.8055	23	-2.28	0.0322
PA			0.1670	0.05819	99	2.87	0.0050
pa2			-0.00354	0.000976	99	-3.63	0.0005
Caffeine 0			1.1760	0.9058	99	1.30	0.1972
Caffeine 1			0	.	.	.	.
Probe 0			1.5006	0.6958	99	2.16	0.0335
Probe 1			0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	99	8.23	0.0050
pa2	1	99	13.16	0.0005
Caffeine	1	99	1.69	0.1972
Probe	1	99	4.65	0.0335

17, 2012 118

Dep variable is reg4 (Y= SctO2, X=SpO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine and pa
march 20, 2012

The Mixed Procedure

Model Information

Data Set	WORK.TEMP2
Dependent Variable	reg4by10
Covariance Structure	Variance Components
Subject Effect	Infant
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	7
Columns in Z Per Subject	25
Subjects	25
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	140
Number of Observations Used	129
Number of Observations Not Used	11

17, 2012 119

Dep variable is reg4 (Y= SctO2, X=SpO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine and pa
march 20, 2012

The Mixed Procedure

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	611.04123175	
1	2	582.60044147	0.00111050
2	1	582.37642866	0.00006797
3	1	582.36386646	0.00000031
4	1	582.36381095	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm Subject Estimate

Infant	Infant	2.9339
Residual		3.5354

Fit Statistics

-2 Res Log Likelihood	582.4
AIC (smaller is better)	586.4
AICC (smaller is better)	586.5
BIC (smaller is better)	588.8

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept			0.3724	0.5361	23	0.69	0.4942
PA			-0.02453	0.02993	101	-0.82	0.4143
pa2			0.000701	0.000493	101	1.42	0.1585
Caffeine 0			-0.9775	0.5163	101	-1.89	0.0612
Caffeine 1			0	.	.	.	.
Probe 0			0.6975	0.3656	101	1.91	0.0592
Probe 1			0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	101	0.67	0.4143
pa2	1	101	2.02	0.1585
Caffeine	1	101	3.58	0.0612
Probe	1	101	3.64	0.0592

17, 2012 121

Dep variable is reg4 (Y= SctO2, X=SpO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine and pa
march 20, 2012
Final Model

The Mixed Procedure

Model Information

Data Set	WORK.TEMP2
Dependent Variable	reg4by10
Covariance Structure	Variance Components
Subject Effect	Infant
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
Infant	25	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 21 22 23 24 25 26
Caffeine	2	0 1
Probe	2	0 1

Dimensions

Covariance Parameters	2
Columns in X	6
Columns in Z Per Subject	25
Subjects	25
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	140
Number of Observations Used	129

17, 2012 122

Dep variable is reg4 (Y= SctO2, X=SpO2) multiplied by 10 11:47 Tuesday, April

independent variable is caffeine and pa
march 20, 2012
Final Model

The Mixed Procedure

Number of Observations

Number of Observations Not Used 11

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
-----------	-------------	-----------------	-----------

0	1	598.06147248	
1	2	571.05360436	0.00066775
2	1	570.92694043	0.00002500
3	1	570.92256363	0.00000004
4	1	570.92255657	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm Subject Estimate

Infant	Infant	2.6757
Residual		3.6189

Fit Statistics

-2 Res Log Likelihood	570.9
AIC (smaller is better)	574.9
AICC (smaller is better)	575.0
BIC (smaller is better)	577.4

Dep variable is reg4 (Y= SctO2, X=SpO2) multiplied by 10 11:47 Tuesday, April

17, 2012 123

independent variable is caffeine and pa
march 20, 2012
Final Model

The Mixed Procedure

Solution for Fixed Effects

Effect	Caffeine	Probe	Standard Estimate	Error	DF	t Value	Pr > |t|
Intercept			0.07765	0.4834	23	0.16	0.8738
PA			0.01510	0.01080	102	1.40	0.1652
Caffeine 0			-0.6745	0.4790	102	-1.41	0.1621
Caffeine 1			0	.	.	.	.
Probe 0			0.6892	0.3692	102	1.87	0.0648
Probe 1			0	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
PA	1	102	1.95	0.1652
Caffeine	1	102	1.98	0.1621
Probe	1	102	3.48	0.0648

```

*****
*****
*libname pos 'S:\SED\Elser-NIRS\Dissertation\Dis_Subject_folders';
*ods rtf file = 'S:\SED\Elser-NIRS\Dissertation\output\mixed_03202012';

*****
*****work.tsaregression is the imported excel file with*****
*****regression coefficientsfor within*****
*****
data work.tsareg_03202012; *sas file is regress2_03162012;
    set work.tsaregressions;

    reg1by10 = reg1*10;
    reg2by10 = reg2*10;
    reg3by10 = reg3*10;
    reg4by10 = reg4*10;

    attrib reg1by10 label = 'y = spo2 X = scto2 reg mult by 10';
    attrib reg2by10 label = 'y = scto2 x = hr reg mult by 10';
    attrib reg3by10 label = 'y = hr x = scto2 reg mult by 10';
    attrib reg4by10 label = 'y = scto2 x = spo2 reg mult by 10';

proc contents data=work.tsareg_03202012;
/*
*****
*****plot the regression coefficients by data collection*****
*****
proc gplot data=work.tsareg_03202012;
    symbol1 color = blue; *line = 1;

    axis1 label=none;
    axis2 label=none;
    *label abdtp = 'abdtp';
    plot reg1by10*dc;
                                * / vaxis = 20 to 80 by 5;

    title1' regression coefficients of spo2 on scto2';
    title2' march 20 2012';

proc gplot data=work.tsareg_03202012;
    symbol1 color = blue; *line = 1;

    axis1 label=none;
    axis2 label=none;
    *label abdtp = 'abdtp';
    plot reg2by10*dc;
                                * / vaxis = 20 to 80 by 5;

    title1' regression coefficients of scto2 on hr';
    title2' march 20 2012';

proc gplot data=work.tsareg_03202012;
    symbol1 color = blue; *line = 1;

    axis1 label=none;
    axis2 label=none;
    *label abdtp = 'abdtp';

```

```

plot reg3by10*dc;
                                * / vaxis = 20 to 80 by 5;

title1' regression coefficients of hr on scto2';
    title2' march 20 2012';

proc gplot data=work.tsareg_03202012;
symbol1 color = blue; *line = 1;

axis1 label=none;
axis2 label=none;
*label abctp = 'abctp';
plot reg4by10*dc;
                                * / vaxis = 20 to 80 by 5;

title1' regression coefficients of scto2 on spo2';
    title2' march 20 2012';
*/

*****
*****pick up all data and write out a file by*****
*****infant and data collection*****
*****
data temp;
    set work.sound_03142012;
    by infant dc;
    if last.dc
    then output;

proc print data=temp;

*****
*****match merge this with data containing*****
*****the regression coefficients*****
*****
data temp2;
    merge temp work.tsareg_03202012;
    by infant dc;
    pa2 = pa*pa;
proc print data=temp2;
var infant dc pa caffeine reg1by10 reg2by10 reg3by10 reg4by10;
title1' data for prox mixed chapter 5';

proc means data=temp2;
class pa;
var reg1by10 reg2by10 reg3by10 reg4by10;

*****
*****scatter plot of regression 2 by postnatal age*****
*****
/*proc gplot data=temp2;
symbol1 color = blue; *line = 1;

axis1 label=none;
axis2 label=none;
*label abctp = 'abctp';
plot reg3*pa;
                                * / vaxis = 20 to 80 by 5;

title1' reg3 by post natal age';

```

title2' march 20 2012';

```
*****  
*****proc mixed on regression 2*****  
*****with pa as the independent variable*****  
*****  
*/
```

```
proc mixed data=temp2;  
class infant caffeine probe;  
model reg1by10 = pa pa2 caffeine probe/ s ;  
random infant /subject = infant;
```

title1' Dep variable is reg1 (Y= SpO2, X= SctO2) multiplied by 10 '
title2' independent variable is caffeine, probe, and pa';
title3' march 20, 2012';
run;

```
proc mixed data=temp2;  
class infant caffeine probe;  
model reg1by10 = pa caffeine probe/ s ;  
random infant /subject = infant;
```

title1' Dep variable is reg1 (Y= SpO2, X= SctO2) multiplied by 10 '
title2' independent variable is caffeine, probe, and pa';
title3' march 20, 2012';
title4' Final Model';
run;

```
proc mixed data=temp2;  
class infant caffeine probe;  
model reg2by10 = pa pa2 caffeine probe/ s ;  
random infant /subject = infant;
```

title1' Dep variable is reg1 (Y= SctO2, X= HR) multiplied by 10 '
title2' independent variable is caffeine, probe, and pa';
title3' march 20, 2012';
run;

```
proc mixed data=temp2;  
class infant caffeine probe;  
model reg2by10 = pa caffeine probe/ s ;  
random infant /subject = infant;
```

title1' Dep variable is reg1 (Y= SctO2, X= HR) multiplied by 10 '
title2' independent variable is caffeine,probe, and pa';
title3' march 20, 2012';
title4' Final Model';
run;

```
proc mixed data=temp2;  
class infant caffeine probe;  
model reg3by10 = pa pa2 caffeine probe/ s ;  
random infant /subject = infant;
```

title1' Dep variable is reg3 (Y=HR, X= SctO2) multiplied by 10 '
run;

```
title2' independent variable is caffeine, probe, and pa';  
title3' march 20, 2012';  
title4' Final Model';  
run;
```

```
proc mixed data=temp2;  
class infant caffeine probe;  
model reg4by10 = pa pa2 caffeine probe/ s ;  
random infant /subject = infant;
```

```
title1' Dep variable is reg4 (Y= SctO2, X=SpO2) multiplied by 10 '  
title2' independent variable is caffeine and pa';  
title3' march 20, 2012';
```

```
run;
```

```
proc mixed data=temp2;  
class infant caffeine probe;  
model reg4by10 = pa caffeine probe/ s ;  
random infant /subject = infant;
```

```
title1' Dep variable is reg4 (Y= SctO2, X=SpO2) multiplied by 10 '  
title2' independent variable is caffeine and pa';  
title3' march 20, 2012';  
title4' Final Model';
```

```
run;
```

