

Individual Differences in Spatial Memory Performance at 12 Months of Age:  
Contributions from Walking Experience and Brain Electrical Activity

Denise Rene Adkins

Thesis submitted to the Faculty of the  
Virginia Polytechnic Institute and State University  
in partial fulfillment of the requirements for the degree of

Master of Science  
in  
Psychology

April 28, 2004

Blacksburg, Virginia

Committee Members:

Martha Ann Bell, PhD, Chair

Robin Cooper, PhD

David Harrison, PhD

Keywords: spatial memory, EEG, walking experience, individual differences

Copyright 2004, Denise R. Adkins

Individual Differences in Spatial Memory Performance at 12 Months of Age:  
Contributions from Walking Experience and Brain Electrical Activity

Denise Rene Adkins

ABSTRACT

This study examined individual differences in spatial memory performance in 12-month-old infants using brain electrical activity and walking experience. Greenough's experience-expectant and experience-dependent model of development was used to examine EEG power values among infants with different levels of walking experience (non-walkers, novice, experienced). In accordance with this model, a trend was shown for novice walkers to have higher EEG power values than both non-walkers and experienced walkers only in the central region. Walkers were also found to score higher on an object retrieval (OR) spatial memory task than non-walkers, with amount of walking experience being inconsequential. In addition, infants who scored higher on the OR spatial memory task showed a trend for higher EEG power values in medial frontal, central and parietal areas than infants scoring lower on the OR task. This was not the case for the manual search spatial memory task (AB). There was no interaction among spatial memory performance, walking experience and brain electrical activity. The utility of OR as a spatial memory task that requires the integration of relevant perceptual-motor integration is discussed.

## Acknowledgements

I would like to thank my advisor, Martha Ann Bell, for her endless patience and support throughout this project. Her knowledge and encouragement helped shape not only the final project, but served to further increase my respect for the intricacy of developmental theory and research methods. I am truly fortunate to have had the benefit of her guidance and look forward to what is yet to come. In addition, I would like to thank my committee members, Robin Cooper and David Harrison for the time and effort they committed to my project.

I also want to specifically thank those who helped with data collection along the way: an undergraduate assistant, Tiffany Clory, and my fellow graduate students and friends, Christy Wolfe and Kacey Morasch. In addition to day-to-day assistance with the project, they also provided moral support, which was invaluable and much appreciated.

Next, I would like to thank those who were influential in shaping my career path in unique ways: Linda Little, Elizabeth Craig, and Robert Carlsen. Also, I want to thank my friends who provided daily support. Specifically, I wish to thank Laura Horsch, Wes Keene, and Susan Anderson who helped me manage the daily stresses and never failed to be able to bring a smile to my face when I needed it most.

Finally, I would like to specifically acknowledge my mom for her undying faith, encouragement and support. She has seen me through everything, good and bad, and has never wavered. Her endless love and her multiple sacrifices and investments in my happiness and success are the reason I have had the opportunities that I have and I appreciate that more I may ever be able to express.

## List of Tables

1. Means and standard errors for spatial memory task performance by walk group (non-walkers, novice walkers, experienced walkers). 43
2. Means and standard errors for spatial memory task performance by walk group (non-walkers, walkers). 44

## List of Figures

1. Frontal pole EEG power values for low and high AB groups.	45
2. Medial frontal EEG power values for low and high AB groups.	46
3. Central EEG power values for low and high AB groups.	47
4. Parietal EEG power values for low and high AB groups.	48
5. Frontal pole EEG power values for low, intermediate and high OR groups.	49
6. Medial frontal EEG power values for low, intermediate and high OR groups.	50
7. Central EEG power values for low, intermediate and high OR groups.	51
8. Parietal EEG power values for low, intermediate and high OR groups.	52
9. Frontal pole EEG power values for non-walkers, novice walkers and experienced walkers.	53
10. Medial frontal EEG power values for non-walkers, novice walkers and experienced walkers.	54
11. Central EEG power values for non-walkers, novice walkers and experienced walkers.	55
12. Parietal EEG power values for non-walkers, novice walkers and experienced walkers.	56

## Table of Contents

Abstract.....	ii
Acknowledgements.....	iii
List of Tables.....	iv
List of Figures.....	v
1 Introduction	
1.1 Greenough’s Model of Brain Development.....	1
1.2 Brain Electrical Activity and Self-Locomotion.....	2
1.3 Self-Locomotion and Spatial Memory Performance.....	3
1.4 Brain Electrical Activity and Spatial Memory Performance.....	5
1.5 Walking Experience.....	7
2 Present Study.....	10
3 Method	
3.1 Participants.....	10
3.2 Procedures.....	11
4 Results.....	19
5 Discussion	
5.1 Walking Experience and Brain Electrical Activity.....	27
5.2 Walking Experience and Spatial Memory Performance.....	28
5.3 Brain Electrical Activity and Spatial Memory Performance.....	30
5.4 Walking Experience, Brain Electrical Activity, Spatial Memory Performance...31	
5.5 Limitations.....	32
5.6 Summary and Conclusions.....	33

6	References.....	36
7	Tables.....	43
8	Figures.....	45
9	Appendix A Informed Consent Form.....	57
10	Appendix B General Information Questionnaire.....	59
11	Curriculum Vitae.....	61

Individual Differences in Spatial Memory Performance at 12 Months of Age:  
Contributions from Walking Experience and Brain Electrical Activity

The relation between self-locomotion and performance on spatial cognition tasks has been examined in behavioral (Acredolo, 1978, 1990; Acredolo & Evans, 1980; Acredolo, Adams & Goodwyn, 1984; Bai & Bertenthal, 1992; Bertenthal, Campos & Kermoian, 1994; Kermoian & Campos, 1988) and electrophysiological (i.e., EEG) research (Bell & Fox, 1997). Briefly, it has been shown that hands-and-knees crawlers score higher on these tasks than non-crawlers. Thus, previous work in this area has focused on hands-and-knees crawling as the means of locomotion. The purpose of the current study was to investigate individual differences in spatial cognition with respect to walking experience and brain electrical activity.

*Greenough's Model of Brain Development*

Greenough proposes a model focusing on two different ways that experience causes changes in the brain (Bruer & Greenough, 2001). One is “experience-expectant” development, where changes in the brain are seen before certain experiences. These experiences are expected to occur at specific times in development for normal development to occur (Black & Greenough, 1986; Greenough & Black, 1992; Greenough, Black & Wallace, 1987). The other is “experience-dependent” development, which is unique to the individual and his/her context (Black & Greenough, 1986; Greenough & Black, 1992; Greenough, Black & Wallace, 1987). Experience-dependent development concerns developing new synapses in response to experience, is relatively age-independent, and allows for us to learn and benefit from experiences throughout life. Experience-expectant development, on the other hand, is limited to developing skills and



neural systems that are characteristic of a given species, including sensory and motor systems. The system usually develops normally because the required or expected experiences are present and readily available to all members of a species in their typical environment. The model postulates that brain development is influenced by excess synaptic connections in anticipation of the expected event, which results in the development of neural connections. These excess synapses are then pruned, with a necessary subset left as a result of the experience.

#### *Brain Electrical Activity and Self-Locomotion*

Because the onset of walking fits Greenough's criteria for an "experience-expectant" event, one can reason that the cortical organization of infants will be modified in anticipation of the onset of walking. Therefore, an overproduction of synapses is expected prior to the onset of walking due to the anticipation of the behavioral change. Thus, infants of a specific age who have not yet begun walking are expected to have a different cortical organization from novice and experienced walkers of the same age. Novice walkers are expected to retain extra synapses as they refine the skill, while the synapses of experienced walkers are expected to have been pruned. Thus, the experienced walker should have less synaptic connections than both the prelocomotor and novice walkers of the same age.

Bell and Fox (1996) used the Greenough "experience-expectant" model paired with EEG evidence to show that hands-and-knees crawling experience was related to changes in cortical organization during infancy. They divided the infants into four groups: prelocomotor infants, novice crawlers with 1-4 weeks of experience, infants with 5-8 weeks of crawling experience, and experienced crawlers with 9+ weeks of

experience. They found that novice crawlers showed greater EEG activity than either prelocomotor or experienced crawlers, suggesting that the anticipation and onset of crawling is associated with an excess of cortical connections. These changes in crawling behavior and cortical organization may be associated with other aspects of development as well.

#### *Self-Locomotion and Spatial Memory Performance*

For example, there is a wide-ranging literature focusing on crawling experience and spatial cognition tasks. Research by Kermoian and Campos (1988) tested individual differences among 8.5-month-old infants, varying in crawling experience, on the classic object search task, A-not-B (AB). Results showed that infants with locomotor experience (either hands-and-knees crawling or using an infant walker) performed better than prelocomotor infants, with performance improving as weeks of experience increased.

