

To the Graduate Council:

I am submitting herewith a thesis written by Heather Sedges entitled “Infant Learning and Physiological Self-Regulation during the Visual Expectation Paradigm.” I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Child and Family Studies.

Tara S. Wass, Major Professor

We have read this thesis
and recommend its acceptance:

Greer Litton Fox

Rena A. Hallam

Accepted for the Council:

Carolyn R. Hodges, Vice Provost and
Dean of the Graduate School

(Original signatures are on file with official student records.)

INFANT LEARNING AND PHYSIOLOGICAL SELF-REGULATION DURING THE
VISUAL EXPECTATION PARADIGM

A Thesis Presented for
the Master of Science
Degree
The University of Tennessee, Knoxville

Heather Sedges
August 2007

Acknowledgements

I would like to offer my sincere appreciation to the members of my thesis committee, as each member played unique and formidable role in my development as a young woman, researcher, and member of the academic community. I would also like to thank Dr. Vey M. Nordquist for his support and guidance throughout this process.

To my family—Mom, Dad, and Peter-Michael—I feel truly blessed and eternally grateful for your love, ceaseless support, wisdom, and unwavering faith in me. Your belief in me was my strength throughout this experience. I would also like to express my heartfelt appreciation to my grandparents, the late Mr. and Mrs. Oreste Gasperini. Their influence forever infused me with a sense of curiosity and hunger for knowledge.

I am joyfully thankful to my soon-to-be husband and forever favorite, Joshua Scott Wallace. Your love, steadfast sureness of me, insightfulness, sense of humor, and patience are the most calming and awesome forces in my life. You have the power to calm my heart and to set it a flutter.

To my honorable maiden and best friend, Bridget Ellen Hatfield—I am so grateful for the blessing of our friendship. Thank you for your age-less wisdom, willing ear, ready laugh, and love of “London Fogs”. Your spirit has been my inspiration. I am also grateful to my fellow graduate students—especially Sally Hunter and Andrea Marable, whose compassion has been a true testament to the spirit of friendship.

Abstract

Learning during infancy is dependent on many factors. One such factor is physiological self-regulation. This study investigated the relationship between physiological self-regulation abilities and evidence of learning based on Visual Expectation Paradigm (VExP) performance. Alterations in High Frequency Heart Period Variability (HFHPV) assessed physiological self-regulation and were hypothesized to correspond with VExP performance. Findings revealed patterns of HFHPV change during the VExP and that HFHPV change negatively corresponded with a resting measure of HFHPV and VExP performance. Results suggested that resting HFHPV was a better predictor of learning during the VExP than patterns of HFHPV change evidenced throughout the task.

TABLE OF CONTENTS

Chapter		Page
1.	INTRODUCTION.....	1
	Contexts of Self-Regulation.....	1
	Purpose of Current Study.....	2
2.	LITERATURE REVIEW.....	6
	Definition and Description of Physiological Self-Regulation.....	6
	Learning during Infancy.....	10
	Foundation for Current Study.....	18
	Hypotheses.....	18
3.	METHODS.....	20
	Participants.....	20
	Sub-Group Samples.....	20
	Apparatus.....	21
	Procedure.....	23
	Data Reduction.....	23
	Exclusion Rationale and Data Cleaning.....	31
	Predicted Value Calculations.....	32
4.	RESULTS.....	35
	Comparisons of Excluded Cases.....	35
	Correlations for HFHPV, RLI, and Demographic Variables.....	35
	Results for Hypotheses.....	37
5.	DISCUSSION.....	46
	Hypothesis One: Specification of HFHPV Percent Change Patterns..	47
	Hypothesis Two: Relationship between Resting HFHPV and HFHPV Change during the VExP.....	49
	Hypothesis Three: Relationship between RLI and HFHPV Change...	52
	Hypothesis Four: Predictive Power of LgBasePwr versus HFHPV Change Patterns.....	53
6.	CONCLUSION.....	55
	Implications.....	55
	Limitations.....	57
	Recommendations for Future Research.....	61
	REFERENCES.....	61
	APPENDICES.....	70

	Page
Appendix A: <i>Figures</i>	71
Appendix B: <i>Descriptive Statistics of Sample</i>	74
Appendix C: <i>Correlations, Distributions, Means, and Mean Differences</i>	78
VITA.....	87

LIST OF FIGURES

Figure		Page
1.	Schematic representation of VExP shifting expectations.....	69
2.	Percent of cases defined as having either low or high resting HFHPV by patterns of HFHPV change.....	70

LIST OF TABLES

Table		Page
B-1.	Descriptive Statistics of Demographic Characteristics for All Samples.....	72
B-2.	Means and Standard Deviations (SD) of Demographic Characteristics for All Samples.....	74
C-1.	Correlations between HFHPV variables, RLI, and significant demographic variables.....	76
C-2.	Percentages of Demographic Variables and Categorical HFHPV Variables.....	77
C-3.	HFHPV Percent Change Pattern Means (SD).....	79
C-4.	LgBasePwr Means (SD) by Sex and HFHPV Percent Change Patterns.....	80
C-5.	Percentages of Males and Females with Low Versus High Resting HFHPV Across HFHPV Change Patterns.....	81
C-6.	RLI Means (SD) by HFHPV Percent Change Patterns.....	82
C-7.	RLI Means (SD) by HFHPV Change Direction per VExP Segment....	83

Abbreviations

BaseMedSpl	Median split of baseline HFHPV
HFHPV	High Frequency Heart Period Variability
LgBasePwr	Log-transformed baseline HFHPV power
PctChgSeg1	Percent change during segment one
PctChgSeg2	Percent change during segment two
PctChgAll	Percent change overall
RLI	Rule Learning Index
VExP	Visual Expectation Paradigm

CHAPTER I: INTRODUCTION

Contexts of Self-Regulation

From the earliest ages of infancy, learning occurs in contexts in which both external and internal factors influence the amount, rate, and quality of learning (Smith, Fagan, and Ulvund, 2002; Stanley, Murray, and Stein, 2004). External factors include proximal and distal environmental factors such as socioeconomic status and maternal responsiveness (Smith et al.; Stanley et al.). For example, Smith et al. demonstrated that higher socioeconomic status predicted better learning abilities, measured as recognition memory during infancy and Stanley et al. found that during infancy, higher maternal responsiveness was associated with better learning, which was demonstrated by producing a motor response to a contingent environmental stimulus.

Internal mechanisms such as intelligence, temperament, and information processing speed also contribute to early learning capabilities. For instance, prior research demonstrated that children classified as having behaviorally inhibited or socially withdrawn temperaments scored lower on cognitive tests and learned at a slower rate than uninhibited peers (Lamb, Garn, and Keating, 1981). Calkins (1996) argued that children with a behaviorally inhibited temperament were more likely to socially withdraw and therefore have fewer interactions with caregivers and peers. Reduced interactions with caregivers and peers may potentially decrease learning opportunities.

Another influential internal mechanism is physiological self-regulation, which can include regulation of attention and emotional states. An example of physiological regulation is when heart rate variability decreases as a result of an increase in heart rate, which inhibits influence from the vagus nerve (discussed later). Physiological self-

regulation is important because it influences the coordination of internal processes that in turn influence the ability to adapt to external demands in a constructive manner (Carlson, 2004). For instance, researchers found that efficient physiological self-regulation, evidenced by increased heart rate, facilitates and supports engagement and attention during a cognitive task (Berg, 1972 & 1974; Buss, Goldsmith, & Davidson, 2005; Hansen, Johnsen, & Thayer, 2003; Kagan, 1987). The active engagement and maintenance of attention during a cognitive task is traditionally viewed as an imperative aspect of learning (Richards, 1988 & Ruff, 1986) because it facilitates the ability to attend to the environment and extract information needed for future reference.

Physiological regulation also influences emotional regulation abilities. Emotional regulation refers to the ability to engage or inhibit appropriate emotional responses to stimuli. An example of emotion regulation is when an infant self-sooths or seeks comfort from others in the environment when in distress. These efforts contribute to the development of social skills and behavior throughout life. In sum, more mature physiological self-regulatory abilities support the infant's ability to regulate attention and emotions (Calkins & Keane, 2004), which in turn facilitate and support learning abilities.

Purpose of Current Study

The purpose of this study was to investigate the relation between infants' physiological self-regulation and learning abilities during a cognitive task. This study examined whether there were patterns of physiological change measured by levels of infants' high frequency heart period variability (HFHPV), a common measure of physiological self-regulation, during the Visual Expectation Paradigm (VExP), and whether patterns of HFHPV change related to resting measures of HFHPV.

This study also explored whether infants' HFHPV change during the VExP related to the ability to abstract and integrate knowledge about the physical and temporal characteristics of VExP stimuli, and whether HFHPV change was a better predictor of this ability than resting HFHPV. Evidence of the ability to abstract and integrate knowledge about the characteristics of the VExP task was based on the pattern of infants' visual anticipations and responses to the predictable pattern of the VExP stimuli.

A pattern of visual anticipations and responses most similar to the pattern of VExP stimuli was considered to be evidence that an infant was able to extract and integrate the physical and temporal VExP characteristics. Assessments of HFHPV change during the VExP task measured infants' abilities to self-regulate physiological responses during the task. Together, measures of HFHPV change and patterns of visual responding were used to examine the relationship between physiological self-regulation and learning in infancy.

Rationale for Measures Used

The primary purpose of this study was to examine the relationship between physiological self-regulation and learning. Therefore, measures used in this study needed to focus solely on infants' physiological self-regulation and learning abilities, rather than assessing external factors such as maternal responsiveness that may also explain learning abilities. Measures of HFHPV change and patterns of visual responses assessed infants' abilities exclusively, whereas other measures, like coded observations of mother-child interactions may have assessed other mediating variables such as attachment.

Additionally, using a physiological measure such as HFHPV change may reveal underlying individual differences accounting for some of the variance in learning beyond

what assessments such as behavioral observations explain. This is important due to the limited range of possible observable behaviors evident during infancy. For instance, there are limited explanations for the differences in infants' facial expressions or fussy versus calm states (e.g., excitement, curiosity and attention, hunger, and/or discomfort). Because of the inability to fully explain and account for differences in behavioral manifestations, infant behaviors may be misinterpreted. This is in contrast to the nearly limitless range of behaviors evident during the toddler years and beyond (e.g., motivation, anger, frustration, fear, etc.) that researchers can observe, measure, assess, and accurately interpret.

Utility of Current Study

Gathering information solely about infant functioning may also provide information relevant to practitioners and early interventionists. For instance, information from this study may contribute to the groundwork and theoretical foundation needed prior to application of these and similar findings allowing for the early assessment and detection of potential learning and/or self-regulation disorders. Practitioners may be able to assess learning and/or self-regulation disorders earlier than ever before since these measures apply to pre-verbal children. In turn, results from early assessments may lead to an increase in early intervention.

The importance of early detection and intervention is paramount. We know there are more sustained outcomes the earlier intervention begins for children with disabilities (Turnbull, Turnbull, Erwin, & Soodak, 2006). This knowledge has even influenced the establishment of federal programs such as Part C of the Individual with Disabilities and Education Act, which emphasizes the importance of early detection and intervention

services for children ages birth to three. Thus, there is evidence and support for the need for early detection, but early assessments used for detection are not possible without well-validated and reliable measures. This study seeks to provide such information.

Additionally, these findings may also be relevant to those working with non-verbal populations. For instance, practitioners may be able to assess whether a non-verbal child who does not have receptive communication skills is able to attend to the presentation of patterned VExP stimuli and evidence that he/she abstracted and integrated information about the stimuli through visual responses patterned in a manner similar to the stimuli. Assessments of the child's ability to abstract and integrate information about the environment may be applicable to the child's rehabilitation services. For instance, based on assessments using the VExP, practitioners may be able to determine whether or not the child is responsive to environmental stimuli and determine the utility of basing intervention on a contingency-based learning paradigm.

CHAPTER II: LITERATURE REVIEW

Definition and Description of Physiological Self-Regulation

Self-regulatory abilities are an imperative aspect of learning during infancy because infants must be able to regulate their physiological response to stimuli in order to attend to and extract relevant and applicable features of presented information.

Physiological self-regulation refers to the ability to adjust internal functions such as respiration and heart rate in response to external or internal demands in order to maintain or regain a state of homeostasis (Groome, Loizou, Holland, Smith & Hoff, 1999). Porges (1995) posited that the ability to adapt to environmental demands in an optimal and efficient manner is dependent on the ability to maintain and regain internal homeostasis. The ability to adapt to environmental demands by regulating internal homeostasis is important because it allows infants to either function in a heightened state of arousal or return to a calm state, both of which can facilitate optimal functioning (Porges, 1973 & 1974).

The autonomic nervous system is responsible for regulating organs, such as the heart, lungs, stomach, pupils, and sweat glands, whose functions contribute to physiological homeostasis (Carlson, 2004). There are two branches of the autonomic nervous system: the sympathetic and the parasympathetic nervous systems (Carlson). The sympathetic nervous system (SNS) is generally involved in regulating functions that affect the body externally (Carlson). For example, the SNS is responsible for activating sweat glands that produce sweat and cool the body in response to increased body temperature (Carlson). The parasympathetic nervous system (PNS) primarily coordinates internal functions necessary for maintaining internal homeostasis and is responsive to

internal changes, such as decreased heart rate that result from external demands (Porges, 1995).

The tenth cranial nerve, also known as the vagus nerve, is part of the PNS and plays an important role in physiological self-regulation because it is involved in the balance between maintaining internal homeostasis and facilitating adaptive responses to environmental stimuli. Porges' (1986) polyvagal theory suggested that when the vagus nerve responds to stimuli, it influences heart period (time between heartbeats) in either an excitatory or inhibitory manner via projections to the sinoatrial node of the heart (Porges, 1995). According to this theory, increased heart period (decreased heart rate) results from increased influence from the vagal nerve, while decreased heart period (increased heart rate) results from decreased influence from the vagal nerve. Influence on heart period from the vagus nerve is referred to as vagal tone or High Frequency Heart Period Variability (HFHPV).