Appendix H Chapter 5 SAS Ouput: Averaged Mixed Models Output

Model #1 16:37 Sunday, April 22, 2012 1093
Dep variable is mean HR over all minutes in a data collection
independent variable is mean Scto2 over all minutes in a data collection
pa is postnatal age
march 20, 2012
Final Model for when Y=HR, X= SctO2

The Mixed Procedure

Model Information

Data Set WORK.DCOUT
Dependent Variable meanhr
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containmentment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	2
Columns in X	6
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	12

Model #1

16:37 Sunday, April 22, 2012 1094

Dep variable is mean HR over all minutes in a data collection
independent variable is mean SctO2 over all minutes in a data collection

pa is postnatal age

march 20, 2012

Final Model for when Y=HR, X= SctO2

The Mixed Procedure

Number of Observations

Number of Observations Read	139
Number of Observations Used	133
Number of Observations Not Used	6

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	1109.75197867	
1	1	1109.75197867	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	0
Residual		239.72

Fit Statistics

-2 Res Log Likelihood	1109.8
AIC (smaller is better)	1111.8
AICC (smaller is better)	1111.8
BIC (smaller is better)	1112.9

Model #1

16:37 Sunday, April 22, 2012 1095

Dep variable is mean HR over all minutes in a data collection
independent variable is mean Scto2 over all minutes in a data collection

pa is postnatal age

march 20, 2012

Final Model for when Y=HR, X= SctO2

The Mixed Procedure

Solution for Fixed Effects

Effect	Standard		DF	t Value	Pr > |t|
	Estimate	Error			
Intercept	164.89	15.5548	23	10.60	<.0001
meanco	-0.4054	0.1898	104	-2.14	0.0350
pa	1.5638	0.3106	104	5.03	<.0001
pa2	-0.02004	0.004419	104	-4.53	<.0001
caffeine	9.3375	4.6958	104	1.99	0.0494
pa*caffeine	-0.3741	0.1673	104	-2.24	0.0275

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
meanco	1	104	4.56	0.0350
pa	1	104	25.35	<.0001
pa2	1	104	20.56	<.0001
caffeine	1	104	3.95	0.0494
pa*caffeine	1	104	5.00	0.0275

Model #2 16:37 Sunday, April 22, 2012 1096
independent variable is mean HR over all minutes in a data collection
march 20, 2012
Final Model for when Y= SctO2, X=HR

The Mixed Procedure

Model Information

Data Set WORK.DCOUT
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containmentment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	2
Columns in X	5
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	139
Number of Observations Used	133
Number of Observations Not Used	6

Model #2 16:37 Sunday, April 22, 2012 1097
independent variable is mean HR over all minutes in a data collection
march 20, 2012
Final Model for when Y= SctO2, X=HR

The Mixed Procedure

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	904.08506965	
1	3	880.19010425	0.00100585
2	1	879.81070374	0.00010301
3	1	879.77516065	0.00000138
4	1	879.77471171	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	16.5931
Residual		33.8918

Fit Statistics

-2 Res Log Likelihood	879.8
AIC (smaller is better)	883.8
AICC (smaller is better)	883.9
BIC (smaller is better)	886.1

Model #2 16:37 Sunday, April 22, 2012 1098
independent variable is mean HR over all minutes in a data collection
march 20, 2012
Final Model for when Y= SctO2, X=HR

The Mixed Procedure

Solution for Fixed Effects

Effect	Standard		DF	t Value	Pr > |t|
	Estimate	Error			
Intercept	86.7459	5.0142	23	17.30	<.0001
meanhr	-0.06517	0.03254	105	-2.00	0.0478
pa	-0.1835	0.04506	105	-4.07	<.0001
caffeine	2.6042	2.0844	105	1.25	0.2143
pa*caffeine	-0.1636	0.05890	105	-2.78	0.0065

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
meanhr	1	105	4.01	0.0478
pa	1	105	16.58	<.0001
caffeine	1	105	1.56	0.2143
pa*caffeine	1	105	7.72	0.0065

Model #3

16:37 Sunday, April 22, 2012 1099

Dependent variable is SpO2 over all minutes in an observation
independent variable is mean scto2 over all minutes in a data collection

pa is postnatal age

march 20, 2012

Final Model for when Y=SpO2, X=SctO2

The Mixed Procedure

Model Information

Data Set	WORK.DCOUT
Dependent Variable	meanpo
Covariance Structure	Variance Components
Subject Effect	Infant
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	2
Columns in X	3
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	12

Model #3

16:37 Sunday, April 22, 2012 1100

Dependent variable is SpO2 over all minutes in an observation
independent variable is mean scto2 over all minutes in a data collection

pa is postnatal age

march 20, 2012

Final Model for when Y=SpO2, X=SctO2

The Mixed Procedure

Number of Observations

Number of Observations Read	139
Number of Observations Used	133
Number of Observations Not Used	6

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	638.92565406	
1	2	633.71559674	0.00000325
2	1	633.71494757	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	1.0119
Residual		5.6858

Fit Statistics

-2 Res Log Likelihood	633.7
AIC (smaller is better)	637.7
AICC (smaller is better)	637.8
BIC (smaller is better)	640.1

Model #3

16:37 Sunday, April 22, 2012 1101

Dependent variable is SpO2 over all minutes in an observation
independent variable is mean scto2 over all minutes in a data collection

pa is postnatal age

march 20, 2012

Final Model for when Y=SpO2, X=SctO2

The Mixed Procedure

Solution for Fixed Effects

Effect	Standard		DF	t Value	Pr > |t|
	Estimate	Error			
Intercept	82.1705	2.5600	23	32.10	<.0001
meanco	0.1903	0.03226	107	5.90	<.0001
pa	0.03235	0.01407	107	2.30	0.0235

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
meanco	1	107	34.82	<.0001
pa	1	107	5.28	0.0235

Model #4 16:37 Sunday, April 22, 2012 1102
independent variable is mean SpO2 over all minutes in a data collection
march 20, 2012
Final Model for when Y=SctO2, X=SpO2

The Mixed Procedure

Model Information

Data Set WORK.DCOUT
Dependent Variable meanco
Covariance Structure Variance Components
Subject Effect Infant
Estimation Method REML
Residual Variance Method Profile
Fixed Effects SE Method Model-Based
Degrees of Freedom Method Containmentment

Class Level Information

Class	Levels	Values
Infant	24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 20 22 23 24 25 26

Dimensions

Covariance Parameters	2
Columns in X	5
Columns in Z Per Subject	24
Subjects	24
Max Obs Per Subject	12

Number of Observations

Number of Observations Read	139
Number of Observations Used	133
Number of Observations Not Used	6

Model #4 16:37 Sunday, April 22, 2012 1103
independent variable is mean SpO2 over all minutes in a data collection
march 20, 2012
Final Model for when Y=SctO2, X=SpO2

The Mixed Procedure

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	878.09686689	
1	5	849.20847911	0.00003958
2	1	849.19696922	0.00000022
3	1	849.19690180	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
Infant	Infant	15.6501
Residual		26.8876

Fit Statistics

-2 Res Log Likelihood	849.2
AIC (smaller is better)	853.2
AICC (smaller is better)	853.3
BIC (smaller is better)	855.6

Model #4 16:37 Sunday, April 22, 2012 1104
independent variable is mean SpO2 over all minutes in a data collection
march 20, 2012
Final Model for when Y=SctO2, X=SpO2

The Mixed Procedure

Solution for Fixed Effects

Effect	Standard		DF	t Value	Pr > |t|
	Estimate	Error			
Intercept	-24.5003	17.3019	23	-1.42	0.1702
meanpo	1.0479	0.1769	105	5.92	<.0001
pa	-0.1912	0.03964	105	-4.82	<.0001
caffeine	2.3939	1.8733	105	1.28	0.2041
pa*caffeine	-0.1483	0.05284	105	-2.81	0.0060

Type 3 Tests of Fixed Effects

Effect	Num Den		F Value	Pr > F
	DF	DF		
meanpo	1	105	35.10	<.0001
pa	1	105	23.25	<.0001
caffeine	1	105	1.63	0.2041
pa*caffeine	1	105	7.87	0.0060

```
*libname final 'S:\SED\Elser-NIRS\Dissertation\Dis_Subject_folders';
*ods rtf file = 'S:\SED\Elser-NIRS\Dissertation\output\mixed_dcmeans_03202012';
data temp;
    set final.aggtest;
    if position eq 1;
    if meanpo le 100;
    pa2= pa*pa;

proc means data = temp;
class infant dc;
var meanco meanhr meanpo pa caffeine probe pa2;
output out=dcout mean = meanco meanhr meanpo pa caffeine probe pa2;
```

```

/*
proc print data=dcout;
where _type_ eq 3;
title1' calculating means of 1 minute means by ';
title2' data collection within infant ';
*/
proc contents data=dcout;
run;

proc means;
var meanco meanpo meanhr;
run;

*****
*****scatter plot of mean hr scto2 and spo2*****
*****calculated over all minutes in a data collection*****
*****
/*proc gplot data=dcout;
where _type_ eq 3;
where infant eq 1;
symbol1 color = blue; *line = 1;

axis1 label=none;
axis2 label=none;
*label abdtp = 'abdtp';
plot meanhr*meanco;
* / vaxis = 20 to 80 by 5;

title1' infant 1 mean hr on y axis mean ';
title2' mean scto2 on x axis';
proc gplot data=dcout;
where _type_ eq 3;
where infant eq 1;
symbol1 color = blue; *line = 1;

axis1 label=none;
axis2 label=none;
*label abdtp = 'abdtp';
plot meanpo*meanco;
* / vaxis = 20 to 80 by 5;

title1' infant 1 mean pulse ox on y axis mean ';
title2' mean scto2 on x axis';

proc gplot data=dcout;
where _type_ eq 3;
*where infant eq 1;
symbol1 color = blue; *line = 1;

axis1 label=none;
axis2 label=none;
*label abdtp = 'abdtp';
plot meanhr*meanco;
* / vaxis = 20 to 80 by 5;

title1' all infants mean hr on y axis mean ';
title2' mean scto2 on x axis';
proc gplot data=dcout;
where _type_ eq 3;