Similarly, research by Acredolo has shown that differences in spatial orientation memory tasks are seen between 6-month-olds and 9-month-olds and these differences may be due to the onset of crawling (1978; Acredolo & Evans, 1980). Acredolo examined differences in infants at 6, 9 and 11 months of age by changing their spatial orientation to hiding sites during object search performance (Acredolo & Evans, 1980). Changing spatial orientation was accomplished by either displacing the infant 180 degrees relative to the hiding site or displacing the hiding site 180 degrees relative to the infant before allowing search. In another study, the infant was either allowed to crawl or was carried to the AB hiding site prior to search initiation (Acredolo, Adams & Goodwyn, 1984). Acredolo and Evans (1980) suggest that self-produced locomotion encourages the use of landmarks during the object search memory task, resulting in better

performance among the 9 and 11 month old infants. These tasks focus on the infant's concept of space and movement in space, both important concepts for crawling.

The Acredolo model of self-and-object displacement has been used to test for individual differences in spatial memory among 9-month-old infants with varied crawling experience and the greatest difference in performance appears to be between the prelocomotor infants and those with crawling experience (Acredolo, 1990). Bai and Bertenthal (1992) modified the Acredolo model of self-and-object displacement by requiring 8-month-old infants to reach toward two hiding sites of different colors located on a table. Following the hiding of the object, the tabletop was rotated 180 degrees (object displacement) or the infant was rotated 180 degrees around the table (self displacement). Sustained attention (i.e. maintaining eye contact) to the hiding site resulted in increased success on both object-and-self displacement trials (Bai & Bertenthal, 1992). Crawling experience was reported to contribute to successful search during the self displacement trials, but not object displacement (Bai & Bertenthal, 1992). Since crawling and visual attention were not correlated, it was concluded that crawling experience affects search performance but not by means of visual attention (Bai & Bertenthal, 1992). Bai and Bertenthal (1992) proposed that use of landmarks during object search may be used by hands-and-knees crawlers to understand the environment spatially. Thus, crawling is proposed to be associated with spatial memory and cognition as the infant develops the ability to move away from egocentric spatial relations (Acredolo, 1990; Bai & Bertenthal, 1992).

Bertenthal, Campos and Kermoian (1994) have also proposed that locomotion is related to the development of infant cognitive behavior. They discuss the use of

landmarks as a means by which locomotor infants may develop understanding of the spatial environment through dynamic interrelations of objects. Furthermore, they hypothesize that it is this understanding of dynamic interrelations which allows locomotor infants to perform better than prelocomotor infants on spatial cognition tasks, including AB.

#### *Brain Electrical Activity and Spatial Memory Performance*

Evidence of this can be seen in Bell & Fox (1997) where individual differences on the manual search AB task, which assesses spatial memory by requiring the infant to remember where the object was hidden in space, was related to crawling experience. This manual search AB task differs from the Acredolo model of self-and-object displacement in that the researcher places a toy in one of two identical hiding sites in plain view of the infant, diverts the visual attention of the infant and then allows him/her to reach for the toy (Bell & Fox, 1992; Diamond, 1985). Because visual attention is diverted before initiation of search on this task, it is reasoned that recall of spatial location is required (Diamond, 1985). In an examination of individual differences on the manual search AB task, Bell and Fox (1997) reported differences in baseline EEG associated with task performance. Baseline EEG power has been used with the classic manual search AB task due to the amount of gross motor movement involved which renders task-related recordings unusable (Bell, 2001). EEG power reflects the excitability of groups of neurons (Nunez, 1981). More recently, attempts are being made to model dendritic changes on both a macroscopic and microscopic level using EEG (Rowe, Rennie, Robinson, & Gordon, 2000). In 8-month-old infants, greater frontal and occipital baseline EEG power values were associated with higher task performance in

hands-and-knees crawlers relative to non-crawlers (Bell & Fox, 1997). Furthermore, frontal EEG power was greater in the right hemisphere relative to the left hemisphere in the high performance group.

Diamond (Diamond, 1990; Diamond, et al, 1997) has developed another spatial search task, object retrieval (OR). This task requires recall of the spatial location (Diamond, 1990a, 1992, Diamond & Goldman-Rakic, 1986). Here, the infant is required to manipulate a transparent box in order to retrieve the toy underneath. The infant has to be able to inhibit reaching along the line of sight and remember how s/he last successfully retrieved the toy in order to succeed because the toy is initially partially outside the box and then hidden deeper inside as the trial progresses. Strategies can be developed to help the infant succeed and s/he can relate the information about the open position of the box to his/her motor movements to retrieve the toy (Diamond, 1992).

Successful performance on manual spatial search tasks has been shown to be related to activation of a specific portion of the frontal cortex (Diamond & Goldman-Rakic, 1986, 1989). Work with non-human primate infants, who share the same developmental progression as human infants, has shown that success on the spatial memory tasks is related to having a mature or intact dorsolateral prefrontal cortex (Diamond, 1990a, 1990b, 1992; Diamond & Goldman-Rakic, 1983, 1989). Infant rhesus monkeys with lesions of the dorsolateral prefrontal cortex in both hemispheres and adult monkeys with prefrontal lesions were impaired on the spatial memory tasks (Diamond & Goldman-Rakic, 1996; Diamond, Zola-Morgan & Squire, 1989). A longitudinal study, following human infants from 7-12 months of age, by Bell and Fox (1992) used EEG to suggest that differences in prefrontal cortex functioning were related to success on the

manual spatial search AB task, but not the object retrieval task. However, Bell and Fox (1992) differed in procedural administration of the object retrieval task, which may explain the lack of support for frontal involvement in task performance.

Because infant brain activity is probably not fully localized (Bell & Wolfe, 2002), one might expect to see increased brain electrical activity not only at the frontal scalp locations which Diamond (1990a, 1990b) has implicated in the successful performance of both spatial memory tasks previously discussed, but in the parietal and occipital areas as well (Bell, 2001; Bell & Fox, 1992, 1997; Bell & Wolfe, 2002). Past studies have failed to report differences in spatial search performance to be associated with brain electrical activity in the temporal region.

As for hemisphericity, the right hemisphere is known to show predominance early in development (Chiron, Jambaque, Nabbout, Lounes, Syrota & Dulac, 1997) and has distinguished between high and low performance on the AB task (Bell & Fox, 1997). However, hemispheric asymmetry is speculated to change sometime in early childhood between 1-3 years with the shift varying based on structure and function (Chiron, et al, 1997). Therefore, hemispheric differences are not unexpected, but no specific hypotheses will be made as the participants for this study fall in the early range for the expected onset of shifting of localization of function from the right hemisphere to the left which may cause hemispheric effects to wash out altogether.

### *Walking Experience*

It has been suggested that cortical reorganization, similar to that which occurred when infants were learning to crawl, occurs when infants are learning to walk unaided (Corbetta & Bojczyk, 2002). It is reasonable to examine whether this new form of self-

locomotion will affect the infant's spatial cognitive ability (Adolph, 1997; Corbetta & Bojczyk, 2002). In a longitudinal study with infants ranging from their first week of crawling through after they started walking, Adolph (1997) found that infants have to learn how to manipulate their environments all over again when they move from crawling to walking. She discusses the Sway Model as an explanation for how infants learn to manipulate their environment. This model states that postural sway requires the infant to relearn coordination and perception of the environment as he/she encounters a new vantage point in moving from one skill to another (Adolph, 2000). For example, when the child is learning to crawl, the wrists are key pivotal joints allowing permissible sway. In turn, the ankles are key during the development of walking. Each milestone requires different vantage points from which the ground is viewed, different muscle groups, different patterns of optic flow resulting from postural sway, and different vestibular, kinesthetic and visual information (Adolph, 2000).

Due to the proposal that visual information and optic flow are concurrent with the onset of walking, one can expect that the infant must learn to re-orient to the environment spatially, as occurs with crawling (Adolph, 2000). Further support for the notion that similar processes occur as infants learn to crawl as when infants learn to walk was demonstrated by Corbetta & Bojczyk (2002). Infants initially reach with both hands when crawling, but are able to reach one-handed after some experience. Corbetta & Bojczyk (2002) showed that infants return to two-handed reaching when learning to walk, yet found that this behavior declined as balance control increased. They speculated that this change may be due to cortical reorganization that may occur with the onset of walking (Corbetta & Bojczyk, 2002). When infants initially begin to reach, it is typically with

two hands and is poorly controlled and poorly adapted to an object's properties. As infants refine their skills, they begin to reach one-handed for smaller objects which is considered more adaptive. They exhibit more control and the ability to intercept objects of different trajectories and to preshape their handgrip to fit the objects properties prior to contact (Corbetta & Bojczyk, 2002).

Following the onset of unaided walking, infants were reported to return to adaptive reaching for three consecutive weeks between 7 and 13 weeks after the onset of walking (Corbetta & Bojczyk, 2002). Thus, two-handed reaching ended as early as 4 weeks and as late as 9-10 weeks, with most infants returning to adaptive reaching after 7 weeks of walking (Corbetta & Bojczyk, 2002). Corbetta and Bojczyk (2002) postulated that the increase of balance control, postural integration and cognitive reorganization all play a role in the development of walking and reaching, with experience resulting in a return to one-handed reaching. They explain that infants learning to walk hold their arms upward in a high guard position thought to aid in balance control and that identical muscles used in the guard position are employed in reaching, which may explain the return to two-handed reaching around the onset of unaided walking and the refinement to one-handed reaching with acquired walking experience (Corbetta & Bojczyk, 2002).