HFHPV is a dynamic measure of physiological regulation (Carlson, 2004; Doussard-Roosevelt, Montgomery, & Porges, 2003; Groome, Loizou, Holland, Smith, & Hoff, 1999; Porges, 1995). Numerous studies demonstrated that the magnitude of HFHPV correlates with individual differences in areas such as behavioral inhibition, emotional regulation, regulatory disorders, as well as attention and learning (Calkins & Dedmon, 1999; Cole, Zahn-Waxler, Fox, Usher, & Welsh, 1996; Doussard-Roosevelt, Montgomery, & Porges; Fox & Porges, 1985; Richards, 1987). Researchers often characterize and define participants as having either high or low HFHPV depending on the magnitude of their HFHPV assessed during a resting state (Bornstein & Suess, 2000;

Calkins, 1996; Fabes, Eisenberg, & Eisenbud, 1993; Garcia-Coll, Kagan, & Reznick, 1984; Kagan, 1982; Stifter & Fox, 1990).

Past research also described sharply divergent characteristics of groups with differing resting HFHPV magnitudes such as differences in expressions of behavior, affect, and regulation abilities. For instance, high resting HFHPV related to greater emotional expressivity and irritability (Field, Woodson, Greenberg, & Cohen, 1982; Porges, Doussard-Roosevelt, & Maiti, 1994), increased likelihood of regulatory disorders such as sleep and feeding problems and hypersensitivity to environmental stimuli (DeGangi, DiPietro, Greenspan, & Porges, 1991). In the aforementioned studies infants with low resting HFHPV demonstrated reactions and behaviors opposite of infants with high resting HFHPV. The affects of high or low HFHPV are multi-dimensional, evidenced by relations between social (noted above), as well as cognitive outcomes.

In addition to the positive relationships between high resting HFHPV and positive affect and low resting HFHPV and negative affect, levels of resting HFHPV relate to attention and learning. In three specific studies infants with high resting HFHPV were less responsive to distractions and had shorter recorded looking times (Bornstein & Suess, 2000; Richards, 1985, 1987). Distractibility and looking time were indices of learning in these studies, based on the concept infants' who were less distractible were engaged in the task and actively learning, whereas infants' who looked at a stimulus for a shorter period of time efficiently processed the information and therefore, no longer needed to look at it (Linnemeyer & Porges, 1986). Linnemeyer and Porges also noted that infants who exhibited learning and sustained attention during a recognition memory task tended to have high resting HFHPV and increased heart period during the task. Thus,

repeated studies (Hansen, Johnsen, & Thayer, 2003; Linnemeyer & Porges; Richards, 1985; Richards & Cronise, 2000) using different cognitive tasks demonstrated that high resting HFHPV was associated with higher levels of sustained attention.

It is useful to note here that sustained attention refers to the ability to regulate attention by engaging, maintaining, and disengaging the attentional system (Richards & Casey, 1991; Ruff, 1986). Sustained attention is critical for learning because infants must attend to a stimulus long enough to extract and process relevant information necessary for learning. Not engaging or attending to the task inevitably reduces the ability to process the information and integrate the information into present schemas (DiLalla, Thompson, Plomin, Phillips, Fagan, Haith, et al., 1990).

As mentioned above, findings from past research relate static measures of resting HFHPV to sustained attention and learning. While a static measure of HFHPV is a useful measure, it is only associated with resting physiological profiles, failing to capture active physiological regulation. Resting HFHPV essentially measures the capacity that infants have to physiologically self-regulate, while change in HFHPV measures the mobilization of that capacity. Investigating the relationship between resting HFHPV and changes in HFHPV in response to environmental stimuli and task engagement may elucidate the relation between resting HFHPV and an active form of physiological self-regulation. Additionally, investigating the relationship between differential outcomes and changes in HFHPV that are responsive to environmental change and task engagement may further clarify the multi-dimensional nature and influence of physiological regulation abilities during infancy.

Recent research is beginning to investigate the relationship between resting HFHPV and changes in HFHPV. Such studies noted an inverse relationship between resting HFHPV and HFHPV changes in response to and during a task (Buss, Davidson, Kalin, & Goldsmith, 2004; Calkins, 1996; DeGangi, DiPietro, Greenspan, & Porges, 1991; Doussard-Roosevelt, Montgomery, & Porges, 2003). For example, infants with high resting HFHPV tend to display a decrease in HFHPV, whereas infants with low resting HFHPV are more likely to display an increase in HFHPV in response to and during a task. These relationships also relate to measures of sustained attention and learning in the same manner as resting HFHPV (Calkins & Keane, 2004; Garcia-Coll, Kagan, & Reznick, 1984; Richards, 1985). Thus, infants with high resting HFHPV who demonstrate a decrease in HFHPV during a task are more likely to demonstrate better learning abilities than infants with low resting HFHPV who demonstrate an increase in HFHPV during a cognitive task. In summary, investigating the relationship between changes in HFHPV and evidence of sustained attention and learning may further explain the nature and implications of physiological self-regulatory abilities beyond what a correlation between measures of resting HFHPV and differential outcomes can explain.

Learning during Infancy

The ability to learn is one of the most foundational processes needed for survival and daily interactions with other people and the environment. Learning refers to the extraction of information from the environment such as visual-spatial placement of objects and the ability to integrate the extracted information with the necessary mental processes in order to respond to environmental cues and integrate information

accordingly. The process of learning is often related to a computer that has to encode, translate, and store information. According to the computer model of learning people receive stimuli from their environment, encode the perceived information into a recognizable form, associate the encoded information with pre-set response patterns, and alter their response based on the specific stimulus, context, and previous knowledge of the situation (Carlson, 2004). The development of this process involves basic memory systems and biological functions which are dependent upon stimuli in the infant's environment and mediated by factors such as physiological self-regulatory abilities.

Processes of Learning during Infancy

Infants must be able to retain information through memory systems in order to integrate and respond to information about novel stimuli. There are mediating factors that influence the ability to attend to and recognize environmental stimuli. These mediating factors include the infant's ability to self-regulate physiological processes in response to and during engagement in a cognitive task. In addition, it is important for infants to be able to attend to the stimuli in order to adequately process the information and integrate it into memory systems so that information can be retrieved at a later point. In order to associate and integrate information from the environment infants must be able to temporarily store perceived stimuli as accessible and valuable information (Baddeley, 1992).

The ability to temporarily store perceived stimuli is known as short-term memory, or working memory. It is important to note that working memory only aids in the area of storage and retrieval, not recognition or comprehension or appropriate information

processing needed to elicit appropriate responses (Baddeley, 1992). Other forms of memory that contribute to recognition and comprehension of information are semantic and episodic memory systems. Semantic memory relates to general knowledge, informing infants about the “what” of things, while episodic memory relates to personal experiences that are integrated and stored for later retrieval and amendment aiding the comprehension of information (Baddeley). According to Pick (1983), there must be an integration of past associations, stimuli perception, and information processing in order for learning to occur. Thus, infants have a better chance to learn about their environment when they have more experiences and exposure to environmental stimuli.

Understanding the underlying biological mechanisms of infant learning is imperative because without such knowledge we cannot relate evidence of learning to physiological processes that may account for different learning abilities. Failing to understand the physiological processes then leads to an inability to support the development of learning and memory formation during the critical periods of infancy. This is to say that without understanding the biological processes of learning abilities we are only speculating about how infants learn, basing our knowledge not on the actual processes, but rather on assumption.

Thus, it is important to look at the biological basis of physiological processes affecting learning abilities in order to better understand influences and possible causes of individual differences not associated with environmental influences. To this end researchers have investigated the processes of neuron growth and development of synaptic connections. Bourgeois (2001) noted that rapid growth of synaptic density

occurs during the last two months of gestation which results in an overproduction of synapses in the infant brain.

The overproduction of synapses in the infant brain creates a “hit or miss” atmosphere through which the input is processed. Neural development and synapse connections either strengthen or weaken during the process of competitive elimination in the postnatal period (Webb, Monk, & Nelson, 2001). For instance, after repeated exposure to specific stimuli a synapse is strengthened and used as the primary pathway for information processing of that specific stimulus. However, if a synapse is not repeatedly used to process information it may essentially “die”.

Hebb was one of the first researchers and theorists to support the hypothesis that experience and exposure to stimuli can influence neural development and brain structure, and subsequently learning about the environment. The Hebb rule states that changes in the chemical composition of the synapse that occur as a result of repeated activation strengthen the connection that is repeatedly activated (as cited in Carlson, 2004). Thus, the concept that infants require repeated exposure to stimuli in order to create and strengthen the neural connections needed to process the information is supported by the Hebb rule.

Assessments of Learning during Infancy

There are varieties of different methods that assess learning during infancy. Quantifications of infants' information processing speed are one way to measure learning during infancy. Past research indicates that learning abilities negatively correlate with information processing speeds. Therefore, infants' with faster information processing abilities are presumed to have better learning abilities. Two methods used to measure learning via information processing speed are recognition memory and habituation tasks.

In a recognition memory task researchers simultaneously present two stimuli (one novel and one previously viewed) to infants. Shorter looking times to previously viewed stimuli and longer looking times to novel stimuli provide evidence of learning because the infant's fixation duration suggests that infants processed information about the previously viewed stimulus on a previous occasion, therefore requiring less time to reprocess information about the stimulus (Fagan, 1976 & 1978).

Based on a similar assumption, habituation tasks present one stimulus across multiple trials. Researchers presume that infants learn and process information about the stimulus if responsiveness to the stimulus declines over time (Colombo, 1985; Richards, 1985). Both recognition memory and habituation tasks require encoding and storage of information (Courage, Howe, & Squires, 2004). During recognition memory and habituation tasks infants have to disengage from the task or stop looking at the stimulus to suggest they have processed information (Thompson & Spencer, 1966; Rose, Feldman, & Jankowski, 2003). Thus, shorter looking times suggest that an infant has processed the necessary information.

Recognition memory and habituation tasks require infants to process information so that the image or object can be recognized later, but they do not require infants to plan and execute patterned responses that rely on encoded and stored information. Thus, recognition memory and habituation tasks rely on passive responses, whereas the Visual Expectation Paradigm (VExP), a newer method for assessing learning abilities and expectation formation developed by Haith, Hazan, and Goodman (1988), requires active responses to reflect rule learning. Evidence of learning in the VExP requires active planning and execution of visual shifts, whereas recognition and habituation tasks base evidence of learning on disengagement from the task.

In the VExP infants encode and store information about the physical and temporal characteristics of stimuli that appear for specific durations and in specific locations on a screen (i.e., How long does the stimulus remain in view?, How much time is there between stimuli?, When the stimulus appears, is it on the left or the right?, How often does the stimulus appear in the same location?, Where will the next stimulus appear?). In order to demonstrate learning in the VExP infants must pattern their visual responses in a manner that reflects expectation of stimuli through anticipatory responses.

In the VExP, infants view a series of pictures presented to the left and right areas of the infant's visual field. Pictures are generated in a systematic pattern, such as left-right-left-right (L-R-L-R). Haith, Hazan, and Goodman (1988) posited that learning is reflected in infants' ability to extract the pattern or "rule" and subsequently use that rule knowledge to anticipate the position of upcoming pictures. For example, it is more likely that an infant learned a Left-Left-Right (L-L-R) patterning rule if their visual responses

shifted to the location of the first stimulus on the left, remained in the same location for the second stimulus, and then shifted to where the third stimulus on the right would appear. But not all infants exemplify this optimal form of rule learning. For example, some infants pattern their responses in a manner suggestive of a probability-based learning paradigm. If we could hear an infant processing information in this manner we might hear, “I’m going to look to the side where it is most likely that something will appear”. Infants who use this paradigm are less likely to shift to the last location on the right in a Left-Left-Right sequence.

There is also evidence that some infants do not apply any sort of anticipatory or expectation-based rule to their responses. Infants who do not demonstrate the use of any rule or reasoning equally distribute their visual responses across all locations. Therefore, if infants’ encode, store, and apply information about the physical and temporal characteristics of VExP stimuli the pattern of their visual responses and anticipations is likely to reflect the pattern of the presented stimuli.

One way to measure the infant’s ability to extract the rule and form expectations about the temporal and physical characteristics of the VExP stimuli is to calculate the percent of anticipatory responses (Dougherty & Haith, 1997; Jacobson, Jacobson, O’Neill, Padgett, Frankowski, & Bihun, 1992; Wass & Donohue, 2006). For instance, Canfield and Smith (1996) presented infants with a Left-Left-Right (L-L-R) or L-L-L-R (L-L-L-R) sequence. Canfield and Smith examined whether percent of anticipatory responses to the last stimulus of the sequence (which appeared in a different location) differed because of increasing or decreasing the number of pictures occurring in the same location before the last stimulus. They found a positive correlation between percent of

anticipatory responses and the number of stimuli appearing before the last stimulus, and noted that there were more anticipatory responses to the last stimulus when there were more stimuli appearing before it (i.e., more anticipatory responses for L-L-L-R than L-L-R) (Canfield & Smith).

Much of an infant's capability to complete the VExP relies on the ability to regulate physiological responses and maintain attention to the task. During the VExP, infants must attend to the task long enough to extract the patterning rule and demonstrate learning by planning and executing shifts to correct locations in order to accurately anticipate the location of stimuli (Haith, Hazan, & Goodman, 1988). It has always been assumed that sustained attention influences learning in this manner, but this assumption have not been tested in the VExP. This assumption is based on the idea that sustained attention may facilitate the infant's ability to extract the patterning rule, and therefore is better able to anticipate the location of stimuli, and execute visual shifts to the expected locations.

As mentioned earlier, sustained attention positively correlates with high resting HFHPV, whereas inattentive states positively correlate with low resting HFHPV (Casey & Richards, 1988; Lansink & Richards, 1997; Richards & Casey, 1991; Richards & Cronise, 2000). Thus, if we follow the assumption that sustained attention facilitates learning, and individual differences in HFHPV correlate with differences in sustained attention, then it follows that VExP performance may be dependent on physiological individual differences such as HFHPV, that support sustained attention during the task.

Foundation of Current Study

Data for the current study originate from the Wass and Donohue (2006) study, which investigated whether physiological individual differences, specifically resting HFHPV, related to patterns of anticipatory visual responses in the VExP. Wass and Donohue hypothesized that infants with high resting HFHPV would demonstrate patterns of anticipatory responding reflective of rule learning in the VExP. Results supported the hypotheses and indicated that infants with high resting levels of HFHPV anticipated the location of stimuli more often than infants with low resting levels of HFHPV.