```

```

*where infant eq 1;
  symbol1 color = blue; *line = 1;

  axis1 label=none;
  axis2 label=none;
  *label abdtpr = 'abdtpr';
  plot meanpo*meanco;

  * / vaxis = 20 to 80 by 5;

  title1' all infants mean pulse ox on y axis mean ';
  title2' mean scto2 on x axis!;

*/
*****
*****proc mixed of means per dc controlling for pa*****
*****with pa as the independent variable*****
*****
/*
proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanhr = meanco pa pa2 caffeine caffeine*pa caffeine*pa2 probe probe*pa probe*pa2/ s ;
random infant /subject = infant;
title1' Dep variable is mean HR over allminutes in a data collection ';
title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

* probe*pa2 not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanhr = meanco pa pa2 caffeine caffeine*pa caffeine*pa2 probe probe*pa/ s ;
random infant /subject = infant;
title1' Dep variable is mean HR over allminutes in a data collection ';
title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

*caffeine*pa2 not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanhr = meanco pa pa2 caffeine caffeine*pa probe probe*pa/ s ;
random infant /subject = infant;
title1' Dep variable is mean HR over allminutes in a data collection ';
title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

*probe*pa not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanhr = meanco pa pa2 caffeine caffeine*pa probe/ s ;

```

```

random infant /subject = infant;
title1' Dep variable is mean HR over allminutes in a data collection ';
title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

```

*probe not significant and removed;
*/

```

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanhr = meanco pa pa2 caffeine caffeine*pa/ s ;
random infant /subject = infant;
title1' Model #1';
title2' Dep variable is mean HR over all minutes in a data collection ';
title3' independent variable is mean Scto2 over all minutes in a data collection';
title4' pa is postnatal age';
title5' march 20, 2012';
title6' Final Model for when Y=HR, X= SctO2';
run;

```

```

/*
proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanhr pa pa2 caffeine caffeine*pa caffeine*pa2 probe probe*pa probe*pa2/ s ;
random infant /subject = infant;
title1' Dep variable is mean Scto2 over all minutes in a data collection ';
title2' independent variable is mean HR over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

```

*probe*pa2 not significant and removed;

```

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanhr pa pa2 caffeine caffeine*pa caffeine*pa2 probe probe*pa/ s ;
random infant /subject = infant;
title1' Dep variable is mean Scto2 over all minutes in a data collection ';
title2' independent variable is mean HR over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

```

*caffeine*pa2 not significant and removed;

```

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanhr pa pa2 caffeine caffeine*pa probe probe*pa/ s ;
random infant /subject = infant;
title1' Dep variable is mean Scto2 over all minutes in a data collection ';
title2' independent variable is mean HR over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';

```

```

run;

*probe*pa not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanhr pa pa2 caffeine caffeine*pa probe/ s ;
random infant /subject = infant;
title1' Dep variable is mean Scto2 over all minutes in a data collection ';
title2' independent variable is mean HR over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

```

*pa2 not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanhr pa caffeine caffeine*pa probe/ s ;
random infant /subject = infant;
title1' Dep variable is mean Scto2 over all minutes in a data collection ';
title2' independent variable is mean HR over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;
*/

```

```

*probe not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanhr pa caffeine caffeine*pa/ s ;
random infant /subject = infant;
title1' Model #2';
title2' Dep variable is mean Scto2 over all minutes in a data collection ';
title2' independent variable is mean HR over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
title4' Final Model for when Y= SctO2, X=HR';
run;

```

```

/*
proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanpo = meanco pa pa2 caffeine caffeine*pa caffeine*pa2 probe probe*pa probe*pa2/ s ;
random infant /subject = infant;
title1' Dep variable is mean SpO2 over all minutes in an observation ';
title2' independent variable is mean scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

```

*caffeine*pa2 not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;

```

```

class infant;
model meanpo = meanco pa pa2 caffeine caffeine*pa probe probe*pa probe*pa2/ s ;
random infant /subject = infant;
title1' Dep variable is mean SpO2 over all minutes in an observation ';
title2' independent variable is mean scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

*probe*pa2 not significant and removed;

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanpo = meanco pa pa2 caffeine caffeine*pa probe probe*pa/ s ;
random infant /subject = infant;
title1' Dep variable is mean SpO2 over all minutes in an observation ';
title2' independent variable is mean scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

*caffeine*pa not significant and removed;

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanpo = meanco pa pa2 caffeine probe probe*pa/ s ;
random infant /subject = infant;
title1' Dep variable is mean SpO2 over all minutes in an observation ';
title2' independent variable is mean scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

*probe*pa not significant and removed;

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanpo = meanco pa pa2 caffeine probe/ s ;
random infant /subject = infant;
title1' Dep variable is mean SpO2 over all minutes in an observation ';
title2' independent variable is mean scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

*pa2 not significant and removed;

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanpo = meanco pa caffeine probe/ s ;
random infant /subject = infant;
title1' Dep variable is mean SpO2 over all minutes in an observation ';
title2' independent variable is mean scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

```

*/
proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanpo = meanco pa/ s ;
random infant /subject = infant;
title1' Model #3';
title2' Dependent variable is SpO2 over all minutes in an observation ';
title3' independent variable is mean scto2 over all minutes in a data collection';
title4' pa is postnatal age';
title5' march 20, 2012';
title6' Final Model for when Y=SpO2, X=SctO2';

/*
proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanpo pa pa2 caffeine caffeine*pa caffeine*pa2 probe probe*pa probe*pa2/ s ;
random infant /subject = infant;
title1' Dep variable is mean HR over all minutes in a data collection ';
title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

*probe*pa2 not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanpo pa pa2 caffeine caffeine*pa caffeine*pa2 probe probe*pa/ s ;
random infant /subject = infant;
title1' Dep variable is mean HR over all minutes in a data collection ';
title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

*caffeine*pa2 not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanpo pa pa2 caffeine caffeine*pa probe probe*pa/ s ;
random infant /subject = infant;
title1' Dep variable is mean HR over all minutes in a data collection ';
title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

*probe*pa not significant and removed;

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanpo pa pa2 caffeine caffeine*pa probe/ s ;
random infant /subject = infant;
title1' Dep variable is mean HR over all minutes in a data collection ';

```

```

title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

```

*pa2 not significant and removed;

```

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanpo pa caffeine caffeine*pa probe/ s ;
random infant /subject = infant;
title1' Dep variable is mean HR over all minutes in a data collection ';
title2' independent variable is mean Scto2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
run;

```

```

*probe not significant and removed;
*/

```

```

proc mixed data=dcout;
where _type_ eq 3;
class infant;
model meanco = meanpo pa caffeine caffeine*pa/ s ;
random infant /subject = infant;
title1' Model #4';
title2' Dep variable is mean SctO2 over all minutes in a data collection ';
title2' independent variable is mean SpO2 over all minutes in a data collection';
title3' pa is postnatal age';
title3' march 20, 2012';
title4' Final Model for when Y=SctO2, X=SpO2';
run;

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ods rtf close;

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7. References

- Als, H., Lawhon, G., Brown, E., Gibes, R., Duffy, F. H., McAnulty, G., & Blickman, J. G. (1986). Individualized behavioral and environmental care for the very low birth weight preterm infant at high risk for bronchopulmonary dysplasia: Neonatal intensive care unit and developmental outcome. *Pediatrics*, *78*(6), 1123-1132.
- Als, H., Lawhon, G., Duffy, F. H., McAnulty, G. B., Gibes-Grossman, R., & Blickman, J. G. (1994). Individualized developmental care for the very low-birth-weight preterm infant. Medical and neurofunctional effects. *Journal of the American Medical Association*, *272*(11), 853-858.
- American Academy of Pediatrics Committee on Environmental Health. (1997). Noise: A hazard for the fetus and newborn. *Pediatrics*, *100*(4), 724-727.
- American Academy of Pediatrics Subcommittee on Hyperbilirubinemia. (2004). Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. [Guideline Practice Guideline]. *Pediatrics*, *114*(1), 297-316.
- Ancora, G., Maranella, E., Aceti, A., Pierantoni, L., Grandi, S., Corvaglia, L., & Faldella, G. (2010). Effect of posture on brain hemodynamics in preterm newborns not mechanically ventilated. *Neonatology*, *97*(3), 212-217. doi: 10.1159/000253149
- Anderson, P. J., & Doyle, L. W. (2008). Cognitive and educational deficits in children born extremely preterm. *Seminars in Perinatology*, *32*(1), 51-58. doi: 10.1053/j.semperi.2007.12.009
- Ashwal, S., & Serna-Fonseca, T. (2006). Brain death in infants and children. *Critical Care Nurse*, *26*(2), 117-124, 126-118.
- Austin, T., Gibson, A. P., Branco, G., Yusof, R. M., Arridge, S. R., Meek, J. H., . . . Hebden, J. C. (2006). Three dimensional optical imaging of blood volume and oxygenation in the neonatal brain. *Neuroimage*, *31*(4), 1426-1433. doi: 10.1016/j.neuroimage.2006.02.038
- Avery, M. E. (1974). *The lung and its disorders* (3rd ed.). Philadelphia: WB Saunders.
- Baenziger, O., Jaggi, J. L., Mueller, A. C., Morales, C. G., Lipp, H. P., Lipp, A. E., . . . Bucher, H. U. (1994). Cerebral blood flow in preterm infants affected by sex, mechanical ventilation, and intrauterine growth. *Pediatric Neurology*, *11*(4), 319-324.
- Baker, C. F. (1984). Sensory overload and noise in the ICU: sources of environmental stress. *CCQ. Critical Care Quarterly*, *6*(4), 66-80.