Zelazo (1983) suggests a cognitive-behavioral model for explaining unaided walking. This model states that unaided walking is contingent on the infant's motor and cognitive development and that the infant has to use memory to integrate balance and coordination needed for unaided walking. He argues that as infants learn to inhibit their reflexive responses throughout the first year of life, they are replaced with instrumental behaviors. Zelazo also hypothesizes that the ability of the infants to process information



more quickly aids in the development of functional play and two-step association performance reliably seen in infants at 12 months of age, all of which supports major cognitive change. He claims that increased information processing enhances memory processing and thus influences response selection and perceptual information. Based on his findings and those of Adolph and Corbetta and Bojczyk, one might hypothesize that walking experience may play a facilitatory role in spatial memory performance.

### Present Study

This study examined individual differences in walking experience and concurrent brain electrical activity and spatial memory performance. It was hypothesized that (a) Infants with more walking experience would perform better on spatial memory tasks, (b) Frontal, occipital and parietal EEG power values would be greater in infants who perform better on spatial memory tasks, c) EEG power values would vary with the amount of walking experience. Prelocomotor infants would show the lowest power values. Novice walkers would show the highest EEG power values and experienced walkers would show power values in between the other two groups and d) An interaction among amount of walking experience, EEG power values, and spatial memory task performance should be seen. As walking experience increases, infants should perform better on spatial memory tasks as evidenced by efficiency seen in EEG power values.

### Method

#### *Participants*

Participants were 50 healthy, 12-month-old infants, 26 male and 24 female, who were recruited from the Developmental Sciences data base. All except one infant weighed six or more pounds at birth. The exception was a twin who weighed five pounds

and 9 ounces. All infants were born within three weeks of their expected due dates. None of the infants had sustained a head injury or had any type of neurological disorder. Infants were seen within three weeks following their 12-month birthday, with the exception of one who was seen 28 days after his birthday.

### *Procedures*

*Electrophysiological Recordings.* EEG was recorded from twelve sites during a baseline recording period: frontal pole (F1, F2), medial frontal (F3, F4), lateral frontal (F7, F8), central (C3, C4), parietal (P3, P4), and occipital (O1, O2) regions, referenced to Cz. Due to equipment failure, data were only available for eight sites for all 50 infants (Fp1, Fp2, F3, F4, C3, C4, P3, and P4). Baseline EEG was recorded for 1 minute while the infant sat on the mother's lap and was entertained by the researcher bouncing balls in an infant toy and for the next minute while the researcher manipulated a pinwheel or blew bubbles. The mother was asked not to speak to her child during this time.

EEG was recorded using an ElectroCap with electrodes in the 10/20 system pattern. After the cap was applied, an abrasive was added to each electrode site and gently rubbed, then a conductive gel was added to each site and rubbed gently. EEG electrode impedances were accepted if they were below 5K ohms (Pivik, et.al, 1993).

The electrical activity for each site was amplified with separate SA Instrumentation Bioamps, bandpassed from .1 to 100 Hz and filtered at 60 Hz. The data were digitized at 512 samples per second for each channel, so the data would not be affected by aliasing.

Software developed by the James Long Company was used to analyze the EEG data. The data were re-referenced by the software for an average reference configuration.

Average referencing was used to weight the electrode sites equally, eliminating the need for a noncephalic reference. Active (Fp1, Fp2, F3, F4, C3, C4, P3, and P4) to reference (Cz) electrodes vary across the scalp, so the re-referencing was necessary to accurately reflect the electrical potential of each site without interelectrode distance being reflected.

Data were artifact scored for eye movements on a peak-to-peak criterion of 100 uV or better. Gross motor movement artifact over 200 uV was scored on a peak-to-peak criterion. These artifacted EEG segments were removed from subsequent data analysis. Data were then analyzed with a discrete Fourier transform (DFT) using a Hanning window of 1-sec width and 50% overlap. Power was computed for the 6-9 Hz frequency band because this band has been distinguished from the others as consistently exhibiting discriminatory capabilities between correct and incorrect infant responses on spatial memory tasks (Bell, 2002). Baseline EEG has been used in past maturation arguments for task differentiation (Bell & Fox, 1992, 1997). EEG power was expressed in mean square microvolts and the data transformed using the natural log (ln) to normalize the distributions.

EEG data were available for 43 infants, 23 male and 20 female. Data were lost for 7 infants: 1 due to bioamp failure, 1 due to electrical interference in the EEG signal, 2 due to heart rate interference in the EEG signal, 2 due to excessive fussiness/crying, and 1 because both raw and transformed power values were more than 3 standard deviations below the mean of this group of infants.

*Manual search AB spatial memory task.* The manual search spatial memory task is also known as the classic A-not-B task (Diamond, 1990a, 1990b; Diamond, Prevor, Callender, Druin, 1997). The infant observed while an object was hidden and was

allowed to retrieve it seconds later by reaching to the hiding site. This task requires the participant to remember where the object was previously hidden in space and to keep in mind the location as the hiding site changes.

The infant was seated in the mother's lap across the table from the experimenter. The table measured 75 cm (L) X 45 cm (W) X 70 cm (H). The toy was hidden in two identical hiding sites 23 cm apart, 45 cm in diameter and 12 cm deep. Identical blue cloths were placed over the sites to hide the toy. The infant was placed midway between the hiding sites. The procedure used here was similar to Bell and Fox (1997), modified from Kermoian and Campos (1988). The order of the task was as follows:

- 1) Object partially covered with one cloth.
- 2) Object completely covered with one cloth.
- 3) Object hidden in tubs under 1 of 2 identical cloths.
- 4) Object alternated between 2 identical hiding sites with 0 delay.
- 5) Object alternated between 2 identical hiding sites with 2-sec delay.
- 6) Object alternated between 2 identical hiding sites with 4-sec delay.
- 7) Object alternated between 2 identical hiding sites with 6-sec delay.
- 8) Object alternated between 2 identical hiding sites with 8-sec delay.
- 9) Object alternated between 2 identical hiding sites with 10-sec delay.

Diamond (1985) found delays longer than 10 seconds are usually needed when testing infants at 12 months of age on the AB spatial memory task to see a search error.

However, a magnitude of this delay has not been replicated (Bell & Fox, 1992;

Matthews, Ellis, Nelson, 1996).

Items 1-3 were considered "warm-up trials" for this age infant. Infants were engaged by a toy manipulated by the experimenter, which was then completely hidden under one cloth to ensure the infant was interested in the toy and would search for it and then hidden in one of two sites under 1 of 2 identical cloths. If the infant's attention was lost, the experimenter regained it and continued. The infant was rewarded with praise

and cheering for correct reaches and allowed to play with the toy for a few seconds. This was not done for incorrect reaches.

Upon successful completion of warm-up items 1-3, the testing procedure (items 4-9) began. After two successful searches at one hiding site, the toy was hidden at the reverse or alternate location. Infants who were successful on all three trials with no delay (test item 4) were increased to a 2-second delay during testing (test item 5). If the infant succeeded at a 2-second delay, s/he was tested at a 6-second delay (test item 7). If the infant failed at the 6-second delay, s/he was tested at a 4-second delay (test item 6). If s/he succeeded at a 6-second delay, the delay was increased at a rate of 2-seconds until the infant made an error on a reversal trial. Infants were increased to a 6-sec delay following success at a 2-second delay because previous research has shown that infants at this age succeed at an average 6 (Bell & Fox, 1992) or 10 seconds (Diamond, 1985).

A distractor was used to call the infant's attention away from the hiding site on the delay trials (Bell & Adams, 1999; Bell & Fox, 1992, 1997; Diamond, 1985). For the no-delay trials, the mother held the infant's hands while the researcher called the infant's name to divert his/her attention from the hiding site. Immediately following the diversion, the researcher asked, "Where is the toy?" In the delay trials, the mother held the infant's hand while the researcher called the infant's name as a diversion. Then, the researcher clapped and counted aloud to distract the infant during the delay, then asked, "Where is the toy?" The aforementioned question served as the cue for the mother to release the infant's hand, so s/he could reach for the hidden toy. Diamond (1985) argues that a distractor is necessary because if visual fixation is allowed during the delay, memory is not required.

AB testing ended following a failed attempt at a specific delay or when the infant was successful at a 10-second delay. Infants were given a score related to their highest score on the AB spatial memory scale (Bell & Adams, 1999). For example, a score of 5 means the infant was last successful at a 2-second delay.

*Object retrieval (OR) spatial memory task.* Infants were required to move around a transparent flexiglass box to locate a toy through an open side, inhibiting the natural response to reach straight toward the toy, while remembering where they reached previously in order to succeed (Bell & Fox, 1992; Diamond, 1992).