This study extends Wass and Donohue's finding that high resting HFHPV positively correlates with VExP task performance by hypothesizing about the relationships between resting HFHPV, changes in HFHPV during the VExP, and VExP performance. Thus, this study is an extension of the Wass and Donohue findings because it incorporates evidence of physiological self-regulation by assessing changes in HFHPV during the VExP rather than correlating resting levels of HFHPV with VExP performance. The relationship between physiological self-regulation (changes in HFHPV) and VExP performance may also validate the assumption that sustained attention is a requirement of learning during the VExP. In addition, this study further tests the use and applicability of the Rule Learning Index (RLI), a newly developed measure used to assess learning by examining the pattern of anticipatory responses to VExP stimuli.

Hypotheses

There were two hypotheses about the relationship between resting HFHPV and HFHPV change for this study based on previous findings (Buss, Davidson, Kalin, &

Goldsmith, 2004; Calkins, 1996; DeGangi, DiPietro, Greenspan, & Porges, 1991; Doussard-Roosevelt, Montgomery, & Porges, 2003). First, this study expected the emergence of HFHPV change patterns to derive from the relationship between resting HFHPV and the direction of HFHPV change in response to and during the VExP. Second, this study expected a negative relationship between resting HFHPV and the direction of HFHPV change (either increase or decrease) in response to and during the VExP. Thus, a pattern of increasing HFHPV evidenced throughout the VExP would consist primarily of infants with low resting HFHPV, whereas infants with high resting HFHPV were expected to decrease HFHPV in response to the VExP and demonstrate either no change or moderately increased HFHPV during segment two.

The third hypothesis was based on previous research indicating that high resting HFHPV, as well as decreased HFHPV during cognitive tasks, positively correlates with sustained attention necessary for extracting and integrating information from the environment and learning (Bornstein & Suess, 2000; Garcia-Coll, et al., 1984; Hansen et al., 2003; Middleton et al., 1999; Richards, 1985 & 1987). Therefore, the third hypothesis for this study predicted a negative correlation between HFHPV change during the VExP and VExP task performance. Finally, this study expected that HFHPV change during the VExP would be a stronger predictor of learning than resting HFHPV measures since HFHPV change reflects active physiological self-regulation facilitating sustained attention and learning abilities.

CHAPTER III: METHODS

Participants

Recruitment letters were sent to new parents living within a one-hour driving radius of the testing location. They were identified through the Tennessee Health Department's Vital Statistics Division. Parents who responded to the recruitment letter were contacted by phone to schedule an appointment when the infant reached the appropriate testing age of three months. Families were not eligible to participate if the infant was born prior to 37 weeks gestational age, exposed to drugs in utero, low birth weight or small for gestational age, or reported any neurological, genetic, or developmental health problems.

Participating families received \$10 and a certificate noting their child's participation in the study. Fifty-eight males and fifty-nine females participated in this study. According to the demographic data collected for this study, the majority of participating infants were Caucasian (88%) and from two-parent households (87.2%). The Hollingshead index assessed families' socioeconomic status. Hollingshead scores ranged from 14 to 66; 82.9% of the families were classified at or above the skilled craftsmen level, suggesting that most of the sample was from middle and upper-middle class families. Table B1, Appendix B, contains additional demographic information (all tables and figures are located in the appendices).

Sub-Group Samples

The sample sizes for analyses examining each hypothesis differed to retain as much data as possible per analysis. The analyses for the first and second hypotheses included all cases with a baseline measure of resting HFHPV and artifact-free or

predicted HFHPV data collected during the VExP ($n = 85$). “Artifact-free” refers to portions of heart rate data that free software errors or miscalculations possibly caused by, interruptions from erratic breathing (e.g., crying, hiccups). The majority of infants included in this sub-sample (sub-sample 1) were Caucasian (88.9%) and from two-parent households (91.4%). Hollingshead scores for sub-sample 1 ranged from 17 to 66; 80.3% of the families were classified at or above the skilled craftsmen level, suggesting that most of the infants in sub-sample 1 were from middle and upper-middle class families. Table B1 contains additional demographic information for sub-sample 1.

Analyses for the third and fourth hypotheses included cases with a baseline measure of resting HFHPV, artifact-free or predicted HFHPV data collected during the VExP, and a valid RLI score calculated from the VExP ($n = 66$). The majority of infants included in this sub-sample (sub-sample 2) were Caucasian (88.9%) and from two-parent households (92.1%). Hollingshead scores for sub-sample 2 ranged from 17 to 66; 84.1% of the families were classified at or above the skilled craftsmen level, suggesting that most of the infants in sub-sample 2 were from middle and upper-middle class families. Table B1 contains additional demographic information for sub-sample 2.

Apparatus

High Frequency Heart Period Variability (HFHPV)

Two AgAgCl electrodes placed on the infant’s chest and one AgAgCl electrode on the abdomen monitored heart rate activity during baseline and throughout the VExP task. The Biopic MP100 system recorded information gathered from the electrodes. Trained research team members used Acknowledge software (Biopic Systems, Goleta, CA) to transform EKG data and calculate HFHPV.

Visual Expectation Paradigm (VExP) Condition Assignment and Task Description

VExP stimuli were presented as either a Left-Left-Right (L-L-R) or R-R-L sequence. Both sequences included a baseline series of eleven stimuli appearing for random durations (500, 700, or 900 ms). The time between baseline stimuli, known as the inter-picture interval (IPI), also varied randomly (750, 950, and 1150 ms). Infants viewed twenty cycles (e.g., L-L-R) of the predictable pattern after baseline segment. During the predictable sequence, individual stimuli appeared on the viewing monitor for a fixed duration of 700 ms with a fixed IPI of 750 ms separating stimuli. Following the baseline period, a trained research team member placed infants' in a supine position on a raised crib under an apparatus housing the stimuli presentation monitor, video camera, and infrared lamps. The 33 cm x 26.6 cm color flat panel computer monitor used to present stimuli was approximately 30.48 cm from the infant's face. BabyPic software (Ingebrigtsen, 1999) generated the sequence of pictures used for the VExP. Pictures were static black, white, or colored geometric shapes and appeared approximately 4.5° of visual angle to the left or right of the infants' visual center.

A Panasonic CCD TV camera (model WV-BP130) and a VCR (Panasonic AG-6300) recorded visual responses to stimuli. A Kodak Safelight (Model B) fitted with a filter (Kodak Safelight filter #11) and a 40-watt light bulb provided lighting that was safe and undetectable to the infant, but still a sufficient source of illumination for video recording in the dark (Reznick, Chawarska, Betts, & Logan, 1997). A Panasonic WJ-810 time-date generator superimposed the time and date of the session and a single digit indicating stimuli position and duration on the video recording.

Procedure

Parent(s) gave verbal and written consent prior to beginning the session. Infants' sat on their parents' lap during the collection of resting heart rate data. In order to use resting heart rate as a baseline measure, rather than a measure of response to environmental stimulation, research team members asked parents' to interact with their child only when necessary. Parents' provided demographic information, such as income and marital status, during the baseline period in order to direct their attention away from the infant. Following resting heart rate and demographic data collection infants and their parents proceeded into a separate testing room where a trained research team member randomly assigned infants to either the L-L-R or R-R-L sequence to control for a potential side preference confound. Following random assignment, the research team member placed the infant in a crib housing the VExP apparatus and the infant viewed the VExP stimuli. Infants remained in the apparatus to complete a visual fixation task after the end of the VExP task. The current study did not use the data collected from the visual fixation task.

Data Reduction

VExP

Trained coders advanced video recordings of infant visual responses frame by frame using a Panasonic AG-6300 VCR. In order to determine the number of frames and time it took infants' to respond to the stimulus a formula in the Microsoft® Office Excel program subtracted the time of the first saccade (small, rapid eyeball movements that comprise a visual shift to a specific location) to a possible picture location from the time

of picture onset, then multiplied the difference by 33.33 to convert the number of frames to milliseconds.

Typically, recoding around 20% of collected data is standard and considered sufficient in infant studies. For this study, an independent, trained coder re-analyzed 17% of the data and achieved an average of 89% agreement with the primary coder. This study defined inter-coder reliability as an agreement on the time of the initiation of the eye movement to the location within one frame.

Canfield and Haith (1991) referred to the location where VExP stimuli appeared as home or target locations. The term “home” (H) referred to the location where stimuli appeared most frequently. The term “target” (T) referred to the location where stimuli appeared less frequently. For example, in a L-L-R sequence, the first stimulus of the sequence appears on the left (H1). The second stimulus (H2) appears in the same location following the offset of the first stimulus and the inter-picture interval (IPI). Following the offset of the second stimulus and the IPI the third and last stimulus of the patterned sequence appears on the right (T). Based on this, the L-L-R and R-R-L VExP conditions used in this study were collapsed into H1, H2, and T locations for analyses.

Based on the study by Haith, Hazan, & Goodman (1988), an anticipatory response to the VExP stimulus was defined as a visual shift to a possible picture location during the IPI or within 200 ms after picture onset. There are correct and incorrect forms of anticipatory responses to VExP stimuli locations. For instance, anticipatory shifting prior to the H1 and T1 locations reflects a correct anticipation of the upcoming picture location. Remaining in the home location following the offset of H1 is considered a correct non-response because the infant has suppressed an incorrect response to the target

location. In contrast, an incorrect response to H2 is when an infant visually shifts to the T location instead of remaining in the H position after H1 offset. Figure one (Appendix A) provides a schematic representation of possible responses to stimuli locations.

Some researchers use the number of correct and incorrect anticipatory responses to VExP stimuli locations to assess rule learning (Wentworth, Haith, & Hood, 2002). In this case, researchers presume that infants “learned” the patterning rule presented in the VExP if they have more correct than incorrect anticipatory responses. This presumption is based on the idea that infants have to extract information about the pattern of presented VExP stimuli (e.g., that H2 appears in the same location and after H1) and use that knowledge to plan and execute correct visual responses (e.g., infant remains looking at the H2 location following H1 offset).

However, Wass and Donohue (2006) noted that quantifying the number of correct versus incorrect responses is limiting because it does not account for the variety of ways infants demonstrate learning during the VExP (e.g., a correct non-response suppression to H2 location). Based on this Wass & Donohue argued that the patterning of anticipatory responses was more important than the total number of correct versus incorrect responses because it does account for variety of ways infants demonstrate learning during the VExP. Wass and Donohue developed the Rule Learning Index (RLI) to quantify infant response patterns and to overcome the limitations of relying solely on the difference between correct and incorrect responses. The RLI formula $((H1 + T1) / 2) - H2 / 1$ quantifies learning as a unitary index by placing responses to H1, H2, and T in relation to one another. According to the RLI, positive scores are more likely to reflect a greater number of correct anticipatory shifts, whereas negative scores are more likely to reflect

more incorrect shifts, while scores near or at zero reflect equitable distribution of both incorrect and correct shifts.

Wass and Donohue (2006) used the RLI to quantify learning during the VExP and to group visual responding patterns into three groups that distinguished the level to which infants' responses were patterned in conjunction with the order of VExP stimuli. The first RLI pattern also referred to as "optimal" specified a visual response pattern suggesting that infants extracted information about the temporal (e.g., order of presentation) and physical (e.g., location of the stimulus) characteristics of the VExP and used the information to anticipate the position of upcoming pictures. Infants who base their visual responses on information about the temporal and physical characteristics of the stimuli reflect the L-L-R VExP pattern by shifting to the H1 location (left stimulus), remaining in the home location awaiting H2 (left stimulus), and then shift to the T location (right stimulus). Therefore, the optimal response pattern reflects a high frequency of correct visual responses to the H1 and T locations and a low frequency of shifting to the H2 location since the correct option after H1 is to suppress visual shifting to the T location and remain in the home location. Thus, the optimal response pattern has the highest RLI scores because of the low frequency of incorrect H2 responses. For instance, infants demonstrating an optimal visual response pattern could have a RLI value of eight if H1 equaled ten, H2 equaled two, and T equaled ten $((10 + 10) / 2) - 2 / 1$.

The second RLI pattern also referred to as "probable" specified visual response patterns that based responding on the physical characteristics of the VExP stimuli. In other words, infants responding in a probable fashion remain in a location based on the likelihood subsequent appearances of more stimuli rather than suppressing responses to

the T location. For instance, infants responding reflecting a probable response pattern were more likely to remain in the H2 location following H1, but less likely to shift to the T location since they assumed that stimuli would eventually appear at the home location. The RLI scores for the probable response pattern are lower than the optimal pattern because of the low frequency of correct responses to the T location. For example, infants responding in a probable pattern could have a RLI value of two (which is lower than the example optimal pattern's RLI score of eight) if H1 equaled ten, H2 equaled four, and T equaled two $((10 + 2) / 2) - 4 / 1$.

The third RLI pattern also referred to as “indiscriminant” specified visual response patterns that did not reflect responses based on information about the temporal or physical characteristics of the VExP stimuli. Infants responding indiscriminately equally distribute their responses across all locations rather than actively suppressing responses to the T location or shifting back to the home location following the T stimulus. Indiscriminant response patterns are more likely to have similar response frequencies across H1, H2, and T locations. Therefore, infants reflecting an indiscriminant pattern of visual responding may have RLI values close to zero. For example, the RLI value would equal zero if H1, H2, and T all equaled ten $((10 + 10) / 2) - 10 / 1$.

HFHPV

This study used HFHPV change as a marker of physiological self-regulatory abilities during the VExP task. HFHPV alterations were used to assess physiological self-regulation because past findings suggest that it correlates with physiological reactivity (Porges, Doussard-Roosevelt, & Maiti, 1994) and self-soothing abilities (Huffman,

Bryan, del Carmen, Pedersen, & Porges, 1992), both of which contribute to initial and sustained reactions to environmental stimuli such as VExP stimuli patterns. To ensure the accurate measurement of physiological self-regulatory abilities, HFHPV calculations were conducted within the “frequency band of .24-1.04 Hz. of the detrended R-R data” (Wass & Donohue, 2006, p. 14). Researchers commonly use this frequency to capture the amount of vagal influence on heart rate regulation (Bornstein & Suess, 2000).

Sections of HFHPV Data

The HFHPV data collected throughout the entire session was divided into three segments in order to assess resting HFHPV and HFHPV change during the VExP task. The five-minute baseline portion was the first segment of HFHPV and was deducted from the front portion of each infant’s VExP time interval. This deduction allowed resting HFHPV to be assessed separately from HFHPV change during the VExP, thereby providing a baseline measure of HFHPV.