- Ballard, J. L., Khoury, J. C., Wedig, K., Wang, L., Eilers-Walsman, B. L., & Lipp, R. (1991). New Ballard Score, expanded to include extremely premature infants. *Journal of Pediatrics*, *119*(3), 417-423.
- Bartick, M. C., Thai, X., Schmidt, T., Altaye, A., & Solet, J. M. (2010). Decrease in as-needed sedative use by limiting nighttime sleep disruptions from hospital staff. *Journal of Hospital Medicine*, *5*(3), E20-24. doi: 10.1002/jhm.549
- Bednarek, F. J., Weisberger, S., Richardson, D. K., Frantz, I. D., 3rd, Shah, B., & Rubin, L. P. (1998). Variations in blood transfusions among newborn intensive care units. SNAP II Study Group. *Journal of Pediatrics*, *133*(5), 601-607.
- Belzberg, H., Shoemaker, W. C., Wo, C. C., Nicholls, T. P., Dang, A. B., Zelman, V., . . . Demetriades, D. (2007). Hemodynamic and oxygen transport patterns after head trauma and brain death: implications for management of the organ donor. *Journal of Trauma*, *63*(5), 1032-1042. doi: 10.1097/01.ta.0000235995.86162.d2
- Benni, P. B., Chen, B., Dykes, F. D., Wagoner, S. F., Heard, M., Tanner, A. J., . . . Short, B. L. (2005). Validation of the CAS neonatal NIRS system by monitoring vv-ECMO patients: preliminary results. *Advances in Experimental Medicine and Biology*, *566*, 195-201. doi: 10.1007/0-387-26206-7_27
- Bentley, S., Murphy, F., & Dudley, H. (1977). Perceived noise in surgical wards and an intensive care area: an objective analysis. *British Medical Journal*, *2*(6101), 1503-1506.
- Beranek, L. L. (1988). *Acoustical measurements* (2nd ed.). New York: American Institute of Physics.
- Berube, M. S. (1995). Sound *Webster's II: New College Dictionary*. Boston: Merriam Webster Online Dictionary.
- Blackburn, S. (1998). Environmental impact of the NICU on developmental outcomes. *Journal of Pediatric Nursing*, *13*(5), 279-289.
- Blackburn, S., & Ditzenberger, G. R. (2007). Neurologic system. In C. Kenner & J. W. Lott (Eds.), *Comprehensive neonatal care: An interdisciplinary approach* (4th ed., pp. 267-299). St. Louis: Saunders Elsevier.
- Bode, H., & Wais, U. (1988). Age dependence of flow velocities in basal cerebral arteries. *Archives of Disease in Childhood*, *63*(6), 606-611.
- Boylan, G. B., Young, K., Panerai, R. B., Rennie, J. M., & Evans, D. H. (2000). Dynamic cerebral autoregulation in sick newborn infants. *Pediatric Research*, *48*(1), 12-17.

- Bracewell, M., & Marlow, N. (2002). Patterns of motor disability in very preterm children. *Mental Retardation and Developmental Disabilities Research Reviews*, 8(4), 241-248. doi: 10.1002/mrdd.10049
- Brandon, D., Ryan, D. J., & Barnes, A. H. (2007). Effect of environmental changes on noise in the NICU. *Neonatal Network*, 26(4), 213-218.
- Brazy, J. E., Lewis, D. V., Mitnick, M. H., & Jobsis-Vander Vliet, F. F. (1985). Monitoring of cerebral oxygenation in the intensive care nursery. *Advances in Experimental Medicine and Biology*, 191, 843-848.
- Brazy, J. E., & Vander-Vliet, F. J. (1989). Clinical application of near infrared spectroscopy to neonatal intensive care. In Y. Kim & F. A. Spelman (Eds.), *Images of the Twenty-First Century: Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Seattle, Washington November 9-12 1989* (Vol. 11, pp. 337-338). NY: IEEE.
- Bremmer, P., Byers, J. F., & Kiehl, E. (2003). Noise and the premature infant: Physiological effects and practice implications. *Journal of Obstetric, Gynecologic, and Neonatal Nursing*, 32(4), 447-454.
- Bruns, A. R., Norwood, B. R., Bosworth, G. A., & Hill, L. (2009). Update for nurse anesthetists—Part 1—The cerebral oximeter: What is the efficacy? *AANA Journal*, 77(2), 137-144.
- Caicedo, A., De Smet, D., Naulaers, G., Ameye, L., Vanderhaegen, J., Lemmers, P., . . . Van Huffel, S. (2011). Cerebral tissue oxygenation and regional oxygen saturation can be used to study cerebral autoregulation in prematurely born infants. *Pediatric Research*, 69(6), 548-553. doi: 10.1203/PDR.0b013e3182176d85
- Calvert, S. A., Ohlsson, A., Hosking, M. C., Erskine, L., Fong, K., & Shennan, A. T. (1988). Serial measurements of cerebral blood flow velocity in preterm infants during the first 72 hours of life. *Acta Paediatrica Scandinavica*, 77(5), 625-631.
- Cameron, O. G., Modell, J. G., & Hariharan, M. (1990). Caffeine and human cerebral blood flow: a positron emission tomography study. *Life Sciences*, 47(13), 1141-1146.
- Carrier, C. T. (2004). Developmental Support. In M. T. Verklan & M. Walden (Eds.), *Core curriculum for neonatal intensive care nursing* (3rd ed., pp. 236-264). St. Louis: Elsevier Saunders.
- Carteaux, P., Cohen, H., Check, J., George, J., McKinley, P., Lewis, W., . . . McConnell, C. (2003). Evaluation and development of potentially better practices for the

prevention of brain hemorrhage and ischemic brain injury in very low birth weight infants. *Pediatrics*, 111(4 Pt 2), e489-496.

CAS Medical Systems. (2008). Patient monitoring: FORE-SIGHT. Retrieved August 3, 2009, from <http://www.casmed.com/foresight.html>

Catlett, A. T., & Holditch-Davis, D. (1990). Environmental stimulation of the acutely ill premature infant: physiological effects and nursing implications. *Neonatal Network*, 8(6), 19-26.

Chan, K., Ohlsson, A., Synnes, A., Lee, D. S., Chien, L. Y., & Lee, S. K. (2001). Survival, morbidity, and resource use of infants of 25 weeks' gestational age or less. *American Journal of Obstetrics and Gynecology*, 185(1), 220-226. doi: 10.1067/mob.2001.115280

Chillon, J. M., & Baumbach, G. L. (2002). Autoregulation: Arterial and intracranial pressure. In L. Edvinsson & D. N. Krause (Eds.), *Cerebral blood flow and Metabolism* (pp. 395-412). Philadelphia: Lippincott, Williams, & Wilkins.

Cifuentes, Javier, & Carlo, Waldemar A. (2007). Respiratory system. In Carole Kenner & Judy Wright Lott (Eds.), *Comprehensive neonatal care: An interdisciplinary approach* (4th ed., pp. 1-17). St. Louis: Saunders Elsevier.

Clairambault, J., Curzi-Dascalova, L., Kauffmann, F., Medigue, C., & Leffler, C. (1992). Heart rate variability in normal sleeping full-term and preterm neonates. *Early Human Development*, 28(2), 169-183.

Cmiel, C. A., Karr, D. M., Gasser, D. M., Oliphant, L. M., & Neveau, A. J. (2004). Noise control: A nursing team's approach to sleep promotion. *American Journal of Nursing*, 104(2), 40-48.

Colombo, J., Shoemaker, W. C., Belzberg, H., Hatzakis, G., Fathizadeh, P., & Demetriades, D. (2008). Noninvasive monitoring of the autonomic nervous system and hemodynamics of patients with blunt and penetrating trauma. *Journal of Trauma*, 65(6), 1364-1373. doi: 10.1097/TA.0b013e31818cc307

Commandeur, Jacques, & Koopman, Siem Jan. (2007). *An introduction to state space time series analysis*. Oxford: Oxford University Press.