During this task, the experimenter manipulated the following variables during testing: 1) the side of the box left open (left, right, front), and 2) how far the toy was from the opening of the box (partially outside, deep inside the box). A transparent box measuring 4.5 X 4.5 X 2 inches was used. Two sides of the box were missing so the box could be placed where the left, right or front side was open, leaving no bottom, or so the top was open, leaving no back.

The infant was again seated in the mother's lap. The infant was provided with a variety of toys to determine preference and the object retrieval box so familiarization could occur. Toys were changed as necessary to keep the attention of the infant. The experimenter placed the chosen toy on the table and placed the transparent box over it for trials where the box opening was at the left, right or front. This was done so as not to cue the infant as to where the box opened. The back left and right corners were secured by the experimenter so the box could not be moved as the infant looked for the toy. As in Diamond, Prevor, Callender, and Druin (1997), the trials were presented in blocks. The

orientation of the box remained constant within each block. Trials always progressed as follows:

- 1) Top-open orientation.
  - a) Toy partially outside box.
  - b) Toy deep inside box.
- 2) Front-open orientation.
  - a) Toy partially outside box.
  - b) Toy deep inside box.
- 3) Side-open orientation.
  - a) Toy partially outside box.
  - b) Toy deep inside box.

The toy immediately inside the box opening was omitted in order to make the task more difficult. Left and right orientations were alternated over trials for side-open orientation.

The experimenter tapped, rattled or jostled the box to regain the infant's attention when necessary. If after ten seconds of search, renewed attempts failed or waned, the experimenter aided the infant by providing clues. Types of aid varied. For trials of front-open orientation, the experimenter simply slid the box back so the toy was completely visible and then slid the box forward covering the toy as the infant reached. For left and right-open orientations, the experimenter aided the infant by turning the box approximately 45 degrees so the infant could see the opening and returning the box to the original position as the infant reached, pulling the toy out of the box and sliding it back in as the infant reached, or sliding the box off of the toy and back on as the infant reached.

If one attempt at aiding the infant failed, another type of aid was tried. After 4 failures, the experimenter provided permanent aid. Here, the experimenter tilted, turned and held the box or slid the box partially off the toy until the infant retrieved the toy. This type of aid violated the purpose of the task because it avoided the detour and was counted as failing the task.

The task was repeated if the infant received either temporary or permanent aid to see if the aid could be lessened or eliminated. If permanent aid was given and the infant was successful, temporary aid was offered on the next trial and if the infant was successful, no aid was offered on the third trial. Trials were scored together as units, based on the orientation of the box, for a total score.

The task was modified slightly from the Diamond model (1997) to make it more difficult. The infants were given only ten seconds to search before they were aided. The toy immediately inside the box trial was omitted in order to make remembering the motor movement more difficult and reaching along the line of sight more likely. Thus, as the task progressed the infant had to not only remember where s/he had reached in the past but also when to repeat that motor movement and when to inhibit it and reach to the alternate side. Therefore, an infant who succeeded flawlessly would reach twice to one side (toy partially outside, toy deep inside) and then when the opening was switched to the opposite side, the infant would have to recall having succeeded by reaching along the line of sight (toy partially outside) the first trial and also to repeat that motor movement to succeed.

Scoring was done in a qualitative fashion based on the work of Bell & Fox (1992). This system focuses on side trials, which are the most challenging.

1= unable to succeed on side trials

2= unable to retrieve the toy without looking along the line of reach (used awkward hand to retrieve toy)

3= able to lean over, look along the line of reach, sit up and then reach (typically used same-side hand to reach)

4= able to retrieve the toy by feeling along the sides of the box and without having to look along the line of reach at all



*Locomotor Assessment.* Wide variability has been seen in the onset of walking among 12-month-olds. For instance, in a study by Corbetta and Bojczyk (2002), 50% of the infants were already walking at 12-months and 50% started walking after their first birthday, with walking onset ranging from 9.5 months to 13.5 months. Since wide variability in walking experience was expected in the participants, infants were not pre-qualified for the study.

So as not to bias the researcher, the parent was asked not to refer to his/her infant's walking ability during recruitment and the infant was carried or held until the locomotor assessment which was gauged at the end of each session following the guidelines used by Corbetta and Bojczyk (2002). Locomotor assessment was accomplished by having the parent coax the infant to locomote approximately 3 meters to reach the parent. Thus, infants were divided into three groups: non-walkers, novice walkers, and experienced walkers. Infants reaching the parent in any form other than walking were classified as non-walking. Infants were then divided into walking groups based on parent report of walking onset date: novice walkers with 1-7 weeks of unaided walking experience and experienced walkers with 8+ weeks of unaided walking experience. This division is based on the pattern for returning to adaptive reaching reported by Corbetta and Bojczyk (2002).

Following the locomotor assessment, the parent was interviewed to see how long their infant had been walking and the infant was placed into the appropriate locomotor group based on this report. During the interview, the parent was asked if the infant was walking unassisted prior to the session, and for each parent affirming this, how many weeks the infant had been doing so. After the parent stated a specific number of weeks,

the recruiter verified this by calculating the infant's age at onset and referencing this with a social event (i.e., "So, he was walking unassisted at Christmas?"). This interview format was similar to that used by Bell & Fox (1997) for mothers to report length of time their infant had been hands-and-knees crawling.

Three infants were reported by their parents to be walkers, but did not walk independently during the locomotor assessment. During the parent interview, it was determined that these infants had only been walking independently a few days, so they were classified as novice walkers solely according to the parent report.

*Home Experiences.* Data on home experiences were collected via parent questionnaire to determine whether use of infant walkers, Johnny-jump-ups, bouncers or saucers might enhance spatial memory task performance. Parents reported the amount of use for each apparatus as none, infrequent or frequent.

## Results

### *Hypothesis A*

It was hypothesized that infants with more walking experience would score higher on spatial memory tasks. This hypothesis was tested with Pearson correlations and one-way ANOVAs. This hypothesis was not supported, as number of days walking was not correlated with either AB ( $r(43) = .11, p = .50$ ) or OR ( $r(43) = .18, p = .26$ ). Further, when grouped according to walking experience (non-walking ( $n = 17$ ), novice ( $n = 14$ ), experienced ( $n = 12$ )), performance on the AB test was not different among groups ( $F(2, 40) = 1.14, p = .33$ ); neither was performance on the OR task ( $F(2, 40) = 2.53, p = .09$ ). Although walking group was not related to spatial memory performance, mean

performance for the groups was in the predicted direction for AB and mean performance of the walking groups was higher than the non-walking group for OR (See Table 1).

Although the 3 original walking groups did not differ on spatial memory performance, when re-grouped into non-walkers ( $n = 17$ ) and walkers ( $n = 26$ ) there was a trend for a group difference in performance on the OR task ( $F(1, 41) = 3.90, p = .06$ ), but not the AB task ( $F(1, 41) = 1.81, p = .19$ ). In addition, the means were in the predicted direction, with walkers scoring higher than non-walkers for AB and OR (See Table 2). Post-hoc examinations to examine the role of age showed that walkers were no older than non-walkers ( $F(1, 41) = .458, p = .50$ ). Post-hoc examinations also showed that OR group membership was not associated with AB group membership, although 44% of participants were in the top performance groups on both tasks ( $\chi^2(2) = 2.39, p = .30$ ).

### *Hypothesis B*

*AB.* Infants who scored higher on AB were hypothesized to show higher power values in frontal and parietal regions relative to infants who scored lower on the tasks. This hypothesis was tested with repeated measures MANOVA. To examine relations between EEG power values and AB performance, infants were divided into groups based on AB performance (Bell & Fox, 1997). Although Diamond (1985) reported that 12-month-olds in a longitudinal sample could tolerate a 10-second delay, this has not been replicated. Matthew, Ellis and Nelson (1996) reported a 5-second delay for their longitudinal sample (7 to 15 months) and Bell and Fox (1992) reported tolerance for a delay of 7.5 seconds in their longitudinal sample (7 to 12 months). Amount of delay tolerated on AB is thought to show developmental progression (Bell & Fox, 1992;

Matthew, Ellis & Nelson, 1996). This study was not longitudinal and only a 4-sec delay was found for the sample. Thus, infants who succeeded with either no delay or a 2-second delay were grouped together and classified as low performers ( $n = 13$ ) and infants who succeeded at a 4-second delay or higher were grouped together and classified as high performers ( $n = 30$ ). A repeated measures MANOVA was used because it is robust to unequal group sizes. Within subject factors were region (i.e., frontal pole, frontal, central, parietal) and hemisphere (i.e., left or right) and between-subjects factor of AB performance group (i.e., low or high). The dependent variable was EEG power in the 6-9 Hz bandwidth.