During the testing session, the experimenter manually recorded the start and stop time (in ms) of the VExP sequence. Due to human error and the fact that the experimenter had to move to see the time, the start and stop times noted are likely to be slightly late. The entire VExP picture sequence lasted 102 seconds. If the noted time interval was too long, which could happen if the experimenter did not immediately record the end time, the extra time was deducted from the end of the time segment. Thus, the time segment remaining after subtraction of the baseline reflected the time span during which the infant completed the VExP (approximately 84.25 seconds). Heart rate data collected during the VExP was divided into two forty-two second segments to assess

patterns of HFHPV change. Infants needed at least 25 seconds of artifact free data within each segment in order for HFHPV to be calculated.

HFHPV Percent Change Calculations

Raw change scores were transformed using the log percentage change formula for two specific reasons. First, the raw change scores were highly skewed; therefore the log transformation was used to create a normal distribution that did not violate statistical assumptions of some of the tests used. Second, percentage scores were used to create a “level measurement field”. In essence, percent change values afforded the ability to examine an individual’s change in HFHPV (both magnitude and direction) and compare change between individuals, regardless of whether the two started with opposite resting HFHPV values.

Percent change calculations included raw HFHPV values for baseline (RawBase), segment one (Seg1), and segment two (Seg2). The percentage of HFHPV change from baseline to segment one (RawPctChgSeg1) and from baseline to segment two (RawPctChgSeg2) quantified physiological self-regulation during the VExP. As expected, the raw distributions for RawBase, RawPctChgSeg1, and RawPctChgSeg2 were negatively skewed. All three raw variables were log transformed to normalize their respective distributions.

Some cases had negative values of percent change (indicative of a decrease in HFHPV), which could not be log transformed. Therefore, calculations determined the lowest possible whole number that could change all negative segment one and two percent change values into positive values, resulting in a constant value of 90. The constant was added to raw percent change values for segments one and two prior to the

log transformation. Manual notations of the sign (+/-) of the raw percent change values were noted prior to adding the constant to identify the direction of change for each case during later analyses. The final HFHPV percent change formulas for segments one (PctChgSeg1) and two (PctChgSeg2) were:

$$\text{PctChgSeg1} = \text{Log} (90 + [((\text{Seg1}-\text{RawBase}) / \text{RawBase}) * 100])$$

$$\text{PctChgSeg2} = \text{Log} (90 + [((\text{Seg2}-\text{RawBase}) / \text{RawBase}) * 100]).$$

Additional measures were created to further examine group and individual differences in physiological self-regulation. A measure of HFHPV percent change across the entire task assessed overall HFHPV change (PctChgAll). This measure used HFHPV values calculated from heart rate data collected during the entire 84.25 seconds of the VExP mentioned earlier. Calculations for PctChgAll were similar to PctChgSeg1 and PctChgSeg2. Calculations subtracted and divided raw values of overall HFHPV power (RawAll) from RawBase values, then multiplied the result by 100. Some cases had negative values of percent change overall, which could not be log transformed.

Therefore, calculations determined the lowest possible whole number that could change all negative values into positive values, resulting in a constant value of 81. A constant added to raw HFHPV percent change overall values (RawPctChgAll) permitted log transformations needed to correct the skewed raw value distribution. Thus, the formula for overall HFHPV percent change (PctChgAll) was:

$$\text{PctChgAll} = \text{Log} (81 + [((\text{RawAll}-\text{RawBase}) / \text{RawBase}) * 100]).$$

A categorical measure of resting HFHPV, BaseMedSplt, categorized cases with values above the median raw value as high resting HFHPV and values below the median raw median value as low resting HFHPV. Two cases equaled the median. To group those

cases appropriately, resting HFHPV (LgBasePwr) values were extended out to five decimal places and grouped accordingly (.67089 grouped as low resting HFHPV and .67346 grouped as high resting HFHPV).

Exclusion Rationale and Data Cleaning

Exclusions

Thirty-two of the original 117 cases were excluded from analyses testing all hypotheses. Data from participants were excluded due to missing (n = 14) or inaccurate (n = 10) VExP beginning or end times, fewer than 25 artifact-free seconds of heart rate data in both segments (n = 2), or equipment failure (n = 1), or infant irritability (n = 4). Additionally, heart rate data for one inattentive infant (never looked at VExP monitor) was also excluded. Thus, pre-cleaned sample for hypotheses one and two included 85 cases.

Inattentive infants were excluded based on the premise that the measure of heart rate would inaccurately capture the infant's typical heart rate responsively since heart rate is lower during inattentive states and because this study was interested in the changes that occur in HFHPV while infants were engaged in the VExP. Irritable infants were excluded on the premise that as infants become irritable, their rate of respiration increases due to crying and increased physical activity. Because heart rate increases in relation with respiration (Kagan, 1987; Porges, Doussard-Roosevelt, & Maiti, 1994) there was the likelihood that heart rate measures of irritable infants were not accurate and therefore excluded.

The third and fourth hypotheses predicted a relationship between HFHPV patterns and RLI scores and that HFHPV patterns would be a better predictor of RLI than resting

HFHPV, respectively. The outcome variable (RLI) for the third and fourth hypotheses required valid responses to at least 65% of the VExP to calculate the pattern of responses to H1, H2, and T locations. Therefore, cases with less than 65% valid VExP responses were excluded due to irritability (n = 9), inattentiveness (n = 8), sleepiness (n = 1), or VExP equipment failure (n = 1). Cases with less than 65% valid VExP data due to irritability or inattentiveness were only excluded from analyses including the RLI outcome variable since it was determined that the level of irritability or inattentiveness did not unduly affect accurate HFHPV assessments. In sum, the pre-cleaned sample for analyses examining the relationship between HFHPV change during the VExP and VExP task performance included 66 cases. See Table B1 for sub-group demographic information.

Data Cleaning

Analyses examined LgBasePwr, PctChgSeg1, PctChgSeg2, PctChgAll, RLI, and all continuous demographic variables for univariate and multivariate outliers using a 2.5 SD criteria. Excluded data points exceeded the cleaning criterion and overly influenced skewness of the variable's distribution. This method resulted in the exclusion of one data point from each of the PctChg variables (PctChgSeg1, PctChgSeg2, and PctChgAll). Analyses also excluded two data points from RLI based on this criteria. There were no influential outliers for any of the demographic variables.

Predicted Value Calculations

Due to artifacts, 11 cases had only one segment of HFHPV data (segment one [n = 1] and segment two [n = 10]). In order to increase the sample size and statistical power for analyses including HFHPV change variables, regression analyses predicted missing

segment values for each case. Preliminary analyses suggested males were significantly less likely to demonstrate a decrease in HFHPV during segment two. Therefore, analyses separated bivariate correlations of demographic, RLI, and HFHPV-related variables by sex to determine possible predictor variables for PctChgSeg1 and PctChgSeg2.

Model Predicting HFHPV Percent Change Values for Segments One and Two for Males

The only variable significantly correlated with PctChgSeg1 and PctChgSeg2 for males was PctChgAll ($r = .76, p < .00$ and $r = .73, p < .00$, respectively). PctChgAll entered into separate regression analyses for segments one and two, accounting for 58% of the variance for male's PctChgSeg1 and 53% for PctChgSeg2. Thus, $\hat{Y} = .32 + .76 * (\text{PctChgAll})$ predicted missing PctChgSeg1 values and $\hat{Y} = .20 + .73 * (\text{PctChgAll})$ predicted PctChgSeg2 values for males.

Model Predicting HFHPV Percent Change Values for Segments One and Two for Females

PctChgSeg1 was not predicted for females because there was no missing data. The variables significantly correlated with PctChgSeg2 for females were PctChgSeg1 ($r = .75, p < .00$), PctChgAll ($r = .79, p < .00$), LgBasePwr ($r = -.44, p < .01$), BaseMedSplt ($r = -.39, p < .01$), and direction of change in segment one ($r = .61, p < .00$).

BaseMedSplt was not entered into the regression equation because of relatively high multicollinearity with LgBasePwr (tolerance = .26), and because it assessed resting baseline HFHPV like the continuous variable LgBasePwr, but in a different manner (dichotomous). Thus, the two variables were not statistically or conceptually unique. A regression analysis used PctChgSeg2 as the dependent variable and forced PctChgSeg1, PctChgAll, LgBasePwr, and direction of change in segment one into the model on

separate steps. PctChgSeg1, PctChgAll, and LgBasePwr all accounted for a significant amount of variance in PctChgSeg2 (55.8%, 11.9%, and 3.8%, respectively). Direction of change in segment one did not account for a significant amount of unique variance, and therefore did not enter into the prediction equation. The final model accounted for 71.5% variance in PctChSeg2 for females. Thus, $\hat{Y} = .74 + .32 * (\text{PctChgSeg1}) + .49 * (\text{PctChgAll}) - .21 * (\text{LgBasePwr})$ predicted missing PctChSeg2 values for females. Analyses included cases with predicted values of PctChgSeg1 and PctChgSeg2 because they did not significantly differ from cases with non-predicted percent change values on any variables and inclusion of the predicted values increased statistical power.

CHAPTER IV: RESULTS

Comparisons of Excluded Cases

One-way ANOVAs and chi-square analyses examined cases excluded from all analyses to the final samples used to investigate the hypotheses. There were no significant differences between included and excluded participants for any of the demographic variables except for sex ($\chi^2 = 6.08, p < .01$). The final samples were less likely to include males. However, males were typically excluded due to differences in data collection ($n = 20$) (e.g., missing or inaccurate VExP times used to calculate HFHPV segments), not systematic participant differences. .

Correlations for HFHPV, RLI, and Demographic Variables

Bivariate correlations investigated potential significant relationships between all demographic and outcome measures. Table C1 in Appendix C, contains bivariate correlations between PctChgSeg1, PctChgSeg2, PctChgAll, LgBasePwr, RLI, and significantly related demographic variables. Results of bivariate correlations indicated significant positive correlations between PctChgSeg1, PctChgSeg2, and PctChgAll, suggestive of consistent HFHPV change during the VExP. Thus, infants' who increased HFHPV during segment one also were likely to continue increasing HFHPV during segment two, resulting in greater HFHPV increases throughout the VExP. Significant negative correlations between LgBasePwr and PctChgSeg1, PctChgSeg2, and PctChgAll indicated that HFHPV changed in the opposing direction of resting HFHPV throughout the VExP. Thus, infants' with low LgBasePwr were more likely to demonstrate an increase in HFHPV throughout the VExP, whereas infants' with high LgBasePwr were more likely to demonstrate a decrease HFHPV throughout the VExP. Bivariate

correlation analyses revealed that RLI was only significantly correlated with LgBasePwr. The positive correlation between RLI and LgBasePwr suggested that infants with higher resting HFHPV values also had higher RLI values.

The only significant correlations between demographic variables and outcome measures were for gestational age, birth weight, and PctChgSeg1. A significant positive correlation between gestational age and birth weight suggested that infants with greater gestational ages were heavier at birth than infants with lower gestational ages. Significant positive correlations between gestational age, birth weight, and PctChgSeg1 suggested that infants who were older and heavier at birth were more likely to increase HFHPV during segment one.

Chi-square analyses were used to investigate potential differences between all of the demographic, HFHPV, and RLI variables. Table C2 contains percentage distributions of demographic characteristics by resting HFHPV, directions of HFHPV change in segments one and two (i.e., increase or decrease), and HFHPV percent change groups. Results of chi-square analyses indicated that (a) resting HFHPV differed significantly for minorities and infants of single parents, (b) that HFHPV percent change groups differed by sex and infants of single parents, and that (c) the direction of change during segment two differed significantly by level of fathers' education. First, minorities and infants of single parents were significantly more likely to have low resting HFHPV (minority: $\chi^2 = 5.56, p < .05$; marital status $\chi^2 = 3.77, p < .05$, respectively). Second, males were less likely to be categorized as Increasers since they were less likely to display an increase in HFHPV throughout the VExp ($\chi^2 = 7.90, p < .05$) and even less likely to increase HFHPV during segment two ($\chi^2 = 8.06, p < .01$). Additionally, infants of single parents were more

likely to be categorized as Changers since they were more likely to demonstrate HFHPV change from positive to negative (or vice versa) between VExP segments ($\chi^2 = 6.58, p < .05$). Thirdly, whether the infant's father had a college degree differed significantly for direction of HFHPV change during segment two ($\chi^2 = 5.10, p < .05$), suggesting that infants of fathers with a college degree were more likely increase HFHPV during segment two.

Results for Hypotheses

Hypothesis One: Presence of HFHPV Percent Change Patterns

One-way ANOVA's, post-hoc tests, and cluster analyses examined the first hypothesis stating that there would be different HFHPV percent change patterns during the VExP. To begin, frequency distributions of HFHPV percent change values for segments one and two were examined for naturally discernable cut-off points suggestive of an intrinsic system of division and classification beyond positive or negative HFHPV change, but there was no evidence supporting this method. Next, for each segment cases were divided into groups based on HFHPV change categorized as: (a) stable (<20% HFHPV change), (b) moderate (21-50% HFHPV change), (c) substantial (51-80% HFHPV change), or (d) extreme (>81% HFHPV change). Sixteen patterns resulted from this classification. A frequency distribution of the sixteen patterns revealed that most cases were classified as either moderately increasing ($n = 20$) or moderately decreasing ($n = 12$) throughout the VExP. The next largest groups were those that moderately increased during segment one and moderately decreased during segment two ($n = 8$) and those that moderately decreased during segment one and moderately increased during segment two ($n = 7$). The remaining thirty-four cases were classified into the other ten patterns, with

group sizes ranging from one to four (there were no cases included in two patterns: (a) the pattern indicating an extreme HFHPV increase during segment one and an extreme decrease during segment two and (b) the pattern indicating extreme HFHPV decrease during segment one and an extreme increase during segment two). One-way ANOVAs did not reveal any significant between-group differences on LgBasePwr ($F(13, 68) = .69, p = .77$), PctChgSeg1 ($F(13, 68) = .72, p = .74$), PctChgSeg2 ($F(13, 68) = .90, p = .56$), or PctChgAll ($F(13, 68) = 1.13, p = .36$). These results were most likely due to the large number of patterns with small sample sizes, possibly reducing between-group variability.