Committee to Establish Recommended Standards for Newborn ICU Design. (2007). Standard 23: Acoustic environment Retrieved February 9, 2010, from <http://www.nd.edu/~nicudes/stan%2023.html>

- Cooke, R. W., Rolfe, P., & Howat, P. (1979). Apparent cerebral blood flow in newborns with respiratory disease. *Developmental Medicine and Child Neurology*, 21(1), 154-160.
- Cope, M., & Delpy, D. T. (1988). System for long-term measurement of cerebral blood and tissue oxygenation on newborn infants by near infra-red transillumination. *Medical and Biological Engineering and Computing*, 26(3), 289-294.
- Cowan, F., & Thoresen, M. (1985). Changes in superior sagittal sinus blood velocities due to postural alterations and pressure on the head of the newborn infant. *Pediatrics*, 75(6), 1038-1047.
- Dani, C., Pratesi, S., Fontanelli, G., Barp, J., & Bertini, G. (2010). Blood transfusions increase cerebral, splanchnic, and renal oxygenation in anemic preterm infants. *Transfusion*, 50(6), 1220-1226. doi: 10.1111/j.1537-2995.2009.02575.x
- De Rogalski Landrot, I., Roche, F., Pichot, V., Teyssier, G., Gaspoz, J. M., Barthelemy, J. C., & Patural, H. (2007). Autonomic nervous system activity in premature and full-term infants from theoretical term to 7 years. *Auton Neurosci*, 136(1-2), 105-109. doi: 10.1016/j.autneu.2007.04.008
- DeVon, H. A., Block, M. E., Moyle-Wright, P., Ernst, D. M., Hayden, S. J., Lazzara, D. J., . . . Kostas-Polston, E. (2007). A psychometric toolbox for testing validity and reliability. *Image: Journal of Nursing Scholarship*, 39(2), 155-164. doi: 10.1111/j.1547-5069.2007.00161.x
- Donohue, P. K., & Graham, E. M. (2007). Earlier markers for cerebral palsy and clinical research in premature infants. *Journal of Perinatology*, 27, 259-261.
- du Plessis, A. J. (1995). Near-infrared spectroscopy for the in vivo study of cerebral hemodynamics and oxygenation. *Current Opinion in Pediatrics*, 7(6), 632-639.
- du Plessis, A. J., & Johnston, M. V. (1999). The pursuit of effective neuroprotection during infant cardiac surgery. *Seminars in Pediatric Neurology*, 6(1), 55-63.
- Dullenkopf, A., Frey, B., Baenziger, O., Gerber, A., & Weiss, M. (2003). Measurement of cerebral oxygenation state in anaesthetized children using the INVOS 5100 cerebral oximeter. *Paediatric Anaesthesia*, 13(5), 384-391.
- Dunser, M. W., & Hasibeder, W. R. (2009). Sympathetic overstimulation during critical illness: adverse effects of adrenergic stress. *Journal of Intensive Care Medicine*, 24(5), 293-316. doi: 10.1177/0885066609340519

- Eichler, F., Ipsiroglu, O., Arif, T., Popow, C., Heinzl, H., Urschitz, M., & Pollak, A. (2001). Position dependent changes of cerebral blood flow velocities in premature infants. *European Journal of Pediatrics*, *160*(10), 633-639.
- Eiselt, M., Curzi-Dascalova, L., Clairambault, J., Kauffmann, F., Medigue, C., & Peirano, P. (1993). Heart-rate variability in low-risk prematurely born infants reaching normal term: a comparison with full-term newborns. *Early Human Development*, *32*(2-3), 183-195.
- Élser, H. E., Holditch-Davis, D., & Brandon, D. H. (2011). Cerebral Oxygenation Monitoring: A Strategy to Detect IVH and PVL. *Newborn Infant Nurs Rev*, *11*(3), 153-159. doi: 10.1053/j.nainr.2011.07.007
- Elser, H. E., Holditch-Davis, D., Brandon, D., & Levy, J. (2012). *Cerebral oxygenation during position changes in stable NICU infants*. Scottsdale, AZ.
- Emery, J. R., & Peabody, J. L. (1983). Head position affects intracranial pressure in newborn infants. *Journal of Pediatrics*, *103*(6), 950-953.
- Fajardo, Barbara, Browning, Margaret, Fisher, David, & Paton, John. (1990). Effect of nursery environment on state regulation in very-low-birth-weight premature infants. *Infant Behavior and Development*, *13*, 287-303. doi: doi:10.1016/0163-6383(90)90036-8
- Fawke, J. (2007). Neurological outcomes following preterm birth. *Seminars in Fetal and Neonatal Medicine*, *12*(5), 374-382. doi: 10.1016/j.siny.2007.06.002
- Fox, N. A. (1983). Maturation of autonomic control in preterm infants. *Developmental Psychobiology*, *16*(6), 495-504. doi: 10.1002/dev.420160605
- Gleason, C. A. , & Back, S. A. . (2005). Neurologic system. In H. W. Taeusch, R. A. Ballard & C. A. Gleason (Eds.), *Avery's diseases of the newborn* (8th ed., pp. 903-907). Philadelphia: Elsevier Saunders.
- Gottlieb, G. (1999). *Probabilistic epigenesis and evolution*. Worcester, MA: Clark University Press.
- Gottlieb, G. (2000). Environmental and behavioral influences on gene activity. *Current Directions in Psychological Science*, *9*(3), 93-97.
- Gottlieb, G. (2002a). Developmental-behavioral initiation of evolutionary change. *Psychological Review*, *109*(2), 211-218.
- Gottlieb, G. (2002b). *From gene to organism: The developing individual as an emergent, interactional, hierarchical system*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

- Gottlieb, G. (2002c). On the epigenetic evolution of species-specific perception: The developmental manifold concept. *Cognitive Development, 17*, 1287-1300.
- Gottlieb, G. (2007). Probabilistic epigenesis. *Developmental Science, 10*(1), 1-11. doi: 10.1111/j.1467-7687.2007.00556.x
- Gournay, V., Drouin, E., & Roze, J. C. (2002). Development of baroreflex control of heart rate in preterm and full term infants. *Archives of Disease in Childhood. Fetal and Neonatal Edition, 86*(3), F151-154.
- Grant, D. A., Franzini, C., Wild, J., Eede, K. J., & Walker, A. M. (2005). Autoregulation of the cerebral circulation during sleep in newborn lambs. *Journal of Physiology, 564*(3), 923-930. doi: 10.1113/jphysiol.2005.083352
- Greisen, G., Hellstrom-Vestas, L., Lou, H., Rosen, I., & Svenningsen, N. (1985). Sleep-waking shifts and cerebral blood flow in stable preterm infants. *Pediatric Research, 19*(11), 1156-1159.
- Griffin, J. P. (1992). The impact of noise on critically ill people. *Holistic Nursing Practice, 6*(4), 53-56.
- Guyton, A. C., & Hall, J. E. . (2006). Membrane potentials and action potentials. In A. C. Guyton & J. E. Hall (Eds.), *Textbook of medical physiology* (pp. 57-71). Philadelphia: Elsevier, Inc.
- Hack, M., Taylor, H. G., Drotar, D., Schluchter, M., Cartar, L., Andreias, L., . . . Klein, N. (2005). Chronic conditions, functional limitations, and special health care needs of school-aged children born with extremely low-birth-weight in the 1990s. *The Journal of the American Medical Association, 294*(3), 318-325. doi: 10.1001/jama.294.3.318
- Hamilton, B. E., Martin, J. A., & Ventura, S. J. (2009). Births: Preliminary data for 2007 Retrieved December 5, 2009, from http://www.cdc.gov/nchs/data/nvsr/nvsr57/nvsr57_12.pdf
- Hansen, N., & Okken, A. (1979). Continuous TcPO₂ monitoring in healthy and sick newborn infants during and after feeding. *Birth Defects, 4*, 503-508.
- Hummel, P., & Fortado, D. (2005). Impacting infant head shapes. *Adv Neonatal Care, 5*(6), 329-340. doi: 10.1016/j.adnc.2005.08.009
- Inder, T. E., & Volpe, J. J. (2004). Pathophysiology of intraventricular hemorrhage in the neonate. In Richard A. Polin, Fox William W. & Steven H. Abman (Eds.), *Fetal and neonatal physiology* (3rd ed., Vol. 2, pp. 1757-1772). Philadelphia: W.B. Saunders Co.
- Ito, H., Kanno, I., Iida, H., Hatazawa, J., Shimosegawa, E., Tamura, H., & Okudera, T. (2001). Arterial fraction of cerebral blood volume in humans measured by positron emission tomography. *Annals of Nuclear Medicine, 15*(2), 111-116.

- Jobsis, F. F. (1977). Non-invasive, infra-red monitoring of cerebral O₂ sufficiency, bloodvolume, HbO₂-Hb shifts and bloodflow. *Acta Neurologica Scandinavica. Supplementum*, 64, 452-453.
- Johnson, A. N. (2001). Neonatal response to control of noise inside the incubator. *Pediatric Nursing*, 27(6), 600-605.
- Jorch, G., & Jorch, N. (1987). Failure of autoregulation of cerebral blood flow in neonates studied by pulsed Doppler ultrasound of the internal carotid artery. *European Journal of Pediatrics*, 146(5), 468-472.
- Jubran, A. (1999). Pulse oximetry. *Critical Care*, 3(2), R11-R17.
- Kahn, D. M., Cook, T. E., Carlisle, C. C., Nelson, D. L., Kramer, N. R., & Millman, R. P. (1998). Identification and modification of environmental noise in an ICU setting. *Chest*, 114(2), 535-540.
- Katona, P. G., & Egbert, J. R. (1978). Heart rate and respiratory rate differences between preterm and full-term infants during quiet sleep: possible implications for sudden infant death syndrome. *Pediatrics*, 62(1), 91-95.
- Katona, P. G., Frasz, A., & Egbert, J. (1980). Maturation of cardiac control in full-term and preterm infants during sleep. *Early Human Development*, 4(2), 145-159.
- Kehrer, M., Blumenstock, G., Eehalt, S., Goelz, R., Poets, C., & Schoning, M. (2005). Development of cerebral blood flow volume in preterm neonates during the first two weeks of life. *Pediatric Research*, 58(5), 927-930. doi: 10.1203/01.pdr.0000182579.52820.c3
- Kehrer, M., & Schoning, M. (2009). A longitudinal study of cerebral blood flow over the first 30 months. *Pediatric Research*, 66(5), 560-564. doi: 10.1203/PDR.0b013e3181ba1a29
- Kinney, H. C., Brody, B. A., Kloman, A. S., & Gilles, F. H. (1988). Sequence of central nervous system myelination in human infancy. II. Patterns of myelination in autopsied infants. *Journal of Neuropathology and Experimental Neurology*, 47(3), 217-234.
- Kirpalani, H., Whyte, R. K., Andersen, C., Asztalos, E. V., Heddle, N., Blajchman, M. A., . . . Roberts, R. S. (2006). The Premature Infants in Need of Transfusion (PINT) study: a randomized, controlled trial of a restrictive (low) versus liberal (high) transfusion threshold for extremely low birth weight infants. *Journal of Pediatrics*, 149(3), 301-307. doi: 10.1016/j.jpeds.2006.05.011