There was a main effect for region (Wilks' Lambda = .13,  $F(3, 39) = 84.33$ ,  $p < .001$ ). There was no main effect for hemisphere (Wilks' Lambda = .99,  $F(1, 41) = .28$ ,  $p = .60$ ). There were no two-way interactions for Region x Group ( $F(3, 39) = .30$ ,  $p = .83$ ), Hemisphere x Group ( $F(1, 41) = .86$ ,  $p = .36$ ), or Region x Hemisphere ( $F(3, 39) = .71$ ,  $p = .55$ ). There was also no three-way interaction for Region x Hemisphere x Group ( $F(3, 39) = 1.59$ ,  $p = .21$ ).

To explore the region main effect, a repeated measures MANOVA was run separately for each region with hemisphere as the within subjects factor and AB group as the between-subjects factor. The dependent variable was EEG power in the 6-9 Hz bandwidth. For the frontal pole region, there was no main effect for hemisphere ( $F(1, 41) = .62$ ,  $p = .38$ ) or AB group ( $F(1, 41) = .52$ ,  $p = .48$ ). There was also no hemisphere x AB group interaction ( $F(1, 41) = .114$ ,  $p = .74$ ). (See Figure 1.)

For the medial frontal region, there was no main effect for hemisphere ( $F(1, 41) = .79, p = .44$ ) or AB group ( $F(1, 41) = .70, p = .41$ ). There was also no hemisphere x AB group interaction ( $F(1, 41) = 1.14, p = .29$ ). (See Figure 2.)

For the central region, there was no main effect for hemisphere ( $F(1, 41) = .01, p = .92$ ) or AB group ( $F(1, 41) = .02, p = .88$ ). There was, however, a hemisphere x AB group interaction ( $F(1, 41) = 4.27, p = .05$ ). The high AB group showed higher power in the right hemisphere (C4) relative to the left hemisphere (C3),  $F(1, 29) = 3.85, p = .06$ . (See Figure 3).

For the parietal region, there was no main effect for hemisphere ( $F(1, 41) = .95, p = .34$ ) or AB group ( $F(1, 41) = .21, p = .65$ ). There was also no hemisphere x AB group interaction ( $F(1, 41) = .82, p = .37$ ). (See Figure 4.)

*OR.* Infants who scored higher on OR were also hypothesized to show higher power values in frontal and parietal regions relative to infants who scored lower on the task. This hypothesis was tested using repeated measures MANOVA. To examine relations between EEG power values and OR performance, infants were divided into three groups based on OR performance (Bell & Fox, 1992). Infants who engaged in a strategy where they leaned and looked while retrieving the toy were grouped together and classified as low performers ( $n = 5$ ). Infants who looked along the line of sight and then sat up and reached were grouped together and classified as intermediate performers ( $n = 12$ ). Finally, infants who did not need to lean and look to retrieve the toy were grouped together and classified as high performers ( $n = 26$ ). A repeated measures MANOVA was used with within subjects factors of region (i.e., frontal pole, frontal, central, parietal) and hemisphere (i.e., left or right) and between-subjects factor of OR performance group

(i.e., low, intermediate or high). The dependent variable was EEG power in the 6-9 Hz bandwidth.

There was a main effect for region (Wilks' Lambda = .17,  $F(3, 38) = 84.33$ ,  $p < .001$ ). There was no main effect for hemisphere (Wilks' Lambda = .96,  $F(1, 41) = .28$ ,  $p = .19$ ). There were no two-way interactions for Region x Group ( $F(6, 78) = 1.26$ ,  $p = .29$ ), Hemisphere x Group ( $F(2, 40) = .96$ ,  $p = .39$ ), or Region x Hemisphere ( $F(3, 38) = .94$ ,  $p = .43$ ). There was a trend for a three-way interaction for Region x Hemisphere x Group ( $F(6, 78) = 2.08$ ,  $p = .066$ ). There was also a trend for a performance group main effect ( $F(2, 40) = 2.74$ ,  $p = .077$ ).

In order to explore the three-way trend among region, hemisphere and performance group, separate MANOVAs were performed on the EEG power values for each region. This analysis also allowed for the interpretation of the trend for performance group. For these MANOVAs, hemisphere (i.e., left or right) was the within subjects factor and OR performance group was the between-subjects factor. EEG power in the 6-9 Hz bandwidth was the dependent variable.

For the frontal pole region, there were no main effects for performance group ( $F(2, 40) = .91$ ,  $p = .41$ ) or hemisphere ( $F(1, 40) = .02$ ,  $p = .90$ ). There was also no Hemisphere x Group interaction ( $F(2, 40) = .55$ ,  $p = .58$ ). (See Figure 5.)

For the medial frontal region, there was no main effect for performance group ( $F(2, 40) = 2.15$ ,  $p = .13$ ). There was a trend for a main effect for hemisphere ( $F(1, 40) = 3.87$ ,  $p = .056$ ). This effect was superseded by a trend for a two-way interaction between Hemisphere x Group ( $F(2, 40) = 2.76$ ,  $p = .075$ ). The low OR performance group showed asymmetry with lower power values in left frontal (F3) than right frontal (F4),  $F$

(1, 4) = 11.98,  $p = .03$  (see Figure 1). No asymmetry was seen in intermediate and high OR performance groups (all  $p$ 's > .30). The high OR group showed higher power values in left medial frontal than the low OR group ( $t(29) = 2.341, p = .03$ ). (See Figure 6.)

There was no main effect for hemisphere in the central region ( $F(1, 40) = .01, p = .91$ ). There was a main effect for OR performance group ( $F(2, 40) = 4.42, p = .02$ ). There was no two-way interaction for Hemisphere x OR Group ( $F(2, 40) = .99, p = .38$ ). Because there was no effect for hemisphere, power values were combined to provide one value for the central region. Infants in the high OR group had higher power values than infants in the low OR group ( $t(29) = 2.26, p = .03$ ) and infants in the intermediate OR group ( $t(36) = 2.18, p = .04$ ). (See Figure 7.)

There were no main effects for OR group ( $F(2, 40) = 2.16, p = .13$ ) or hemisphere ( $F(1, 40) = 1.21, p = .28$ ) in the parietal region. However, there was an interaction between Hemisphere x OR Group ( $F(2, 40) = 4.03, p = .03$ ). There was a trend in the intermediate OR group for higher power values in the right parietal region (P4) than in left parietal (P3),  $F(1, 11) = 4.29, p = .06$ . There was also a trend with the high OR group showing higher power in left parietal than both the low OR group ( $t(29) = 1.86, p = .07$ ) and intermediate OR group ( $t(36) = 1.94, p = .06$ ). (See Figure 8.)

### *Hypothesis C*

It was hypothesized that EEG power values would vary with the amount of walking experience and specifically that novice walkers would show the highest level of EEG power, non-walkers would show the lowest level of power and experienced walkers would fall in between the other two. A repeated measures MANOVA was used to test this hypothesis with walkgroup as the between-subjects factor and region and hemisphere

as the within subjects factors. The dependent variable was EEG power in the 6-9 Hz bandwidth. There was a main effect for region ( $F(3, 38) = 99.91, p < .01$ ). There were no main effects for walkgroup ( $F(2, 40) = 1.84, p = .17$ ) or hemisphere ( $F(1, 40) = .748, p = .39$ ). There were no interactions for Region x Walkgroup ( $F(6, 78) = 1.20, p = .31$ ), Hemisphere x Walkgroup ( $F(2, 40) = .20, p = .82$ ), or Region x Hemisphere ( $F(3, 38) = .32, p = .81$ ). There was also no three-way interaction for Region x Hemisphere x Walkgroup ( $F(6, 78) = 1.52, p = .18$ ). Thus, exploratory analyses examined each region separately.

For the frontal pole region, there were no main effects for walkgroup ( $F(2, 40) = 1.09, p = .35$ ) or hemisphere ( $F(1, 40) = .15, p = .70$ ). There was also no interaction for Hemisphere x Walkgroup ( $F(2, 40) = .35, p = .71$ ). (See Figure 9.)

For the medial frontal region, there were no main effects for walkgroup ( $F(2, 40) = 1.66, p = .20$ ) or hemisphere ( $F(1, 40) = .43, p = .52$ ). There was also no interaction for Hemisphere x Walkgroup ( $F(2, 40) = .65, p = .53$ ). (See Figure 10.)

For the central region, there was a trend for a main effect for walkgroup ( $F(2, 40) = 2.70, p = .08$ ). There was no main effect for hemisphere ( $F(1, 40) = .42, p = .52$ ), but there was a two-way interaction for Hemisphere x Walkgroup,  $F(2, 40) = 3.29, p = .05$ . Novice walkers showed higher EEG power in the right hemisphere (C4) than non-walkers ( $t(29) = 2.13, p = .04$ ) and experienced walkers ( $t(24) = 2.68, p = .01$ ). Novice walkers also showed higher power values in the right hemisphere (C4) relative to their own left hemisphere (C3),  $F(1, 13) = 8.47, p = .01$ . (See Figure 11.)



For the parietal region, there were no main effects for walkgroup ( $F(2, 40) = .98$ ,  $p = .38$ ) or hemisphere ( $F(1, 40) = .39$ ,  $p = .53$ ). There was also no interaction for Hemisphere x Walkgroup ( $F(2, 40) = .95$ ,  $p = .40$ ). (See Figure 12.)