To refine and accurately capture the most likely HFHPV patterns, frequency distributions of PctChgSeg1 and PctChgSeg2 values were further examined. The manual examination of frequency analyses revealed a distinguishable division between positive (indicative of HFHPV increase) and negative (indicative of HFHPV decrease) HFHPV percent change for PctChgSeg1 and PctChgSeg2. However, as mentioned earlier, the direction of HFHPV change was manually noted prior to the addition of the constant value (which changed all values to positive whole number) needed to log transform the percent change values. Values equal to or less than 1.98 and 1.96 indicated negative directionality (i.e., HFHPV decrease) during segments one and two, respectively.

Therefore, it was logical that a natural cut-point emerged from this technique.

However, cluster analyses that were blind to the a-priori specification of directionality recognized positive and negative HFHPV percent change groups for each segment. Two groups naturally emerged when PctChgSeg1 and PctChgSeg2 were entered into separate unforced two-step cluster analyses. The means of the two PctChgSeg1 groups, which were specified by the cluster analysis suggested that the

clusters were classified by positive and negative HFHPV values. For instance, for PctChgSeg1 the mean of cluster group one was 1.60 (SD = .24), indicative of negative HFHPV change since it was less than 1.98, and the mean of cluster group two was 2.33 (SD = .25), indicative of positive HFHPV change, since it was greater than 1.98. For PctChgSeg2 the mean of cluster group one was 1.53 (SD = .28), indicative of negative HFHPV change since it was less than 1.96, and the mean of cluster group two was 2.29 (SD = .29), indicative of positive HFHPV change, since it was greater than 1.96. The means of the two cluster groups for PctChgSeg1 differed significantly ($F(1, 81) = 196.01$, $p < .00$), as did the means of the two cluster groups for PctChgSeg2 ($F(1, 80) = 138.18$, $p < .00$).

Based on findings from the frequency and cluster analyses which supported the presence of increasing and decreasing directions of HFHPV change during segments one and two, infants' HFHPV percent change values, including the predicted values, were grouped by directions of HFHPV change indicating either an increase (positive HFHPV value) or a decrease (negative HFHPV) during segments one and two. Cases grouped according to the direction of PctChgSeg1 and PctChgSeg2 formed four HFHPV change patterns: (a) "Increasers" (i.e., positive change in both segments) ($n = 32$), (b) "Decreasers" (i.e., decreasing throughout the VExP) ($n = 27$), (c) increasing during segment one and decreasing during segment two ($n = 9$), and (d) decreasing during segment one and increasing during segment two of the VExP ($n = 15$).

Combining HFHPV Change Patterns

One-way ANOVAs with PctChgSeg1, PctChgSeg2, PctChgAll, and LgBasePwr as the dependent variables and a dichotomous variable specifying Increase-to-Decreasers

and Decrease-to-Increasers entered as the independent variable, examined between-group differences. However, there were no significant group differences for PctChgSeg2 ($F(1, 23) = .64, p = .44$), PctChgAll ($F(1, 23) = .66, p = .43$), or LgBasePwr ($F(1, 23) = .56, p = .46$) and minimal difference on PctChgSeg1 ($F(1, 23) = 4.22, p = .05$). Thus, the two groups with HFHPV that changed direction between segments one and two were collapsed into one group referred to as “Changers” ($n = 24$).

Results from one-way ANOVAs confirmed that HFHPV patterns (Increasers, Decreasers, and Changers) significantly differed by LgBasePwr ($F(2, 79) = 7.24, p < .01$), PctChgSeg1 ($F(2, 79) = 57.91, p < .01$), PctChgSeg2 ($F(2, 79) = 14.07, p < .01$), and PctChgAll ($F(2, 79) = 35.34, p < .01$). Post-hoc Bonferroni analyses from a series of one-way ANOVAs with LgBasePwr, PctChgSeg1, PctChgSeg2, and PctChgAll entered as dependent variables and the variable specifying HFHPV patterns of Increasers, Decreasers, and Changers (ChgPattern) entered as the independent variable, examined between-group differences (see Table C3). Results revealed significant differences between all patterns for PctChgSeg1 and PctChgAll. The group means for LgBasePwr differed significantly between Increasers and Decreasers and between Decreasers and Changers, but not between Increasers and Changers. The group means for PctChgSeg2 differed significantly between Increasers and Decreasers and between Increasers and Changers, but not between Decreasers and Changers.

Hypothesis Two: Relationship between Resting HFHPV and HFHPV Change

The second hypothesis stated that infants' direction of HFHPV change (either increase or decrease) would be related to resting HFHPV in a manner suggesting that infants with low resting HFHPV would be more likely to increase HFHPV during the

VExP and infants with high resting HFHPV would be more likely to decrease HFHPV during the VExP. Bivariate correlations between LgBasePwr and PctChgSeg1, PctChgSeg2, and PctChgAll were used to examine this hypothesis. The only significant relationships with LgBasePwr were PctChgSeg1 ($r = -.39, p < .01$) and PctChgAll ($r = -.28, p < .05$), suggesting that infants with lower resting HFHPV values were likely to increase HFHPV throughout the VExP, especially during segment one and infants with higher resting HFHPV values were likely to decrease HFHPV throughout the VExP, with the most change occurring during segment one. Results also indicated a negative, but non-significant relationship between PctChgSeg2 and LgBasePwr, suggesting that HFHPV continues to change in the same direction throughout the VExP, but that the most substantial change in HFHPV occurs during the first segment of the VExP.

To further investigate this hypothesis, one-way ANOVAs were conducted with PctChgSeg1 and PctChgSeg2 entered as the dependent variables and the dichotomous variable specifying cases with low versus high resting HFHPV (BaseMedSplT) entered as the independent variable. Results revealed a trend toward significant difference on PctChgSeg1 for infants with low versus high HFHPV ($F(1, 80) = 3.76, p < .06$), suggesting that infants with low resting HFHPV had higher PctChgSeg1 values than infants with high resting HFHPV. There were no differences between infants with low versus high resting HFHPV on PctChgSeg2 ($F(1, 80) = .03, p < .96$). These findings corroborate past findings noting a negative relationship between resting HFHPV and HFHPV change.

Relationship between LgBasePwr and HFHPV Percent Change Patterns by Sex

The relationship between resting HFHPV and HFHPV change patterns was examined separately by sex since earlier prediction analyses suggested that LgBasePwr accounted for variance in HFHPV change measures only for females. A one-way ANOVA investigating between-group differences for females indicated that 'Increasers', 'Decreasers', and 'Changers' LgBasePwr differed significantly, ($F(2, 45) = 6.11, p < .01$). Table C4 contains means statistics by sex. A post-hoc Bonferroni test revealed that like the results including both sexes, LgBasePwr did not differ significantly between female 'Increasers' and female 'Changers'. LgBasePwr only differed significantly in comparisons of female 'Increasers' versus female 'Decreasers' and female 'Decreasers' versus female 'Changers'. In contrast, post-hoc Bonferroni tests revealed that LgBasePwr did not significantly differ for male 'Decreasers', 'Increasers', or 'Changers'.

Crosstabulation analyses run separately by sex examined the distribution of infants' with low versus high resting HFHPV across HFHPV patterns to further investigate the relationship between resting HFHPV and HFHPV change during the VExp (see table C5). Results revealed that female infants were just as likely to increase or decrease HFHPV if she was classified as having high resting HFHPV. However, a female infant was much more likely to increase HFHPV if she was classified as having low resting HFHPV. Females with low or high resting HFHPV were equally as likely to have HFHPV that changed direction between segments one and two.

However, analyses revealed different findings for males. Male infants were nearly as likely to increase or decrease if he was classified as having low resting HFHPV. However, males were much more likely to decrease HFHPV if they were classified as

having high resting HFHPV. Males with low or high resting HFHPV were equally as likely to have HFHPV that changed direction between segments one and two. Thus, the second hypothesis was only partially supported when infants' sex was included in analyses.

Hypothesis Three: Relationship between HFHPV Percent Change Patterns and Rule Learning Index (RLI)

The third hypothesis for this study predicted a negative relationship between HFHPV change during the VExP and RLI, suggesting that infants who decreased HFHPV during the VExP would have higher RLI scores than infants who increased HFHPV during the VExP. A one-way ANOVA and post-hoc Bonferroni test specifying RLI as the dependent variable and ChgPattern as the independent variable was used to examine this hypothesis (See tables C6 and C7 for group means). Results of these tests indicated no significant between-group differences in RLI.

However, ANOVAs with RLI as the dependent variable and the direction of HFHPV change (positive value = HFHPV increase / negative value = HFHPV decrease) as the independent variable were conducted separately by segment. Results indicated that mean RLI was significantly higher for infants whose HFHPV decreased during segment one ($F(1, 64) = 4.70, p < .05$). There was no mean RLI difference between infants whose HFHPV decreased versus increased during segment two ($F(1, 64) = .68, p = .41$).

Additionally, ANOVAs with RLI as the dependent variable and the direction of HFHPV change as the independent variable were conducted separately by segment, as well as separately by sex. Tests conducted separately by segment and sex did not reveal any significant differences. In sum, results provided only partial support for the

hypothesis predicting a negative relationship between direction of HFHPV change during the VExP and RLI. More specifically, the hypothesis could only be supported for HFHPV change during segment one, not throughout the entire VExP task.

Hypothesis Four: HFHPV Percent Change Patterns as a Better Predictor of RLI than LgBasePwr

The fourth hypothesis predicted that HFHPV change during the VExP would be a stronger predictor of learning (assessed by VExP task performance) than resting HFHPV. To investigate this hypothesis step-wise regression analyses examined the predictive power of HFHPV change patterns. Dummy-coded variables were created for Increasers and Changers, with Decreasers as the reference group. The dummy-coded variables and the resting HFHPV variable (LgBasePwr) were entered on three separate steps into a step-wise regression with RLI as the dependent variable. This analysis was also run separately by sex. For analyses including both males and females LgBasePwr was the only variable accounting for a significant amount of RLI variance ($R^2 = .07, p < .05$). Variance accounted for by LgBasePwr did not change when the order of entry was changed for analyses including both males and females. Analyses run separately by sex revealed that neither LgBasePwr, nor the dummy-coded HFHPV percent change groups accounted for any significant RLI variance. The same results were achieved when the order of entry was reversed.

To further investigate this hypothesis, LgBasePwr, PctChgSeg1, PctChgSeg2, and PctChgAll were forced into a regression analysis on four separate steps, with RLI as the dependent variable. This was also conducted separately by sex. Again, the only variable to account for any significant amount of RLI variance was LgBasePwr ($R^2 = .07, p < .05$)

in analyses including both males and females. Analyses run separately by sex revealed that LgBasePwr, PctChgSeg1, PctChgSeg2, nor PctChgAll accounted for any significant RLI variance. The same results were achieved for analyses run with both males and females, as well as separately by sex. Therefore, the results did not confirm the hypothesis and suggested that HFHPV change during the VExP assessed as either a categorical variable (HFHPV patterns) or as a continuous variable (PctChgSeg1, PctChgSeg2, or PctChgAll) was not a better predictor of learning during the VExP task performance than resting measures of HFHPV (LgBasePwr).

CHAPTER V: DISCUSSION

How do infants respond to environmental stimuli such as mobiles hanging above their cribs or images flashing on a television screen? Some infants are highly sensitive and bothered by these forms of environmental stimuli and may even divert their attention away in an effort to control the amount of stimulation he/she receives. However, some infants are intrigued by these forms of environmental stimuli and actively attend to them. If we assume that the characteristics of an environmental stimulus have the potential to teach infants something, then which infant is more likely to learn about those properties—the one that does divert his/her attention or the one who actively attends to the stimulus? Presumably, the answer is the infant who actively engages in observing the stimuli focuses his/her attention to the task, not the infant who directs his /her attention elsewhere. But what accounts for these individual differences and do these differences actually influence the amount of information infants acquire from their environment?

The primary purpose of this study was to investigate how individual differences, such as physiological self-regulatory abilities, influence infants abilities to attend to a cognitive task in order to extract and integrate information about the task. Porges (1995) explained that the ability to adapt to environmental stimuli and attend to a cognitive task, such as the L-L-R stimuli pattern of the VExP, is dependent on the ability to regain and maintain internal homeostasis.

The process of regaining and maintaining internal homeostasis is considered to be a form of physiological self-regulation, which the current study measured as levels of HFHPV during the VExP. HFHPV is a salient measure of physiological self-regulation because it reflects the amount of influence exerted on the heart by the vagus nerve, which

is part of the parasympathetic nervous system (the system responsible for adaptive functions such as flight or fight responses). For instance, increased input from the vagus nerve increases HFHPV, which corresponds to lower heart rate frequency and decreased input (also known as suppression) decreases HFHPV, which corresponds to higher heart rate frequency.

Previous research indicated that levels of HFHPV assessed during a task negatively correlate with sustained attention and task engagement (Richards & Gibson, 1997). As HFHPV decreases, expectations are that attention to a task or environmental stimuli increase. Therefore, it follows that decreased HFHPV correlates with the ability to extract information in a more efficient manner due to sustained attention. In previous research, resting measures of HFHPV have primarily been the main form of physiological assessment correlated with task performance. This study extends knowledge about the relationship between resting HFHPV, physiological self-regulation, and VExP task performance by distinguishing how infants regulate and/or maintain their physiological changes when engaged in a cognitive task. This study answered four specific hypotheses regarding (a) whether there are different patterns of physiological self-regulation, (b) how resting HFHPV related to physiological self-regulation, (c) how physiological regulation related to learning abilities, and (d) whether active physiological self-regulation, measured via HFHPV change during the VExP was a better predictor of performance than a resting measure of HFHPV.

Hypothesis One: Specification of HFHPV Percent Change Patterns

The presence of HFHPV change patterns supported the first hypothesis, and suggested that individual differences in physiological self-regulation may be categorized

into groups. Initial hypotheses speculated that the magnitude of HFHPV change would contribute to the definition of individual differences specifying group membership. However, according to results, direction of HFHPV percent change (positive/increase or negative/decrease) was a more salient method for establishing group differences in HFHPV percent change than magnitude of HFHPV percent change. Support for this assertion derived from the finding that LgBasePwr, PctChgSeg1, PctChgSeg2, and PctChgAll did not differ significantly between groups when HFHPV change was categorized as stable, moderate, substantial, or extreme during segments one and two. However, when HFHPV change was categorized by direction HFHPV change (increase or decrease) during segments one and two, LgBasePwr, PctChgSeg1, PctChgSeg2, and PctChgAll differed significantly between groups. Thus, classifying HFHPV change according to magnitude may obscure the inherent between group differences.