- Klaessens, J. H., Hopman, J. C., Liem, K. D., van Os, S. H., & Thijssen, J. M. (2005). Effects of skin on bias and reproducibility of near-infrared spectroscopy measurement of cerebral oxygenation changes in porcine brain. *J Biomed Opt*, *10*(4), 44003. doi: 10.1117/1.1989315
- Kontos, H. A., Wei, E. P., Navari, R. M., Levasseur, J. E., Rosenblum, W. I., & Patterson, J. L., Jr. (1978). Responses of cerebral arteries and arterioles to acute hypotension and hypertension. *American Journal of Physiology*, *234*(4), H371-383.
- Kornhauser, M., & Schneiderman, R. (2010). How plans can improve outcomes and cut costs for preterm infant care. *Managed Care*, *19*(1), 28-30.
- Kryter, Karl. (1985). *The effects of noise on man*. New York, NY: Academic Press.
- Kurtis, P. S., Rosenkrantz, T. S., & Zalneraitis, E. L. (1995). Cerebral blood flow and EEG changes in preterm infants with patent ductus arteriosus. *Pediatric Neurology*, *12*(2), 114-119.
- Lagercrantz, Hugo, Hanson, Mark, Evrard, Philippe, & Rodeck, Charles. (2002). *The newborn brain: Neuroscience and clinical applications*. New York: Cambridge University Press.
- Lemmers, P. M., Toet, M., van Schelven, L. J., & van Bel, F. (2006). Cerebral oxygenation and cerebral oxygen extraction in the preterm infant: the impact of respiratory distress syndrome. *Experimental Brain Research*, *173*(3), 458-467. doi: 10.1007/s00221-006-0388-8
- Lemmers, P. M., & van Bel, F. (2009). Left-to-right differences of regional cerebral oxygen saturation and oxygen extraction in preterm infants during the first days of life. *Pediatric Research*, *65*(2), 226-230. doi: 10.1203/PDR.0b013e318191fb5d
- Lickliter, R. (2008). The growth of developmental thought: Implications for a new evolutionary psychology. *New Ideas in Psychology*, *26*(3), 353-369. doi: 10.1016/j.newideapsych.2007.07.015
- Long, J. G., Lucey, J. F., & Philip, A. G. (1980). Noise and hypoxemia in the intensive care nursery. *Pediatrics*, *65*(1), 143-145.
- Longin, E., Gerstner, T., Schaible, T., Lenz, T., & Konig, S. (2006). Maturation of the autonomic nervous system: differences in heart rate variability in premature vs. term infants. *Journal of Perinatal Medicine*, *34*(4), 303-308. doi: 10.1515/jpm.2006.058

- Lott, Judy Wright. (2007). Cardiovascular system. In Carole Kenner & Judy Wright Lott (Eds.), *Comprehensive neonatal care: An interdisciplinary approach* (4th ed.). St. Louis, MS: Saunders Elsevier.
- Lou, H. C., Lassen, N. A., & Friis-Hansen, B. (1979). Impaired autoregulation of cerebral blood flow in the distressed newborn infant. *The Journal of Pediatrics*, 94(1), 118-121.
- Lukas, J. (1976). Noise and sleep: A literature review and proposed criterion for assessing effect. *Journal of the Acoustical Society of America*, 58, 1232-1240.
- Lundstrom, K. E., Pryds, O., & Greisen, G. (1995). Oxygen at birth and prolonged cerebral vasoconstriction in preterm infants. *Archives of Disease in Childhood. Fetal and Neonatal Edition*, 73(2), F81-86.
- Lunt, M. J., Ragab, S., Birch, A. A., Schley, D., & Jenkinson, D. F. (2004). Comparison of caffeine-induced changes in cerebral blood flow and middle cerebral artery blood velocity shows that caffeine reduces middle cerebral artery diameter. *Physiological Measurement*, 25(2), 467-474.
- MacDonald, H. (2002). Perinatal care at the threshold of viability. *Pediatrics*, 110(5), 1024-1027.
- MacLeod, David, Ikeda, K., Keifer, J. C., Moretti, E., & Ames, W. (2006). *Validation of the CAS adult cerebral oximeter during hypoxia in healthy volunteers*. Paper presented at the International Anesthesia Research Society, San Francisco, CA.
- MacLeod, David, Ikeda, K., Moretti, E., Keifer, J. C., & Grocott, H. (2005). Using the CAS cerebral oximeter to estimate cerebral venous oxygen saturation. *Anesthesiology*, 2005, A16. Retrieved from www.asaabstracts.com
- Madan, A., Hamrick, S. E., & Ferriero, D. M. (2005). Central nervous system injury and neuroprotection. In H. W. Taeusch, R. A. Ballard & C. A. Gleason (Eds.), *Avery's diseases of the newborn* (8th ed., pp. 965-992). Philadelphia: Saunders Elsevier.
- Madan, A., MacMahon, J. R., & Stevenson, D. K. (2005). Neonatal hyperbilirubinemia. In H. W. Taeusch, R. A. Ballard & C. A. Gleason (Eds.), *Avery's diseases of the newborn* (8th ed., pp. 1226-1256). Philadelphia: Saunders Elsevier.
- Madsen, P. L., Skak, C., Rasmussen, A., & Secher, N. H. (2000). Interference of cerebral near-infrared oximetry in patients with icterus. *Anesthesia and Analgesia*, 90(2), 489-493.
- Magnusson, David, & Cairns, Robert B. (1996). Developmental sciences: Toward a unified framework. In Robert B. Cairns, Glen H. Elder & E. Jane Costello (Eds.),

Developmental science (pp. 7-30). New York: Cambridge University Press.

Maitre, N. L., Marshall, D. D., Price, W. A., Slaughter, J. C., O'Shea, T. M., Maxfield, C., & Goldstein, R. F. (2009). Neurodevelopmental outcome of infants with unilateral or bilateral periventricular hemorrhagic infarction. *Pediatrics*, *124*(6), e1153-1160. doi: 10.1542/peds.2009-0953

Mann, H. E., Holditch-Davis, D., & Brandon, D. (2010). *Feasibility of the FORE-SIGHT Cerebral Oximeter in Stable Intensive Care Infants*. Duke University School of Nursing. Durham, NC.

Mann, H. E., Holditch-Davis, D., Brandon, D., & Levy, J. (2010). Cerebral oxygenation patterns during head position changes. Baltimore, MD: 2010 International Conference on Infant Studies.

Markakis, C., Dalezios, M., Chatzicostas, C., Chalkiadaki, A., Politi, K., & Agouridakis, P. J. (2006). Evaluation of a risk score for interhospital transport of critically ill patients. *Emergency Medicine Journal*, *23*(4), 313-317. doi: 10.1136/emj.2005.026435

Martin, R. J., Okken, A., & Rubin, D. (1979). Arterial oxygen tension during active and quiet sleep in the normal neonate. *Journal of Pediatrics*, *94*(2), 271-274.

Mazursky, J. E., Birkett, C. L., Bedell, K. A., Ben-Haim, S. A., & Segar, J. L. (1998). Development of baroreflex influences on heart rate variability in preterm infants. *Early Human Development*, *53*(1), 37-52.

McLendon, D., Check, J., Carteaux, P., Michael, L., Moehring, J., Secrest, J. W., . . . Whitfield, J. M. (2003). Implementation of potentially better practices for the prevention of brain hemorrhage and ischemic brain injury in very low birth weight infants. *Pediatrics*, *111*(4 Pt 2), e497-503.

McNeill, S., Gatenby, J. C., McElroy, S., & Engelhardt, B. (2011). Normal cerebral, renal and abdominal regional oxygen saturations using near-infrared spectroscopy in preterm infants. *Journal of Perinatology*, *31*(1), 51-57. doi: 10.1038/jp.2010.71

Meek, J. H., Tyszczuk, L., Elwell, C. E., & Wyatt, J. S. (1998). Cerebral blood flow increases over the first three days of life in extremely preterm neonates. *Archives of Disease in Childhood. Fetal and Neonatal Edition*, *78*(1), F33-37.

Merriam-Webster. (2010). Probabilistic. *Merriam-Webster Online Dictionary* Retrieved April 14, 2010, from <http://www.merriam-webster.com/dictionary/probabilistic>

- Milan, A., Freato, F., Vanzo, V., Chiandetti, L., & Zaramella, P. (2009). Influence of ventilation mode on neonatal cerebral blood flow and volume. *Early Human Development*, *85*(7), 415-419. doi: 10.1016/j.earlhumdev.2009.01.008
- Mississippi State University. (2007). Animal functional genomics laboratory Retrieved November 4, 2007
- Mower, W. R., Sachs, C., Nicklin, E. L., & Baraff, L. J. (1997). Pulse oximetry as a fifth pediatric vital sign. *Pediatrics*, *99*(5), 681-686.
- Mower, W. R., Sachs, C., Nicklin, E. L., Safa, P., & Baraff, L. J. (1995). Effect of routine emergency department triage pulse oximetry screening on medical management. *Chest*, *108*(5), 1297-1302.
- Munro, M. J., Walker, A. M., & Barfield, C. P. (2004). Hypotensive extremely low birth weight infants have reduced cerebral blood flow. *Pediatrics*, *114*(6), 1591-1596. doi: 10.1542/peds.2004-1073
- National Instruments Corporation. (2009). What is Leq sound level? Retrieved December 15, 2009, from <http://digital.ni.com/public.nsf/allkb/FCE0EC0A6B193A028625722E006DE298>
- Nightingale, Florence. (1860). Notes on nursing: What is it, and what is it not. 1st American Edition. Retrieved March 21, 2010, from <http://digital.library.upenn.edu/women/nightingale/nursing/nursing.html>
- O'Donnell, C. P., Stone, R. J., & Morley, C. J. (2002). Unlicensed and off-label drug use in an Australian neonatal intensive care unit. *Pediatrics*, *110*(5), e52.
- Ohning, B. L. (2006). Transport of the critically ill newborn Retrieved April 20, 2008, from <http://www.emedicine.com/ped/topic2730.htm>
- Owen-Reece, H., Smith, M., Elwell, C. E., & Goldstone, J. C. (1999). Near infrared spectroscopy. *British Journal of Anaesthesia*, *82*(3), 418-426.
- Pamphlett, R., Raisanen, J., & Kum-Jew, S. (1999). Vertebral artery compression resulting from head movement: a possible cause of the sudden infant death syndrome. *Pediatrics*, *103*(2), 460-468.
- Patural, Hugues, Pichot, Vincent, Jaziri, Fethi, Teyssier, Georges, Gaspoz, Jean-Michel, Roche, Frederic, & Barthelemy, Jean-Claude. (2008). Autonomic cardiac control of very preterm newborns: A prolonged dysfunction. *Early Human Development*, *84*, 681-687.