#### *Hypothesis D*

The final hypothesis was exploratory and predicted an interaction between walking experience, EEG power values, and spatial memory. This was explored using a repeated measures MANOVA with AB group, OR group, and walkgroup as between-subjects factors and region and hemisphere as within subjects factors. There was no significant interaction for Region x Hemisphere x Walkgroup x OR group x AB group ( $F(3, 37) = .49$ ,  $p = .69$ ).

#### *Home Experience*

To determine whether infants with more experience using walkers, bouncers, jumpers and pushcarts would perform higher on spatial memory tasks was tested using a series of one-way ANOVA's. Experiential groups were divided into three categories: no experience, infrequent experience, and frequent experience, based on parent perception. There was no difference among Johnny jump-up experience groups on AB performance ( $F(2, 38) = .07$ ,  $p = .93$ ) or OR performance ( $F(2, 38) = .61$ ,  $p = .55$ ).

There was no difference among bouncer experience groups on AB performance ( $F(2, 38) = .73$ ,  $p = .49$ ) or OR performance ( $F(2, 38) = .15$ ,  $p = .86$ ). There was no difference among infant walker experience groups on AB performance ( $F(2, 38) = .30$ ,  $p = .75$ ) or OR performance ( $F(2, 38) = .39$ ,  $p = .68$ ). There was no difference among pushcart experience groups on AB performance ( $F(2, 38) = .69$ ,  $p = .51$ ) or OR performance ( $F(2, 38) = 1.28$ ,  $p = .29$ ).

## Discussion

### *Walking Experience and Brain Electrical Activity*

Greenough's model of experience-expectant and experience-dependent development was used to examine EEG power among three groups of infants varying in amount of walking experience. Groups included non-walkers, novice walkers with 1-7 weeks of experience, and experienced walkers with 8+ weeks of experience. There were no regional or hemispheric group differences for the walking experience groups. However, following some exploratory analyses, it was discovered that novice walkers displayed higher EEG power in the central region than both non-walkers and walkers. This finding may be spurious as there was no overarching group interaction with either region or hemisphere. Interestingly, Bell and Fox (1996, 1997) found that novice crawlers displayed greater EEG activity than prelocomotor or experienced crawlers, suggesting that the anticipation and the onset of hands-and-knees crawling contributed to an overproduction of synapses in specific regions. Pruning of those synapses were speculated to be the source of the decreased power in experienced hands-and-knees crawlers. Bell and Fox (1996, 1997) did not record at the central sites, but it makes sense that the effect would be there because this is the supplementary motor area, which helps control voluntary motor movements (Babiloni, Carducci, delGratta, Demartin, Romani, Babiloni, & Rossini, 2003).

Further exploratory analyses suggested novice walkers displayed greater right central (C4) power relative to their own left central (C3) power. This again may be spurious and in need of replication, but would support the literature that suggests the right hemisphere is dominant in human infants, with functions initially localized on the right

and later shifting to the left (Chiron, et al, 1997). In addition, focusing on hands-and-knees crawling as the form of self-locomotion, Bell and Fox (1996) found greater EEG activity for right hemisphere than left.

#### *Walking Experience and Spatial Memory Performance*

There was a trend for locomotor status to be related to spatial memory performance on OR. Performance was enhanced for infants who had walking experience. There was no advantage found for amount of walking experience on OR performance. Similarly, Bell & Fox (1997) found that any amount of hands-and-knees crawling experience was related to higher AB performance relative to no hands-and-knees crawling experience. However, AB was not related to walking status in this study. AB requires the infant search for a toy in one of two identical hiding sites, whereas OR requires the infant to manipulate a transparent box to locate a toy. The OR task may be more relevant to the type of obstacles that infants face when traversing their everyday environments.

Past work has used the visual cliff (Gibson & Walk, 1960) to show that self-produced in the form of hands-and-knees crawling promotes wariness of visual depth (Bertenthal, Campos, & Barrett, 1984). The infant is presented with a visual cliff that can be varied in spatial extent and has shallow and deep sides. In some designs, a transparent cover is placed across the cliff so that the infant could safely cross if s/he chose to do so. Further evidence has shown that more experienced crawlers show increased heart rate and latency to cross the cliff to their mothers relative to inexperienced crawlers (Campos, Bertenthal, & Kermoian, 1992). Titzer (1997) used the visual cliff paradigm with two groups of infants to show that infants who had more experience manipulating transparent

boxes to retrieve a toy crossed the cliff more readily than their counterparts in the control group. Thus, it may be that quality of locomotor experience (more engagement with transparent objects) is most important for succeeding when the integration of transparency and spatial extent are necessary for task success.

In a study examining perceptual-motor integration, it was found that infants did not vary on barrier crossing when transparency was an issue at 12-months, but did vary when transparency and spatial extent were combined, with infants more likely to cross the barrier with a transparent wall in between than with a transparent pole (Schmuckler, 1996). Infants with more walking experience were more likely to cross the barriers than novice walkers and crawlers (Schmuckler, 1996). These findings suggest that some infants are aware of task relevant versus irrelevant information and can use that information for task success (Gibson, 1969). Together these studies suggest that discrimination of task relevant versus irrelevant information required by the OR task, due to the transparency of the box paired with the spatial demands of the task, may have allowed for differentiation among OR groups. The spatial memory required by AB may be enough to allow an advantage for hands-and-knees crawlers (who are just beginning to manipulate the environment) relative to non-crawlers. However, OR may help distinguish between walkers and non-walkers (who still have experience manipulating the environment due to crawling) because it requires not only spatial memory like AB, but the integration of task-relevant information as well. It follows that walkers may have had more experience with transparent objects and spatial demands which combined across forms of locomotion allowed for them to perform more successfully than non-walkers.

This argument falls in line with others that argue for selective effects of experience (Schmuckler, 1996; Ulrich et al, 1990).

*Brain Electrical Activity and Spatial Memory Task Performance*

The results here failed to support evidence for regional or hemispheric EEG differences for infants on AB performance. This may be due to the fact that the task was ended when the experimenter was confident a search error had been made, which was typically following one reversal trial. Other studies report that two of three errors are necessary on a reversal trial at a given delay to determine the AB score (Bell & Fox, 1992, 1996, 1997; Diamond, et al, 1997; Matthews, et al, 1996).

The data here suggest there may be regional and hemispheric differences in OR performance among 12-month-olds. Infants in the high OR group showed a trend toward higher power in the left medial frontal than the low group. Infants in the high OR group had higher power values in the central region, with a trend for higher power values in the left parietal region relative to that of both the low and intermediate groups. Past studies have recorded from all sites (frontal pole, medial frontal, lateral frontal, central, temporal, parietal and occipital) and have shown successful spatial search to be associated with frontal (Diamond, 1990a, 1990b; Diamond, Prevor, Callender & Druin, 1997), parietal and occipital brain electrical activity (Bell, 2001; Bell & Fox, 1992, 1997; Bell & Wolfe, 2002). Specific hypotheses were not made for the temporal or central regions. However, the central sites were recorded because Diamond (1990b) has suggested the supplementary motor area is required for successful OR performance. The trends evidenced in the current study, although in need of replication, support the hypothesis that higher power values in the frontal and parietal regions would be seen in infants

scoring higher on spatial memory tasks. This was not hypothesized for the central region, but supports the hypothesis that infant brain activity is not fully localized (Bell & Wolfe, 2002). The central region finding also supports Diamond's work which suggests that the supplementary motor area is necessary for successful OR task performance as it underlies voluntary motor control which is more effortful in the OR task because the infant has to detour a barrier (Diamond, 1990b).

The low OR group showed higher power in the right medial frontal region than the left, whereas there was a trend for the intermediate OR group to show higher power values in the right parietal region than the left. The right hemisphere is known to show predominance early in development (Chiron, et al, 1997) and has distinguished between high and low performance on the AB task (Bell & Fox, 1997). Here, the finding that infants high on OR performance showed higher left hemisphere power than right hemisphere relative to the lower groups in the medial frontal and parietal regions may mean that these infants have already shifted away from right hemisphere dominance. Because hemispheric asymmetry is speculated to change sometime in early childhood between 1-3 years and varies based on structure and function, it may be that we are seeing the shift in this group of infants (Chiron, et al, 1997).

#### *Walking Experience, Brain Electrical Activity and Spatial Memory Performance*

Finally, there was no interaction among spatial memory performance, walking experience and brain electrical activity. It was hypothesized that walking infants would perform better on spatial memory tasks as evidenced by EEG. This was an exploratory hypothesis which replicated the finding of Bell and Fox (1997) that there was 3-way no interaction among hands-and-knees crawling, spatial memory performance and EEG

power values. They found that individual differences in hands-and-knees crawling and frontal and occipital EEG power were separately related to AB performance. The current study found that individual differences in walking experience was related to OR performance. There was also a trend for individual differences in parietal, central and frontal EEG power values to be related to OR performance. Therefore, OR performance was more closely related to both walking experience and brain electrical activity than AB.