Results do not necessarily indicate that categorizing HFHPV percent change according to magnitude is an improper method of classification, just that this method was not the most advantageous technique for this sample. Perhaps the important factor is the direction of HFHPV change, not how much HFHPV change there actually is (magnitude). For example, according to this method, two cases, one with a 15% HFHPV decrease and one with 60% HFHPV decrease, cluster into one category based on their direction of change. Thus, the direction of change, not the amount of change, is more important when specifying patterns of HFHPV change.

HFHPV Change Pattern Differences

All HFHPV patterns did not differ significantly on all of the variables. For instance, LgBasePwr did not differ significantly between Changers and Increasers and PctChgSeg2 did not differ significantly for Changers and Decreasers. These findings may be because the Changer group consisted of cases that either increased during segment one and decreased during segment two or decreased during segment one and increased during segment two. Collapsing cases that changed direction of HFHPV percent change during the VExP may be advantageous when trying to increase statistical power and to achieve a more parsimonious system of classification. However, collapsing such cases may result in an increase of within-group variability, causing between group differences to decrease. This effect may potentially mask differences between HFHPV percent change pattern groups, and thus fail to explain the nature of individual differences in physiological self-regulation in the most complete manner.

Hypothesis Two: Relationship between Resting HFHPV and HFHPV Change during the VExP

Richards (1987), Garcia-Coll, Kagan, and Reznick (1984), and Linnemeyer and Porges (1986) found that resting measures of HFHPV were negatively associated with direction of HFHPV change at task onset. One purpose of this study was to extend those findings to the patterning of HFHPV changes throughout the VExP. To accomplish this aim, the second hypothesis predicted a negative relationship between resting HFHPV and direction of HFHPV change throughout the VExP, suggesting that infants with high resting HFHPV were more likely to decrease HFHPV throughout the task, whereas infants with low resting HFHPV were more likely to increase HFHPV throughout the

VExP. LgBasePwr was negatively correlated with PctChgSeg1, but not with PctChgSeg2, suggesting that HFHPV primarily changes during the first VExP segment. This may indicate that this study's findings do not extend previous research about the relationship between resting HFHPV and HFHPV change at task onset, since there were no significant relationships with HFHPV change past the first VExP segment. Additionally, because this study's findings indicate that infants who increase HFHPV during segment one are likely to continue increasing HFHPV during segment two, it may be just as prudent to investigate only the initial change in HFHPV at task onset.

The relationship between resting HFHPV and direction of change throughout the task may suggest that infants with high resting HFHPV have more physiological ability to decrease their HFHPV than infants with low resting HFHPV and vice versa. Conversely, infants with low resting HFHPV may have to first increase their HFHPV to a basal level of arousal before being able to attend to a task.

Differences in Resting HFHPV across HFHPV Change Patterns and Sex

An interesting finding is that while Decreasers' LgBasePwr was significantly higher than Increasers' and Changers', Increasers' LgBasePwr was only significantly lower than Decreasers', but not Changers'. This may be due to a number of reasons. One reason may be that the mean of LgBasePwr for Changers fell between the means for Increasers and Decreasers (see Table C3 for means). This may be due to the fact that Changers' LgBasePwr mean reflects the combination two groups that should have differing means. In other words, the Increasing to Decreasing group would have lower LgBasePwr because they initially increased in HFHPV, whereas the Decreasing to Increasing group would have higher LgBasePwr since they initially decreased HFHPV.

Therefore, the mean of the Changers' group reflects the combination of the two groups' LgBasePwr values. Another reason that Decreasers' LgBasePwr was significantly higher than Increasers' and Changers', but that Increasers' LgBasePwr was only significantly lower than Decreasers' (and not Changers') may be that Increasers' HFHPV values changed more than Decreasers' overall. This may suggest that infants with low resting HFHPV who were more likely to be "Increasers" have more physiological flexibility than infants with high resting HFHPV who were more likely to be "Decreasers". Greater physiological flexibility may afford infants the ability to alter responses in more varied ways, thereby increasing the likelihood that they can react to different environmental contexts in an adaptive and supportive manner.

The relationship between resting HFHPV and HFHPV change patterns was also examined separately by sex. Findings suggested that LgBasePwr is a significant predictor of physiological self-regulation abilities only for females. Initially, it may seem that this is due unequal sample sizes between males ($n = 34$) and females ($n = 49$) used in this analysis (although, not a significant difference). However, there was not a significant difference in the distribution of sex across low versus high BaseMedSpl variables. An alternative explanation of this finding is that females had higher HFHPV percent change values for both segments, although post-hoc analyses revealed that this difference is only significant for HFHPV change during segment two ($F(1, 79) = 3.93, p < .05$). The fact that females had higher HFHPV percent change overall, and significantly more so during the second segment, suggests that at 3.5 months post-gestation, female infants in this sample may be more physiologically mature than the males included in analyses, and thus able

to physiologically self-regulate in a more advantageous manner since HFHPV increases during a cognitive task are indicative of more efficient regulation abilities.

Hypothesis Three: Relationship between RLI and HFHPV Change

Previous research has not examined whether differences in physiological self-regulation during the VExP relate to overall task performance. Therefore, one of the primary purposes of this study was to fill that gap. Results did not support the hypothesis predicting a relationship between HFHPV change throughout the VExP and RLI scores. Instead, there was only a significant negative correlation between LgBasePwr and RLI. Moreover, the only variable accounting for significant RLI variance was LgBasePwr, even when controlling for sex and HFHPV patterns.

However, infants demonstrating a decrease in HFHPV during the first segment had higher RLI scores than infants demonstrating an increase in HFHPV during the VExP. This finding suggests that decreased HFHPV may be an advantageous form of physiological self-regulation that supports the ability to sustain attention and thereby extract and integrate information from environmental stimuli. Thus, the ability to physiologically self-regulate at the beginning of the task may have supported the ability to extract information about the presented stimuli pattern and integrate that knowledge throughout the VExP task. This finding supports previous literature noting that efficient physiological self-regulation facilitates more optimal task performance (Bornstein & Suess, 2000; Garcia-Coll, et al., 1984; Hansen et al., 2003; Middleton et al., 1999; Richards, 1985 & 1987).

An interesting finding was that gestational age and birth weight significantly correlated with PctChgSeg1. These correlations suggested that infants who were older

(greater gestational age) and heavier at birth demonstrated an increase in HFHPV from resting baseline. However, infants who increased HFHPV during the VExP had lower RLI scores, suggesting that they did not extract or integrate information about the task. Thus, it may be that physiological self-regulation abilities are dependent on factors other than physical maturation, such as sex.

In this study females had higher RLI scores than males, but not significantly. The insignificant results may be due to the high mean standard deviations of RLI for both males and females, suggesting high variability in VExP performance across sex. This trend may suggest that if females in this study are indeed more physiologically mature at 3.5 months post-gestation, and therefore more capable of self-regulating during a cognitive task, that such a capacity is supportive of their learning abilities. Based on Gunnar and Donahue's (1980) findings that females were significantly more responsive to auditory stimuli than males, it may be that females were more likely to be responsive to the visual stimuli than males and thus increase the probability of looking in the correct direction of the stimuli. This action may have been recorded as a correct visual anticipation when in fact, all the visual shift indicates is that girls look toward the stimuli more often than males.

Hypothesis Four: Predictive Power of LgBasePwr versus HFHPV Change Patterns

Wass and Donohue (2006) examined the relationship and prediction strength of resting HFHPV and VExP task performance (i.e., RLI scores). This study sought to extend those findings by hypothesizing about the relationship between HFHPV change during the VExP and RLI scores. The hypothesis that HFHPV change during the VExP task would be a stronger predictor of RLI scores than resting HFHPV is contingent on the

idea that more efficient physiological self-regulation during a cognitive task relates to greater levels of sustained attention, and that more sustained attention increases the likelihood of higher RLI scores. However, this study's findings do not support this, and suggest that resting HFHPV is a more salient and significant predictor of VExP task performance than physiological self-regulation during the VExP (as measured by HFHPV patterns).

While this study's findings do not necessarily extend Wass and Donohue's (2006) findings, they certainly support them. For instance, the findings that LgBasePwr significantly correlated with and is a significant predictor of VExP task performance (as measured by RLI scores) corroborate Wass & Donohue's results. In that study, Wass and Donohue found that resting HFHPV positively correlated with RLI scores. Thus, like this study, infants' with high resting HFHPV also had higher RLI scores. Additionally, Wass and Donohue found that resting HFHPV accounted for a significant portion of RLI variance, beyond what sex and maternal age explained. That result is comparable to this study's finding that LgBasePwr accounts for more RLI variance than HFHPV patterns or sex. Based on findings from the current study and Wass and Donohue's study LgBasePwr is a stronger predictor of VExP performance than measurement of physiological self-regulation during the VExP.

CHAPTER VI: CONCLUSION

Implications

Characterizing individual differences of infants' physiological self-regulatory abilities based on the directions of HFHPV change during the first and second segments of the VExP may be a useful diagnostic tool and have implications for early intervention. Specifying the relationship between physiological self-regulatory abilities and learning abilities may afford researchers and practitioners the ability to detect and diagnosis infants who may be at risk for learning delays resulting from regulation disorders. Early detection of a regulatory disorder may in turn afford the ability to provide early intervention services that facilitate the child's acquisition of techniques useful for coping with the symptoms of a regulatory disorder.

Early intervention services that teach self-regulatory techniques may influence a child's academic performance and social skills (Reid, Trout, & Schartz, 2005). For instance, a child diagnosed with a regulatory disorder may not be able to sustain attention to a group task in a classroom setting, potentially affecting his/her later academic performance since he/she is not engaged in the activity designed to provide the child with useful information. An early intervention technique, such as teaching the child how to take slow, deep breaths in order sustain or regain a calm state and control heart rate may, as evidenced by this and other studies influence the child's initial ability to sustain attention to a task. In turn, the ability to initially engage in a task, which was afforded by the ability to cope with symptoms of a regulatory disorder, may help the child gain information presented during the activity. This may be particularly relevant in early childhood learning environments where children are gaining crucial information that

affects later academic performance, such as learning the alphabet or mathematical skills (e.g., patterning and seriation).

Teaching a child how to maintain or regain a calm state could also influence better peer relations. For example, other children without a regulatory disorder may be more willing to work, play, and interact with a child diagnosed with a regulatory disorder if he/she is able to restrain him/herself from being destructive or disruptive to the group's mission. Increased peer interaction may result in the acquisition of better social skills, which may increase long-term friendships and help the child with a regulatory disorder feel less isolated because of his/her symptoms.

There are also methodological implications for this study which may be important for future researchers. For instance, the ability to categorize infants' physiological self-regulatory abilities according to direction of HFHPV change during a cognitive task may enable future researchers to examine other between-group differences that are influenced by physiological self-regulatory abilities, such as peer-interactions, effortful control, or behavioral inhibition. This study also supports the utility of resting baseline measures of HFHPV. Results suggested that most infants' HFHPV initially changed in the opposite direction of their resting state and that this change was sustained throughout the VExP task. Additionally, this study found that a resting measure of physiological self-regulation was a better predictor of VExP performance than measures of physiological change during the VExP task. Given these findings, it may be more prudent for future researchers to use a measure of resting HFHPV to assess outcomes than to try to assess physiological change throughout a cognitive task. Measuring only resting HFHPV may in turn afford researchers the logistic ability to investigate the relationship between HFHPV and other

outcomes that are difficult to measure in an isolated testing environment (e.g., peer interactions, playground behaviors, or levels of involvement in group activities).

Significant between-group differences in RLI scores were masked by high standard deviations. However, according to the RLI means of low versus high resting HFHPV it is evident that infants with high resting HFHPV also had higher RLI scores than infants with low resting HFHPV and were most likely to decrease HFHPV during the VExP. Therefore, this study provides evidence that internal factors such as resting HFHPV and physiological change influence learning abilities. This information may help practitioners, researchers, and educators understand that in addition to external factors like SES, internal factors such as resting HFHPV and physiological self-regulatory abilities are influential variables that may further decipher what accounts for differences in learning abilities. However, practitioners, researchers, and educators should keep in mind that there were high standard deviations for each HFHPV change group and that even when children are grouped according to similar physiological profiles, that variance within those groups still exists and requires careful attention and effort to not cater to one end of the learning ability spectrum.

Limitations

Despite the utility of the aforementioned findings, there were some limitations to this study. First, a limitation of this study was the relatively small sample size. The loss of nearly half the sample was a result of needing both good heart rate and VExP data, both of which are very sensitive measures—meaning that it didn't have to take much for an infant to be excluded (the heart rate data could have been unusable due to a plethora of reasons—hiccups, crying, misplaced sensors, error in the software, etc., etc.). In

addition, infants had to have at least 65% valid responses to the stimuli, thus if something else in the environment caught their attention they may have been more likely to attend to that, rather than to the VExP stimuli.

There may have been more infants demonstrating an increase in HFHPV during the first segment and decreased HFHPV during the second VExP segment and more infants demonstrating a decrease in HFHPV during the first segment and increased HFHPV during the second VExP segment if the sample was larger. This may have increased the likelihood of significant between-group differences that would have justified keeping the groups separate, rather than combining them into one group (i.e., “Changers”). Increasing the sample size may have also helped increase the demographic heterogeneity of the sample and perhaps extend how well these results generalize to diverse populations. Another limitation of this study is that the results are limited to interpretation within the scope of the VExP task. Thus, interpretation and application of the findings may not generalize to other forms of learning such as classical or operant conditioning.

Recommendations for Future Research

This study’s findings may inform future research investigating factors accounting for individual differences in learning abilities. One suggestion is for future studies is to further investigate the ability to group infants according to magnitude and direction of HFHPV change, rather than relying solely on direction of HFHPV change. Incorporating magnitude in the categorization of physiological self-regulatory abilities may enable researchers to further investigate other potential patterns and the relationship between learning abilities and more refined patterns of physiological self-regulation resulting from

inclusion of HFHPV magnitude. Using magnitude and direction of HFHPV change to categorize infants' physiological self-regulatory abilities would create more groups and in turn, allow researchers to further investigate and possibly reveal significant group differences in VExP performance.