- Pellicer, A., Gaya, F., Madero, R., Quero, J., & Cabanas, F. (2002). Noninvasive continuous monitoring of the effects of head position on brain hemodynamics in ventilated infants. *Pediatrics*, *109*(3), 434-440.
- Perlman, J. M. (2004). Cerebral blood flow in premature infants: Regulation, measurement, and pathophysiology of intraventricular hemorrhage. In R. A. Polin, W. W. Fox & S. H. Abman (Eds.), *Fetal and neonatal physiology* (3rd ed., Vol. 2, pp. 1745-1757). Philadelphia: Saunders.
- Perlman, J. M., & Volpe, J. J. (1985). Episodes of apnea and bradycardia in the preterm newborn: Impact on cerebral circulation. *Pediatrics*, *76*(3), 333-338.
- Petrova, I. Y., Petrov, Y. Y., Esenaliev, R. O., Deyo, D. J., Cicenaitis, I., & Prough, D. S. (2009). Noninvasive monitoring of cerebral blood oxygenation in ovine superior sagittal sinus with novel multi-wavelength optoacoustic system. *Opt Express*, *17*(9), 7285-7294. doi: 179201 [pii]
- Philbin, M. K., Robertson, A., & Hall, J. W. (1999). Recommended permissible noise criteria for occupied, newly constructed or renovated hospital nurseries. *Journal of Perinatology*, *19*(8), 559-563.
- Phillips Electronics. (2007). General imaging: Ultrasound. Retrieved April 15, 2008
- Pichler, G., Schmolzer, G., Muller, W., & Urlesberger, B. (2001). Body position-dependent changes in cerebral hemodynamics during apnea in preterm infants. *Brain and Development*, *23*(6), 395-400. doi: S0387760401002455 [pii]
- Pichler, G., Urlesberger, B., Schmolzer, G., & Muller, W. (2004). Effect of tilting on cerebral haemodynamics in preterm infants with periventricular leucencephalomalacia. *Acta Paediatrica*, *93*(1), 70-75.
- Pichler, G., van Boetzlar, M. C., Muller, W., & Urlesberger, B. (2001). Effect of tilting on cerebral hemodynamics in preterm and term infants. *Biology of the Neonate*, *80*(3), 179-185.
- Pollard, V., Prough, D. S., DeMelo, A. E., Deyo, D. J., Uchida, T., & Stoddart, H. F. (1996). Validation in volunteers of a near-infrared spectroscope for monitoring brain oxygenation in vivo. *Anesthesia and Analgesia*, *82*(2), 269-277.
- Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A., McNamara, J. O., & White, L. E. . (2008a). The auditory system. In *Neuroscience* (4th ed., pp. 313-342). Sunderland, MA: Sinauer Associates, Inc.
- Purves, D., Augustine, G. J., Fitzpatrick, D., Hall, W. C., LaMantia, A., McNamara, J. O., & White, L. E. . (2008b). Modification of brain circuits as a result of

experience. In D. Purves, G. J. Augustine, D. Fitzpatrick, W. C. Hall, A. LaMantia, J. O. McNamara & L. E. White (Eds.), *Neuroscience* (4th ed., pp. 611-633). Sunderland, MA: Sinauer Associates, Inc.

- Rais-Bahrami, K., Rivera, O., & Short, B. L. (2006). Validation of a noninvasive neonatal optical cerebral oximeter in veno-venous ECMO patients with a cephalad catheter. *Journal of Perinatology*, *26*(10), 628-635. doi: 10.1038/sj.jp.7211573
- Roche-Labarbe, N., Carp, S. A., Surova, A., Patel, M., Boas, D. A., Grant, P. E., & Franceschini, M. A. (2010). Noninvasive optical measures of CBV, StO(2), CBF index, and rCMRO(2) in human premature neonates' brains in the first six weeks of life. *Human Brain Mapping*, *31*(3), 341-352. doi: 10.1002/hbm.20868
- Roche-Labarbe, N., Fenoglio, A., Aggarwal, A., Dehaes, M., Carp, S. A., Franceschini, M. A., & Grant, P. E. (2012). Near-infrared spectroscopy assessment of cerebral oxygen metabolism in the developing premature brain. *Journal of Cerebral Blood Flow and Metabolism*, *32*(3), 481-488. doi: 10.1038/jcbfm.2011.145
- Rubio, A., Hakami, L., Munch, F., Tandler, R., Harig, F., & Weyand, M. (2008). Noninvasive control of adequate cerebral oxygenation during low-flow antegrade selective cerebral perfusion on adults and infants in the aortic arch surgery. *Journal of Cardiac Surgery*, *23*(5), 474-479. doi: 10.1111/j.1540-8191.2008.00644.x
- Russell, R. B., Green, N. S., Steiner, C. A., Meikle, S., Howse, J. L., Poschman, K., . . . Petrini, J. R. (2007). Cost of hospitalization for preterm and low birth weight infants in the United States. *Pediatrics*, *120*(1), e1-9. doi: 10.1542/peds.2006-2386
- Rutter, N. (1988). The immature skin. *British Medical Bulletin*, *44*(4), 957-970.
- Saigal, Saroj, & Doyle, Lex W. (2008). An overview of mortality and sequelae of preterm birth from infancy to adulthood. *The Lancet*, *371*, 261-269.
- Sakata, Y. S., Grinberg, O. Y., Grinberg, S., Springett, R., & Swartz, H. M. (2005). Simultaneous NIR-EPR spectroscopy of rat brain oxygenation. *Advances in Experimental Medicine and Biology*, *566*, 357-362. doi: 10.1007/0-387-26206-7_47
- Sanes, D. H., Reh, T. A., & Harris, W. A. (2006). Synapse formation and function. In D. H. Sanes, T. A. Reh & W. A. Harris (Eds.), *Development of the nervous system* (pp. 207-246). Burlington, MA: Elsevier Academic Press.
- Saoud Abd El-Moneim, E., Hans-Otto, F., Markus, K., Abou Elmagd, A., Brandis, M., Schulte-Moenting, J., & Hentschel, R. (2008). Infant-ventilator interaction can affect cerebral blood flow in preterm infants: Comparison between 2 modes. *Pediatrics*, *121*(2), S135-S136.

- Schnapp, L. M., & Cohen, N. H. (1990). Pulse oximetry. Uses and abuses. *Chest*, 98(5), 1244-1250.
- Schubert, David, & Leyba, John. (2008). Electrical circuits. In *Chemistry and physics for anesthesia: A student centered approach* (pp. 265-285). Wichita, KS: Newman University.
- Seidel, H. M., Ball, J. W., Dains, J. E., & Benedict, G. W. (2003a). Blood vessels *Mosby's guide to physical examination* (5th ed., pp. 462-495). St. Louis: Mosby, Inc.
- Seidel, H. M., Ball, J. W., Dains, J. E., & Benedict, G. W. (2003b). Chest and lungs *Mosby's guide to physical examination* (5th ed., pp. 356-413). St. Louis: Mosby, Inc.
- Severinghaus, J. W. (2007). Takuo Aoyagi: Discovery of pulse oximetry. *Anesthesia and Analgesia*, 105(6), S1-S4. doi: 10.1213/01.ane.0000269514.31660.09
- Singh, J., & Stock, A. (2006). Head trauma Retrieved December 7, 2007, from <http://www.emedicine.com/ped/topic929.htm>
- Somanetics Corporation. (2009). Invos System Retrieved August 3, 2009, from <http://www.somanetics.com/invos.asp>
- Sorensen, L. C., & Greisen, G. (2009). The brains of very preterm newborns in clinically stable condition may be hyperoxygenated. *Pediatrics*, 124(5), e958-963. doi: 10.1542/peds.2008-2394
- Sorensen, L. C., Leung, T. S., & Greisen, G. (2008). Comparison of cerebral oxygen saturation in premature infants by near-infrared spatially resolved spectroscopy: observations on probe-dependent bias. *J Biomed Opt*, 13(6), 064013. doi: 10.1117/1.3013454
- Sorensen, L. C., Maroun, L. L., Borch, K., Lou, H. C., & Greisen, G. (2008). Neonatal cerebral oxygenation is not linked to foetal vasculitis and predicts intraventricular haemorrhage in preterm infants. *Acta Paediatrica*, 97(11), 1529-1534. doi: 10.1111/j.1651-2227.2008.00970.x
- Soul, J. S., Hammer, P. E., Tsuji, M., Saul, J. P., Bassan, H., Limperopoulos, C., . . . Du Plessis, A. J. (2007). Fluctuating pressure-passivity is common in the cerebral circulation of sick premature infants. *Pediatric Research*, 61(4), 467-473.
- Strauss, R. G. (1991). Transfusion therapy in neonates. *American Journal of Diseases in Childhood*, 145, 904-911.
- Strauss, R. G. (1995). Red blood cell transfusion practices in the neonate. *Clinics in Perinatology*, 22(3), 641-655.