Past work investigating the relation of the classic AB task to brain electrical activity has shown differences in baseline EEG with higher task performance being associated with greater EEG power (Bell & Fox, 1992, 1997). A longitudinal examination of classic AB task performance from 7-12 months found increasing performance on AB was related to differences in baseline EEG activity (Bell & Fox, 1992). It may be that baseline recordings at 12-months of age are not sufficient to differentiate between high and low performance on the AB task. The argument in past studies for using baseline EEG data is based on a maturational argument, suggesting that the maturation of the frontal cortex supports task improvement (Bell & Fox, 1992; Diamond & Goldman-Rakic, 1989; Diamond, Zola-Morgan, & Squire, 1989). This study differs in trying to also examine individual experiences relevant to task success (also see Bell & Fox, 1997).

### *Limitations*

Twelve months is close to the maximum age for using OR and AB, which were used to assess spatial memory in this study. This paired with having only baseline EEG data for the participants may be one reason for the lack of strong support for the

hypotheses. Task-related EEG data may be more likely to reveal individual differences in spatial memory in relation to brain electrical activity. Recent work has shown differences in baseline to task EEG with a looking version of the AB task (Bell, 2001, 2002). However, this was not feasible for this study, as gross motor movements would not allow for the task-related recordings which may be necessary at this age to see differences for both OR and the classic manual search AB task. In fact, the differences found in object retrieval were based on qualitative scoring (Bell & Fox, 1992) rather than quantitative scoring (Diamond, et al, 1997). Quantitative scoring, which would be more in line with a maturational argument, showed no differences in OR groups. With qualitative scoring, there was a trend for a hemisphere x OR group interaction in the medial frontal region where the high performance OR group showed greater left medial frontal power than the low OR group. Perhaps, the differences are experience-dependent so that task-related EEG would distinguish between high and low performance groups.

#### *Summary and Conclusions*

Overall weak support was found for the hypotheses in this study. Yet, the trends suggest there may be potential support for the Greenough model and for the role of walking experience and brain electrical activity to be uniquely related to spatial memory task performance. Briefly, the findings for this study suggest that the OR task may be more relevant than AB for tapping spatial memory in this age group. They also suggest, if the finding is not spurious, that there were individual differences in central and parietal EEG power values depending on OR performance. The finding, which again may be spurious, that there was higher power in the central region only for novice walkers relative to non-walkers and experienced walkers may support localization since this



group effect was seen across several regions with hands-and-knees crawlers (Bell & Fox, 1996, 1997). Despite the limitations of the study, it helps build on research focusing on individual differences in spatial memory performance in relation to locomotor experience and EEG power.

Replications of the trends in this study are needed before we can embrace walking experience as being intricately tied to spatial memory in the manner hands-and-knees crawling experience has been. Tasks should be chosen which integrate spatial demands and transparency since these factors stood out here and in past research as possible determinants of task success. Using the visual cliff may also provide insight because it taps these abilities. EEG and heart rate data could be collected while the infant is lowered over the cliff and prior to allowing the mother to coax the infant across the transparent surface. This would allow for baseline to task comparison for physiological data of infants with varying amounts of self-locomotion experience. Perhaps, if the infant were seated in a high chair instead of on the mother's lap, EEG and HR could also be collected during the object retrieval task. Also, shortening the delay from 10 seconds to 5 seconds before assistance is provided on the OR task should provide more variability in the sample. Diamond (1990b) has reported an average of a 5 second delay for 12-month-olds in a longitudinal sample on this task. Infants could also be tested on their ability to manipulate various opaque and transparent containers to retrieve a toy. This would provide an index of spatial understanding while still keeping the transparency component. Follow-ups with the parent to determine the date of walking onset for the non-walking sample would allow for better testing of the Greenough model through addition of a fourth group, the non-walkers who were in the anticipation stage during

their visit to the lab. Having more balanced groups will help increase power, which was an issue in the current study and is a further reason that the trends should be investigated to ensure they were not chance findings. Requesting information regarding the quality of self-locomotion experiences incurred by the infant via a parent questionnaire may also aid in further understanding the relation of walking experience to spatial search performance. These modifications of the present study would allow for a more thorough examination of the relation of brain electrical activity and walking experience to spatial memory task performance at 12-months of age.

## References

- Acredolo, L. (1978). Development of spatial orientation in infancy. *Developmental Psychology, 14*, 224-234.
- Acredolo, L. (1990). Individual differences in spatial displacement. In J. Colombo & J. Fagen (Eds.), *Individual differences in infancy: Reliability, stability, prediction* (pp. 321-340). Hillsdale, NJ: Erlbaum.
- Acredolo, L., Adams, A., & Goodwyn S.W. (1984). the role of self-produced movement and visual tracking in infant spatial orientation. *Journal of Experimental Child Psychology, 38*, 312-327.
- Acredolo, L. & Evans, D. (1980). Developmental changes in the effects of landmarks on infant spatial behavior. *Developmental Psychology, 16*, 312-318.
- Adolph, Karen, E. (1997). Learning in the development of infant locomotion. *Monographs of the Society for Research in Child Development, 62*(3), 1-140.
- Adolph, Karen, E. (2000). Specificity of learning: Why infants fall over a veritable cliff. *Psychological Science, 11*(4), 290-295.
- Babiloni, C., Carducci, F., delGratta, C., Demartin, M., Romani, G.L., Babiloni, F. & Rossini, P.M. (2003). Hemispherical asymmetry in human SMA during voluntary simple unilateral movements: An fMRI study. *Cortex, 39*, 293-305.
- Bai, D.L. & Bertenthal, B.I. (1992). Locomotor experience and the development of spatial search skills. *Child Development, 63*, 215-226.

- Bell, M.A. (2001). Brain Electrical Activity associated with cognitive processing during a looking version of the A-not-B task. *Infancy*, 2, 311-330.
- Bell, M.A. (2002). Power changes in infant EEG frequency bands during a spatial working memory task. *Psychophysiology*, 39, 450-458.
- Bell, M.A. & Adams, S.E. (1999). Comparable performance on looking and reaching versions of the A-not-B task at 8 months of age. *Infant Behavior and Development*, 22, 221-235.
- Bell, M.A. & Fox, N.A. (1992). The relations between frontal brain electrical activity and cognitive development during infancy. *Child Development*, 63, 1142-1163.
- Bell, M.A. & Fox, N.A. (1996). Crawling experience is related to changes in cortical organization during infancy: Evidence from EEG coherence. *Developmental Psychobiology*, 29, 551-561.
- Bell, M.A. & Fox, N.A. (1997). Individual differences between object permanence at 8 months: Locomotor experience and brain electrical activity. *Developmental Psychobiology*, 31, 287-297.
- Bell, M.A. & Wolfe, C.D. (2002). 6-9 HZ EEG synchronization during cognitive processing at 8 months and 4 years. *Psychophysiology*, 39, S20.
- Benson, J.B. (1990). The significance and development of crawling in human infancy. In J.E. Clark & J.H. Humphrey (Eds.), *Advances in motor development research* (Vol. 3, pp.91-142). New York: AMS.
- Bertenthal, B.I., Campos, J.J., & Barrett, K. (1984). Self-produced locomotion: An

- organizer of emotional, cognitive, and social development in infancy. In R. Emde & R. Harmon (Eds.), *Continuities and discontinuities in development* (pp. 174-210). New York: Plenum.
- Bertenthal, B.I., Campos, J.J., & Kermoian, R. (1994). An epigenetic perspective on the development of self-produced locomotion and its consequences. *Current directions in Psychological Science*, 3, 140-145.
- Black, J.E. & Greenough, W.T. (1986). Induction of pattern in neural structure by experience: Implications for cognitive development. In M.E. Lamb, A.L. Brown, & B. Rogott (Eds.), *Advances in developmental psychology*, Vol. 4, (pp. 1-50). Hillsdale, NJ: Erlbaum.
- Bruer, J.T. & Greenough, W.T. (2001). The subtle science of how experience affects the brain. In D.B. Bailey & J.T. Breur (Eds.), *Critical thinking about critical periods* (pp. 209-232). Baltimore: Brookes Publishing.
- Campos, J.J., Bertenthal, B.I., & Kermoian, R. (1992). Early experience and emotional development: The emergence of wariness of heights. *Psychological Science*, 3, 61-64.
- Carlson, N.R. (Ed.). (1997). *Physiology of behavior* (7<sup>th</sup> ed.). Boston: Allyn and Bacon.
- Chiron, C., Jambaque, I., Nabbout, R., Lounes, R., Syrota, A. & Dulac, O. (1997). The right brain hemisphere is dominant in human infants. *Brain*, 120, 1057-1065.

Corbetta, D. & Bojczyk, K.E. (2002). Infants return to two-handed reaching when they are learning to walk. *Journal of Motor Behavior*, 34(1), 83-95.

Diamond, A. (1985). Development of the ability of to use recall to guide action, as indicated by infants' performance on AB. *Child Development*, 56, 868-883.