Another suggestion for future research is to look more systematically at the “Changers” group. This may be accomplished by utilizing a larger sample containing more infants whose HFHPV changed direction during the first and second VExP. Dividing the “Changers” into two separate groups would result in two groups that categorize infants as (a) demonstrating an increase in HFHPV during the first segment and decreased HFHPV during the second segment or (b) demonstrating a decrease in HFHPV during the first segment and increased HFHPV during the second segment. Examining infants whose HFHPV changed direction between segments enables researchers to see if the groups are indeed a group categorized primarily by inconsistent HFHPV levels or if they are mutually exclusive groups. Having a larger sample size that affords the division of the Changers group will allow researchers to investigate the uniqueness of these two groups and potentially explain differences in resting HFHPV and HFHPV change during the second VExP segment. This may provide further clarification for whether it is advantageous to assess physiological change past the point of task onset.

Nearly 5% of the missing data for hypotheses three and four was a result of missing or inaccurate VExP times that noted the beginning and end times of the task. The manually noted times were needed to calculate the mid-point of the VExP to create two segments. In future research, there should be a refinement to the procedure used. Specifically, that there should be “markers” in the software that automatically note the

start, mid, and end times of the VexP. Instead, in this study, lab assistant was supposed to write down the approximate start time and end time of the VExP in a notebook. This was perhaps difficult if there was only one lab assistant present at the time of testing (there was a lot to do—ensuring that the baby was safe in the apparatus, focusing the camera on the eyeball, starting the time/date generator, starting the VExP task...). Another idea is that perhaps random data integrity/quality checks should be employed during the data collection stage.

Future research should also consider factors other than family demographics and resting HFHPV (e.g., biological mother, father, and sibling(s) self-regulatory abilities), that may account for individual differences in physiological self-regulatory abilities. According to this study and the Wass and Donohue study (2006) there is evidence for potential sex differences in physiological self-regulatory abilities how those abilities differentially affect male and female learning during the VExP. Therefore, future research may want to specify a priori hypotheses about possible sex differences.

In sum, this study contributes to current literature in three primary ways. First, this study provides evidence that there are patterns of physiological self-regulation during a cognitive task. Second, this study found that an infant's pattern of physiological self-regulation evidenced during a cognitive task is contingent upon his or her level of resting HFHPV. Finally, this study supports past research specifying that decreased HFHPV relates to greater levels of sustained attention and more efficient learning abilities.

References

References

- Baddeley, A. D. (1992). Working memory: The interface between memory and cognition. *Journal of Cognitive Neuroscience*, 4, 281-288.
- Berg, K. W. (1972). Habituation and dishabituation of cardiac responses in 4-month-old, alert infants. *Journal of Experimental Child Psychology*, 14, 92-107.
- Berg, K. W. (1974). Cardiac orienting responses of 6- and 16-week-old infants. *Journal of Experimental Child Psychology*, 17, 303-312.
- Bornstein, M. H., & Suess, P. E. (2000). Physiological self-regulation and information processing in infancy: Cardiac vagal tone and habituation. *Child Development*, 71, 273-287.
- Bourgeois, J. P. (2001). Synaptogenesis in the neocortex of the newborn: The ultimate frontier for individuation (pp. 23-34). In M. Luciana & C. A. Nelson (Eds.). *Handbook of Developmental Cognitive Neuroscience*, Impressions: Madison, WI.
- Buss, K. A., Davidson, R. J., Kalin, N. H., & Goldsmith, H. H. (2004). Context-specific freezing and associated physiological reactivity as a dysregulated fear response. *Developmental Psychology*, 40, 583-594.
- Buss, K. A., Goldsmith, H. H., & Davidson, R. J. (2005). Cardiac reactivity is associated with changes in negative emotion in 24-month-olds. *Developmental Psychobiology*, 46, 118-132.
- Calkins, S. D. (1996). Cardiac vagal tone indices of temperamental reactivity and behavioral regulation in young children. *Developmental Psychobiology*, 31, 125-135.

- Calkins, S. D., & Dedmon, S. E. (1999). Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. *Journal of Abnormal Child Psychology*, 28, 103-118.
- Calkins, S. D., & Keane, S. P. (2004). Cardiac vagal regulation across the preschool period: stability, continuity, and implications for childhood adjustment. *Developmental Psychobiology*, 45, 101-112.
- Canfield, R. L., & Haith, M. M. (1991). Young infants; visual expectation for symmetric and asymmetric stimulus sequences. *Developmental Psychology*, 27, 198-208.
- Canfield, R. L., & Smith, E. G. (1996). Number-based expectations and sequential enumeration by 5-month-old infants. *Developmental Psychology*, 32, 269-279.
- Carlson, N. R. (2004). Learning and memory: Basic mechanisms (pp.410-450), in K. May (Ed.). *Physiology of behavior* (8th Ed.). Pearson Education: Boston.
- Casey, B. J., & Richards, J. E. (1988). Sustained visual attention in young infants measured with an adapted version of the visual preference paradigm. *Child Development*, 59, 1514-1521.
- Cole, P. M., Zahn-Waxler, C., Fox, N. A., Usher, B. A., & Welsh, J. D. (1996). Individual differences in emotion regulation and behavior problems in preschool children. *Journal of Abnormal Psychology*, 105, 518-529.
- Colombo, J. (1985). Spectral complexity and infant attention. *Journal of Genetic Psychology*, 146, 519-526.
- Courage, M. L., Howe, M. L., & Squires, S. E. (2004). Individual differences in 3.5-month-olds' visual attention: What do they predict at 1 year? *Infant Behavior and Development*, 27, 19-30.

- DeGangi, G. A., DiPietro, J. A., Greenspan, S. I., & Porges, S. W. (1991). Psychophysiological characteristics of the regulatory disordered infant. *Infant Behavior and Development, 14*, 37-50.
- DiLalla, L. F., Thompson, L. A., Plomin, R., Phillips, K., Fagan, J. F., & Haith, M. M., et al. (1990). Infant predictors of preschool and adult IQ: A study of infant twins and their parents. *Developmental Psychology, 26*, 759-769.
- Dougherty, T. M., & Haith, M. M. (1997). Infant expectations and reaction time as predictors of childhood speed of processing and IQ. *Developmental Psychology, 33*, 146-155.
- Doussard-Roosevelt, J. A., Montgomery, L. A., & Porges, S. W. (2003). Short-term stability of physiological measures in kindergarten children: Respiratory sinus arrhythmia, heart period, and cortisol. *Developmental Psychobiology, 43*, 231-242.
- Fabes, R. A., Eisenberg, N., & Eisenbud, L. (1993). Behavioral and physiological correlates of children's reactions to others in distress. *Developmental Psychology, 29*, 655-663.
- Fagan, J. F. (1976). Infants' recognition on invariant features of faces. *Child Development, 47*, 627-638.
- Fagan, J. F. (1978). Facilitation of infants' recognition memory. *Child Development, 49*, 1066-1075.
- Field, T. M., Woodson, R., Greenberg, R., & Cohen, D. (1982). Discrimination and imitation of facial expressions by neonates. *Science, 218*, 179-181.

- Fox, N. A., & Porges, S. W. (1985). The relation between neonatal heart period patterns and developmental outcome. *Child Development*, 56, 28-37.
- Garcia-Coll, C., Kagan, J., & Reznick, S. (1984). Behavioral inhibition in young children. *Child Development*, 55, 1005-1019.
- Greenough, W. T., Black, J. E., & Wallace, C. S. (1987). Experience and brain development. *Child Development*, 58, 539-559.
- Groome, L. J., Loizou, P. C., Holland, S. B., Smith, L. A., & Hoff, C. (1999). High vagal tone is associated with more efficient regulation of homeostasis in low-risk human fetuses. *Developmental Psychobiology*, 35, 25-34.
- Gunnar, M. R., & Donohue, M. (1980). Sex differences in social responsiveness between six months and twelve months. *Child Development*, 51, 262-265.
- Haith, M. M., Hazan, C., & Goodman, G. S. (1988). Expectation and anticipation of dynamic visual events by 3.5 month-old babies. *Child Development*, 59, 467-479.
- Hansen, A. L., Johnsen, B. H., & Thayer, J. F. (2003). Vagal influence on working memory and attention. *International Journal of Psychophysiology*, 48, 263-274.
- Houston-Price, C., & Nakai, S. (2004). Distinguishing novelty and familiarity effects in infant preference procedures. *Infant and Child Development*, 13, 341-348.
- Huffman, L. C., Bryan, Y. E., del Carmen, R., Pedersen, F. A., Doussard-Roosevelt, J. A., & Porges, S. W. (1992). Infant temperament and cardiac vagal tone: Assessments at twelve weeks of age. *Child Development*, 69, 624-635.
- Ingebrigtsen, J. P. (1999). BabyPic (Version 2.1) [Computer software]. Denver, CO: Center for Infant Development.

- Jacobson, S. W., Jacobson, J. L., O'Neill, J. M., Padgett, R. J., Frankowski, J. J., & Bihun, J. T. (1992). Visual expectation and dimensions of infant information processing. *Child Development*, 63, 711-724.
- Kagan, J. (1982). The construct of difficult temperament: A reply to Thomas, Chess, and Korn. *Merrill Palmer Quarterly*, 28, 21-24.
- Kagan, J. (1987). *Perspectives on infancy*. In Handbook of Infant Development, 2nd ed. (Osofsky, J. D., Ed.). Wiley –Interscience: New York.
- Lamb, M. E., Garn, S. M., & Keating, M. T. (1981). Correlations between sociability and cognitive performance among eight-month-olds. *Child Development*, 52, 711-713.
- Lansink, J. M., & Richards, J. E. (1997). Heart rate and behavioral measures of attention in six-, nine-, and twelve-month-old infants during object exploration. *Child Development*, 68, 610-620.
- Linnemeyer, S. A., & Porges, S. W. (1986). Recognition memory and cardiac vagal tone in 6-month infants. *Infant Behavior and Development*, 9, 43-56.
- Middleton, H. C., Sharma, A. A., Agouzoul, D., Sahakian, B. J., & Robbins, T. W. (1999). Contrasts between the cardiovascular concomitants of tests of planning and attention. *Psychophysiology*, 36, 610-618.
- Pick, H. L. (1983). Some issues on the relation between perceptual and cognitive development (pp.293-305), in T. J Tighe & B. E. Shepp (Eds.). *Perception, cognition, and development: Interactional analyses*. Lawrence Erlbaum Associates: Hillsdale, NJ.

- Porges, S. W. (1973). Heart rate variability: An autonomic correlate of reaction time performance. *Bulletin of the Psychonomic Society*, 1, 270-272.
- Porges, S. W. (1974). Heart rate indices of newborn attentional responsivity. *Merrill Palmer Quarterly*, 20, 231-254.
- Porges, S. W. (1995). Vagal tone: A physiologic marker of stress vulnerability. *Pediatrics*, 90, 498-504.
- Porges, S. W., Doussard-Roosevelt, J. A., & Maiti, A. K. (1994). Vagal tone and the physiological regulation of emotion. *Monographs of the Society for Research in Child Development*, 59, 250-283.
- Porges, S. W., Doussard-Roosevelt, J. A., Portales, A.L., & Greenspan, S. I. (1996). Infant regulation of the vagal "brake" predicts child behavior problems: A psychobiological model of social behavior. *Developmental Psychobiology*, 29, 697-712.
- Reid, R., Trout, A. L., & Schartz, M. (2005). Self-regulation interventions for children with attention deficit/hyperactivity disorder. *Exceptional Children*, 71, 361-377.
- Reznick, J. S., Chawarska, K., Betts, S. L., & Logan, B. (1997). A simple system for monitoring the timing of infant gaze to stimuli at specific locations. *Behavior Research Methods, Instruments, & Computers*, 29, 528-533.
- Richards, J. E. (1985). Respiratory sinus arrhythmia predicts heart rate and visual responses during visual attention in 14 and 20 week old infants. *Psychophysiology*, 22, 101-109.
- Richards, J. E. (1987). Infant visual sustained attention and respiratory sinus arrhythmia. *Child Development*, 58, 488-496.

- Richards, J. E. (1988). Heart rate offset responses to visual stimuli in infants from 14 of 26 weeks of age. *Psychophysiology*, 25, 278-291.
- Richards, J. E., & Casey B. J. (1991). Heart rate variability during attention phases in young children. *Psychophysiology*, 28, 43-53.
- Richards, J. E., & Cronise, K. (2000). Extended visual fixation in the early preschool years: Look duration, heart rate changes, and attentional inertia. *Child Development*, 71, 602-620.
- Richards, J. E., & Gibson, T. L. (1997). Extended visual fixation in young infants: Look distributions, heart rate changes, and attention. *Child Development*, 68, 1041-1056.
- Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2003). Infant visual recognition memory: Independent contributions of speed and attention. *Developmental Psychology*, 39, 563-571.
- Ruff, H. A. (1986). Components of attention during infants' manipulative exploration. *Child Development*, 56, 621-630.
- Smith, L., Fagan, J. F., & Ulvund, S. E. (2002). The relation of recognition memory in infancy and parental socioeconomic status to later intellectual competence. *Intelligence*, 30, 247-259.
- Stanley, C., Murray, L., & Stein, A. (2004). The effect of postnatal depression on mother-infant interaction, infant response to the Still-face perturbation, and performance on an instrumental learning task. *Developmental and Psychopathology*, 16, 1-18.
- Stifter, C. A., & Fox, N. A. (1990). Infant reactivity: Physiological correlates of newborn and 5-month temperament.

- Thompson, R. F., & Spencer, W. A. (1966). Habituation: A model phenomenon for the study of neural substrates of behavior. *Psychological Review*, 73, 16-43.
- Turnbull, A., Turnbull, R., Erwin, E., & Soodak, L. (2006). *Families, professionals, and exceptionality: Positive outcomes through partnerships and trust* (5th ed.). New Jersey: Pearson Education, Inc.
- Wass, T. S., & Donohue, R. L. (2006) *Individual differences in anticipatory responding and learning during early infancy*. Manuscript submitted for publication.
- Webb, S. J., Monk, C. S., & Nelson, C. A. (2001). Mechanisms of postnatal neurobiological development: Implications for human development. *Developmental Neuropsychology*, 19, 147-171.
- Wentworth, N., Haith, M. M., & Hood, R. (2002). Spatiotemporal regularity and interevent contingencies as information for infants' visual expectations. *Infancy*, 3, 303-322.