- Sugarman, R. A. (2002). Structure and function of the neurologic system. In K. L. McCance & S. E. Huether (Eds.), *Pathophysiology: The biologic basis for disease in adults and children* (4th ed., pp. 363-400). St. Louis: Mosby, Inc.
- Surethiran, S. S., Wilbraham, K., May, J., Chant, T., Emmerson, A. J., & Newton, V. E. (2003). Noise levels within the ear and post-nasal space in neonates in intensive care. *Archives of Disease in Childhood. Fetal and Neonatal Edition*, 88(4), F315-318.
- Thomas, K. A., & Uran, A. (2007). How the NICU environment sounds to a preterm infant: update. *MCN; American Journal of Maternal Child Nursing*, 32(4), 250-253. doi: 10.1097/01.NMC.0000281966.23034.e9
- Tina, L. G., Frigiola, A., Abella, R., Artale, B., Puleo, G., D'Angelo, S., . . . Gazzolo, D. (2009). Near Infrared Spectroscopy in healthy preterm and term newborns: correlation with gestational age and standard monitoring parameters. *Curr Neurovasc Res*, 6(3), 148-154.
- Toet, M. C., & Lemmers, P. M. (2009). Brain monitoring in neonates. *Early Human Development*, 85(2), 77-84. doi: 10.1016/j.earlhumdev.2008.11.007
- Toet, M. C., Lemmers, P. M., van Schelven, L. J., & van Bel, F. (2006). Cerebral oxygenation and electrical activity after birth asphyxia: their relation to outcome. *Pediatrics*, 117(2), 333-339. doi: 10.1542/peds.2005-0987
- Tracy, M., Klimek, J., Hinder, M., Ponnampalam, G., & Tracy, S. (2010). Does caffeine impair cerebral oxygenation and blood flow velocity in preterm infants? *Acta Paediatrica*. doi: 10.1111/j.1651-2227.2010.01828.x
- Tsuji, M., Saul, J. P., du Plessis, A., Eichenwald, E., Sobh, J., Crocker, R., & Volpe, J. J. (2000). Cerebral intravascular oxygenation correlates with mean arterial pressure in critically ill premature infants. *Pediatrics*, 106(4), 625-632.
- Tsuji, M., Saul, J. P., Plessis, A., Eichenwald, E., Sobh, J., Crocker, R., & Volpe, J. J. (2000). Cerebral intravascular oxygenation correlates with mean arterial pressure in critically ill premature infants. *Pediatrics*, 106(4), 625-632.
- Tyszczyk, L., Meek, J., Elwell, C., & Wyatt, J. S. (1998). Cerebral blood flow is independent of mean arterial blood pressure in preterm infants undergoing intensive care. *Pediatrics*, 102(2), 337-341.
- United States Environmental Protection Agency. (1974). Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety Retrieved October 3, 2008, from <http://www.nonoise.org/library/levels74/levels74.htm>

- United States Environmental Protection Agency. (1978). Protective Noise Levels Retrieved March 5, 2012, from <http://nonoise.org/library/levels/levels.htm>
- Vacchiano, Charles. (2009). *Concepts: Recording the ECG, CO₂ elimination, ETCO₂, and SpO₂ measurement*. Chemistry and Physics of Anesthesia. Duke University School of Nursing. Durham, NC.
- Vargo, Lyn. (2003). Cardiovascular assessment. In Ellen P. Tappero & Mary Ellen Honeyfield (Eds.), *Physical assessment of the newborn: A comprehensive approach to the art of physical examination* (3rd ed., pp. 81-96). Santa Rosa, CA: NICU Ink Book Publishers.
- Verhagen, E. A., Keating, P., ter Horst, H. J., Martijn, A., & Bos, A. F. (2009). Cerebral oxygen saturation and extraction in preterm infants with transient periventricular echodensities. *Pediatrics*, *124*(1), 294-301. doi: 10.1542/peds.2008-2057
- Vogelberg, C., Taut-Sack, H., Friebel, D., Maier, U., & Rupperecht, E. (2004). Bradycardia and hypoxaemia due to position-dependent hypoperfusion of the brain stem in a preterm infant. *Acta Paediatrica*, *93*(2), 275-278.
- Vohra, H. A., Modi, A., & Ohri, S. K. (2009). Does use of intra-operative cerebral regional oxygen saturation monitoring during cardiac surgery lead to improved clinical outcomes? *Interactive Cardiovascular and Thoracic Surgery*, *9*(2), 318-322. doi: icvts.2009.206367 [pii] 10.1510/icvts.2009.206367
- Volpe, J. J. (2001a). The developing nervous system: A series of review articles. *Pediatric Research*, *50*(5), 553-562.
- Volpe, J. J. (2001b). Hypoxic-ischemic encephalopathy: Biochemical and physiological aspects *Neurology of the newborn* (4th ed.). Philadelphia: W. B. Saunders Company.
- Volpe, J. J. (2008). Specialized studies in the neurological evaluation. In Joseph J. Volpe (Ed.), *Neurology of the newborn* (5th ed., pp. 154-202). Philadelphia: Saunders Elsevier.
- Volpe, J. J., Herscovitch, P., Perlman, J. M., Kreusser, K. L., & Raichle, M. E. (1985). Positron emission tomography in the asphyxiated term newborn: Parasagittal impairment of cerebral blood flow. *Annals of Neurology*, *17*(3), 287-296. doi: 10.1002/ana.410170312
- Waltz, C. F., Strickland, O., & Lenz, E. R. (2005a). Measurement reliability. In C. F. Waltz, O. Strickland & E. R. Lenz (Eds.), *Measurement in nursing and health research* (pp. 137-153). NY: Springer Publisher.

- Waltz, C. F., Strickland, O., & Lenz, E. R. (2005b). Validity of measures. In C. F. Waltz, O. Strickland & E. R. Lenz (Eds.), *Measurement in nursing and health research* (pp. 154-189). NY: Springer Publisher.
- Watson, G. H. (1974). Effect of head rotation on jugular vein blood flow. *Archives of Disease in Childhood, 49*(3), 237-239.
- Watzman, H. M., Kurth, C. D., Montenegro, L. M., Rome, J., Steven, J. M., & Nicolson, S. C. (2000). Arterial and venous contributions to near-infrared cerebral oximetry. *Anesthesiology, 93*(4), 947-953.
- Weinstein, N. D. (1978). Individual differences in reactions to noise: a longitudinal study in a college dormitory. *Journal of Applied Psychology, 63*(4), 458-466.
- Werner, L. A. (2004). Early development of the human auditory system. In H. W. Taesch, R. A. Ballard & C. A. Gleason (Eds.), *Fetal and neonatal physiology* (3rd ed., Vol. 2, pp. 1803-1819). Philadelphia: Saunders.
- Wong, F. Y., Leung, T. S., Austin, T., Wilkinson, M., Meek, J. H., Wyatt, J. S., & Walker, A. M. (2008). Impaired autoregulation in preterm infants identified by using spatially resolved spectroscopy. *Pediatrics, 121*(3), e604-611. doi: 10.1542/peds.2007-1487
- Wong, F. Y., Witcombe, N. B., Yiallourou, S. R., Yorkston, S., Dymowski, A. R., Krishnan, L., . . . Horne, R. S. (2011). Cerebral oxygenation is depressed during sleep in healthy term infants when they sleep prone. *Pediatrics, 127*(3), e558-565. doi: 10.1542/peds.2010-2724
- Yodh, A. G. (2009). Diffuse optics for monitoring brain hemodynamics. *Conf Proc IEEE Eng Med Biol Soc, 2009*, 1991-1993. doi: 10.1109/iembs.2009.5333424
- Yoshitani, K., Kawaguchi, M., Tatsumi, K., Kitaguchi, K., & Furuya, H. (2002). A comparison of the INVOS 4100 and the NIRO 300 near-infrared spectrophotometers. *Anesthesia and Analgesia, 94*(3), 586-590; table of contents.
- Young, T. E., & Mangum, B. (2003). Caffeine Citrate. In *Neofax* (16th ed., pp. 178-179). Raleigh, NC: Acorn Publishing, Inc.
- Younkin, D., Delivoria-Papadopoulos, M., Reivich, M., Jaggi, J., & Obrist, W. (1988). Regional variations in human newborn cerebral blood flow. *The Journal of Pediatrics, 112*(1), 104-108.
- Younkin, D., Reivich, M., Jaggi, J., Obrist, W., & Delivoria-Papadopoulos, M. (1987). The effect of hematocrit and systolic blood pressure on cerebral blood flow in newborn infants. *Journal of Cerebral Blood Flow and Metabolism, 7*(3), 295-299.

8. Biography

Heather Elaine Elser was born in Wauseon, Ohio and resided most of her childhood in Tipp City, Ohio. In 2001, she received her BSN from Thomas More College in Northern Kentucky and she became a Duke Alumnus with an MSN in 2007 (Neonatal Nurse Practitioner and Neonatal Clinical Nurse Specialist). Heather has cared for mothers and newborns during her nursing practice in Level III neonatal intensive care units at Kaiser Permanente, Walnut Creek, California and Miami Valley Hospital, Dayton, Ohio. During her time as a PhD student, Heather was funded by an individual National Research Service Award (NRSA) from the National Institute of Health and a recipient of the Association of Critical Care Nurses (AACN)/Sigma Theta Tau Critical Care Grant. Heather is a member of the National League for Nursing, The Council for the Advancement of Nursing Science, International Society on Infant Studies, Southern Nursing Research Society, American Association of Critical Care Nurses, Sigma Theta Tau- Epsilon Chapter, and the National Association of Neonatal Nurses. She has presented numerous poster and podium presentations at national and international conferences and guest lectured for the ABSN students at Duke University School of Nursing. Heather will reside in Raleigh, North Carolina after graduation.