Appendices

Appendix A

Figures

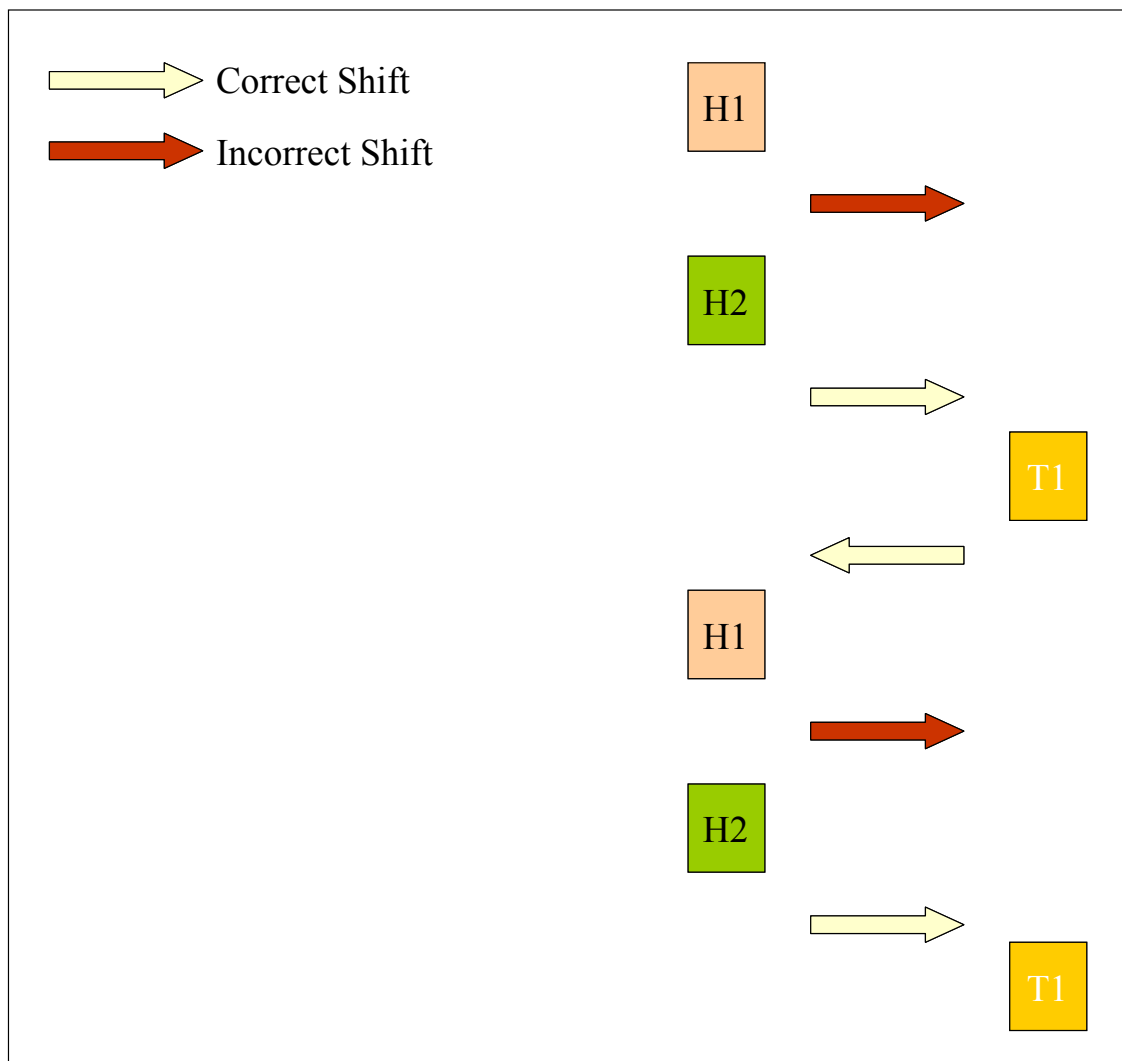


Figure 1. Schematic representation of VExP shifting expectations.

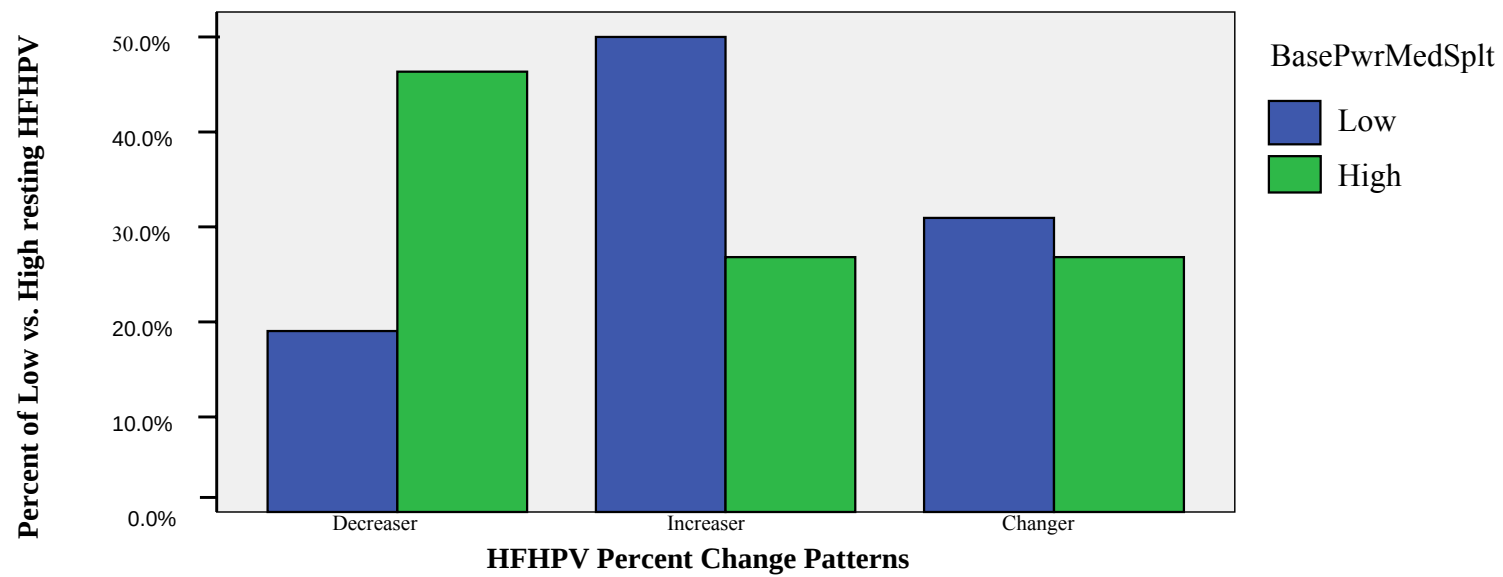


Figure 2. Percent of cases defined as having either low or high resting HFHPV by patterns of HFHPV change.

Appendix B

Descriptive Statistics of Sample

Table B1

Descriptive Statistics of Demographic Characteristics for All Samples

		Percent		
		Total	Subsample 1 ^b	Subsample 2 ^c
		Sample ^a		
Sex				
	Male	50.4	42.0	42.9
	Female	49.6	58.0	57.1
Ethnicity				
	Non-Minority	88.0	88.9	88.9
	Minority	12.0	11.1	11.1
Maternal Education				
	≤ College Degree	51.3	53.1	58.7
	≥ College Degree	48.7	46.9	41.3
Paternal Education				
	≤ College Degree	53.5	48.7	49.2
	≥ College Degree	46.5	51.3	50.8

^a = 117. ^b Included in hypotheses one and two = 81. ^c Included in hypothesis three = 64.

Table B1 Continued

Descriptive Statistics of Demographic Characteristics for All Samples

		Percent		
		Total	Subsample	Subsample
		Sample ^a	1 ^b	2 ^c
Marital status				
	Married	87.2	91.4	92.1
	Not Married	12.8	8.6	7.9
Hollingshead Category				
	Unskilled laborers, menial service workers	5.1	4.9	4.8
	Machine operators semiskilled workers	12.0	14.8	11.1
	Skilled craftsmen, clerical, sales workers	28.2	23.5	25.5
	Medium business, minor professional, technical	29.9	29.6	27.0
	Major business and professional	24.8	27.2	31.7

^a = 117. ^b Included in hypotheses one and two = 81. ^c Included in hypothesis three = 64.

Table B2

Means and Standard Deviations (SD) of Demographic Characteristics for All Samples

	Total Sample ^a	Subsample 1 ^b	Subsample 2 ^c
Gestational age (wks.)	39.12 (1.14)	39.22 (1.07)	39.10 (1.03)
Birth weight (lbs.)	7.78 (.97)	7.76 (.93)	7.68 (.91)
Maternal age (yrs.)	30.08 (5.31)	29.78 (5.39)	29.37 (5.12)
Paternal age (yrs.)	32.80 (5.99)	32.73 (6.10)	32.65 (6.46)
Infant age at test (wks.)	92.82 (3.78)	93.30 (3.65)	93.13 (3.56)

^a = 117. ^b Included in hypotheses one and two = 81. ^c Included in hypothesis three = 64.

Appendix C

Correlations, Distributions, and Means

Table C1

Correlations between HFHPV variables, RLI, and significant demographic variables.

	1	2	3	4	5	6	7
1. PctChgSeg1	--						
2. PctChgSeg2	.62**	--					
3. PctChgAll	.67**	.66**	--				
4. LgBasePwr	-.36**	-.36**	-.26*	--			
5. RLI	-.17	-.24	-.07	.28*	--		
6. Gestational Age	.24*	-.01	-.01	-.11	.05	--	
7. Birth Weight	.22*	.09	-.01	-.09	.14	.41**	--

Table C2

Percentages of Demographic Variables and Categorical HFHPV Variables.

		BaseMedSpl		Change Direction (Seg. 1)		Change Direction (Seg. 2)		HFHPV Percent Change Patterns		
		Low	High	Increase	Decrease	Increase	Decrease	Increases	Decreases	Changers
Sex										
	Male	41.2	58.8	41.2	58.8	37.5	62.5	23.5	47.1	29.4
	Female	59.6	40.4	59.6	40.4	70.7	29.3	51.1	21.3	27.7
Ethnicity										
	Non-Minority	47.2	52.8	51.4	48.6	57.8	42.2	41.7	33.3	25.0
	Minority	88.9	11.1	55.6	44.4	44.4	55.6	22.2	22.2	55.6

Table C2 continued.

Percentages of Demographic Variables and Categorical HFHPV Variables.

	BaseMedSpl		Change Direction (Seg. 1)		Change Direction (Seg. 2)		HFHPV Percent Change Patterns		
	Low	High	Increase	Decrease	Increase	Decrease	Increases	Decreases	Changers
Paternal Education									
≤ College Degree	44.7	55.3	47.4	52.6	42.9	57.1	28.9	39.5	31.6
≥ College Degree	57.5	42.5	57.5	42.5	69.4	30.6	50.0	25.0	25.0
Marital Status									
Not Married	85.7	14.3	28.6	71.4	60.0	40.0	14.3	14.3	71.4
Married	48.6	51.4	54.1	45.9	55.9	44.1	41.9	33.8	24.3

Table C3

HFHPV Percent Change Pattern Means (SD)

	HFHPV Percent Change Pattern Group		
	Increasesers ^a	Decreasers ^b	Changers ^c
LgBasePwr	.57 (.30) ^b	.87 (.32) ^{a, c}	.62 (.33) ^b
PctChgSeg1	2.36 (.25) ^{b, c}	1.56 (.27) ^{a, c}	1.89 (.34) ^{a, b}
PctChgSeg2	2.43 (.27) ^{b, c}	1.56 (.29) ^a	1.87 (.34) ^a
PctChgAll	2.31 (.41) ^{b, c}	1.57 (.28) ^{a, c}	1.81 (.24) ^{a, b}
RLI	1.21 (7.77)	5.12 (7.86)	3.76 (6.42)

Note. Lack of superscript indicates that there was not a significant difference, whereas the presence of a group's superscript indicates that the groups significantly differed.

Table C4

LgBasePwr Means (SD) by Sex and HFHPV Percent Change Patterns

	Female	Male
Increasesers	.55 (.28) ^a	.63 (.37)
Decreasers	.95 (.38) ^b	.83 (.29)
Changers	.61 (.32)	.63 (.37)

^a Significantly lower than female Decreasers ($p < .01$), but not significantly lower than female Changers. ^b Significantly higher than female increasers ($p < .01$) and female changers ($p < .05$).

Table C5

*Percentages of Males and Females with Low versus High Resting HFHPV across
HFHPV Change Patterns*

	Increasers	Decreasers	Changers
Low resting HFHPV			
Male ^a	28.6	35.7	35.7
Female ^b	60.7	10.7	28.6
High resting HFHPV			
Male ^c	20.0	55.0	25.0
Female ^d	33.3	38.1	28.6

^a n = 14. ^b n = 28. ^c n = 20. ^d n = 21.

Table C6

RLI Means (SD) by HFHPV Percent Change Patterns

HFHPV Percent Change Patterns	RLI Means (SD)
Increasesers ^a	.88 (7.80)
Decreasers ^b	5.13 (7.65)
Changers ^c	3.76 (6.42)
^a n = 26. ^b n = 20. ^c n = 18.	

Table C7

RLI Means (SD) by HFHPV Change Direction per VExP Segment

HFHPV Change Direction	Segment 1	Segment 2
Increase	1.07 (7.71)	2.41 (6.87)
Decrease	5.01 (6.81)	3.98 (7.68)

Vita

Heather Sedges graduated in 1999 from Knoxville Catholic High School in Tennessee.

She attained her Bachelor of Science degree from the University of Tennessee, Knoxville in 2003, with a major in Human Ecology and a minor in psychology. Ms. Sedges plans to continue her education by pursuing her Ph.D in Human Ecology at the University of Tennessee, Knoxville.