Diamond, A. (1990a). The development and neural bases of memory functions as indexed by the AB and delayed response tasks in human infant and infant monkeys. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions* (pp. 267-317). New York: New York Academy of Sciences Press.

Diamond, A. (1990b). Developmental time course in human infants and infant monkeys, and the neural bases, of inhibitory control in reaching. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions* (pp. 267-317). New York: New York Academy of Sciences Press.

Diamond, A. & Goldman-Rakic, P.S. (1986). Comparative development in human infants and infant rhesus monkeys of cognitive functions that depend on prefrontal cortex. *Society for Neuroscience Abstracts*, 12, 742.

Diamond, A. & Goldman-Rakic, P.S. (1989). Comparison of human infants and rhesus monkeys on Piaget's AB task: Evidence for dependence on dorsolateral prefrontal cortex. *Experimental Brain Research*, 74, 24-40.

- Diamond, A., Prevor, M.B., Callender, G., & Druin, D.P. (1997). Prefrontal cortex deficits in children treated early and continuously for PKU. *Monographs of the Society for Research in Child Development*, 62 (4, Serial No. 252).
- Diamond, A., Zola-Morgan, S., & Squire, L.R. (1989). Successful performance by monkeys with lesions of the hippocampal formation AB and object retrieval, two tasks that mark developmental changes in human infants. *Behavioral Neuroscience*, 103, 526-537.
- Gibson, E.J., & Walk, R.D. (1960). The "visual cliff." *Scientific American*, 202, 64-71.
- Gibson, E.J. (1969). *Principles of perceptual learning and development*. Englewood Cliffs, NJ: Prentice-Hall.
- Greenough, W.T., & Black, J.E. (1992). Induction of brain structure by experience: Substrates for cognitive development. In M.R. Gunnar & C.A. Nelson (Eds.), *Developmental behavioral neuroscience: The Minnesota Symposia on Child Psychology, Vol. 24* (pp. 155-200). Hillsdale, NJ: Erlbaum.
- Greenough, W.T., Black, J.E., & Wallace, C. (1987). Effects of experience on brain development. *Child Development*, 58, 540-559.
- Kermoian, R. & Campos, J.J. (1988). Locomotor experience: A facilitator of spatial cognitive development. *Child Development*, 59, 908-917.
- Matthews, A., Ellis, A., & Nelson, C.A. (1996). Development of AB, recall memory,

- transparent barrier detour, and means-end task performance in pre-term and full-term infants. *Child Development*, 67, 2658-2676.
- Nunez, P.L. (1981). *Electric fields of the brain: The neurophysics of EEG*. New York: Oxford University Press.
- Pivik, R.T., Broughton, R.J., Coppola, R., Davidson, R.J., Fox, N.A., & Nuwer, M.R. (1993). Guidelines for the recording and quantitative analysis of electroencephalographic activity in research contexts. *Psychophysiology*, 30, 547-558.
- Rowe, D.L., Rennie, C.A., Robinson, P.J., & Gordon, E. (2000). Dynamical structures on the edge of chaos in EEG modeling. Talk presented at the Tenth Annual International Conference of the Society for Chaos Theory in Psychology and Life Sciences: PA.
- Schmuckler, M.A. (1996). Development of visually guided locomotion: Barrier crossing by toddlers. *Ecological Psychology*, 8(3), 209-236.
- Thatcher, R.W. (1994). Cyclic cortical reorganization: Origins of human cognitive development. In G. Dawson & K.W. Fischer (Eds.). *Human behavior and the developing brain* (pp. 232-266). New York: Guilford.
- Thatcher, R.W., Krause, P.J., & Hrybyk, M. (1986). Cortico-cortical associations and EEG coherence: A two-compartmental model. *Electroencephalography and Clinical Neurophysiology*, 64, 123-143.



- Titzer, R. C. (1997). Infants' understanding of transparency: A reinterpretation of studies using the object retrieval task and visual cliff. *Dissertation Abstracts International: Section B: the Sciences & Engineering*, 58(3-B), 1570. US: Univ Microfilms International.
- Ulrich, B.D, Thelen, E., & Niles, D. (1990). Perceptual determinants of action: Stair climbing choices of infants and toddlers. In J.E. Clark & J.H. Humphrey (Eds.), *Advances in motor development research* (Vol. 3, pp. 1-15). New York: AMS.
- Zelazo, Phillip, R. (1983). The development of walking: New findings and old assumptions. *Journal of Motor Behavior*, 15(2), 99-137.

Table 1

*Means and Standard Errors for Spatial Memory Task Performance by Walk Group*

Walk Group	<u>Spatial Memory Task</u>			
	AB		OR	
	Mean	SE	Mean	SE
Non-walk (n = 17)	5.76	.28	3.24	.20
Novice (n = 14)	6.14	.38	3.79	.11
Experienced (n = 12)	6.50	.40	3.50	.19

Table 2

*Means and Standard Errors for Spatial Memory Task Performance by Walk Group*

Walk Group	<u>Spatial Memory Task</u>			
	AB		OR	
	Mean	SE	Mean	SE
Non-walkers (n = 17)	5.76	.28	3.24	.20
Walkers (n = 26)	6.31	.27	3.65	.11

Figure 1. EEG power values (ln 6-9 Hz) from frontal pole (F1, F2) scalp locations for low and high AB groups.

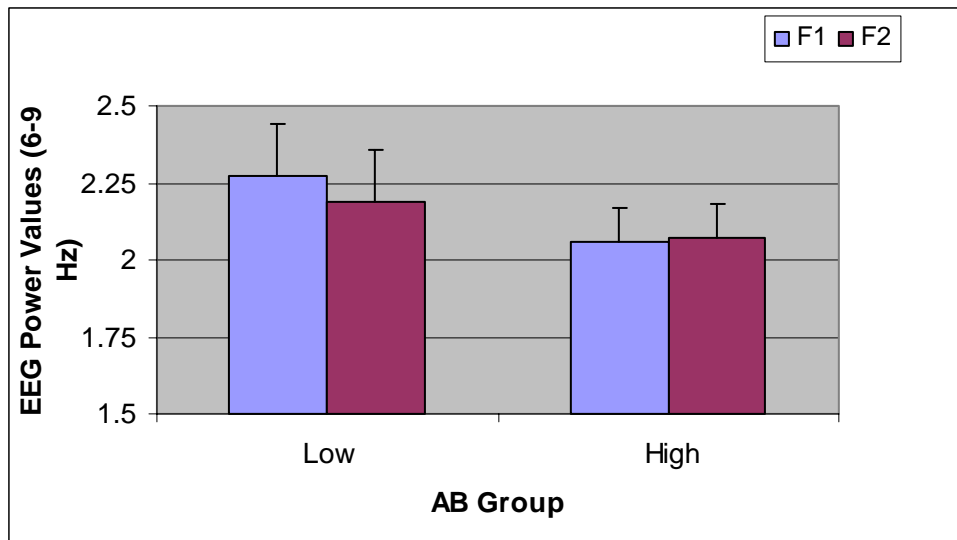


Figure 2. EEG power values (ln 6-9 Hz) from medial frontal (F3, F4) scalp locations for low and high AB groups.

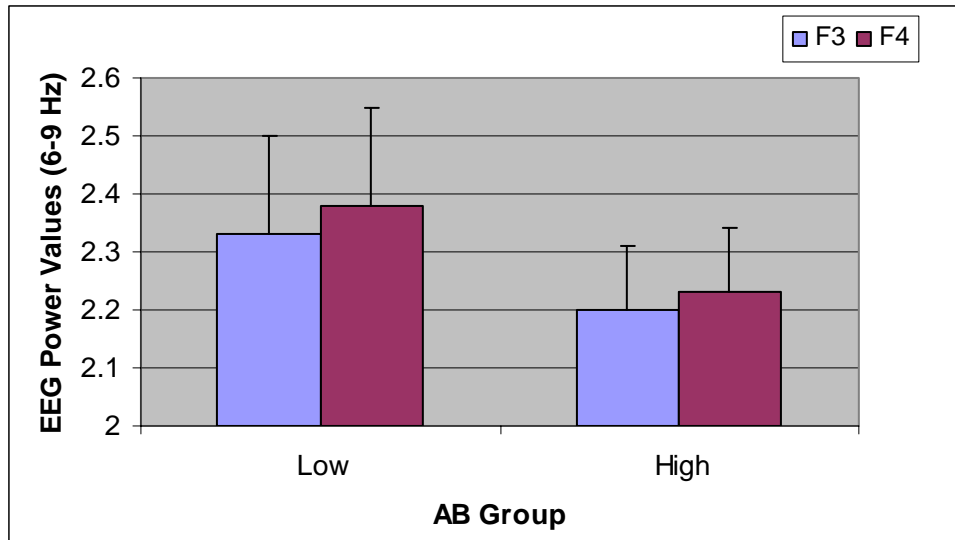


Figure 3. EEG power values (ln 6-9 Hz) from central (C3, C4) scalp locations for low and high AB groups.

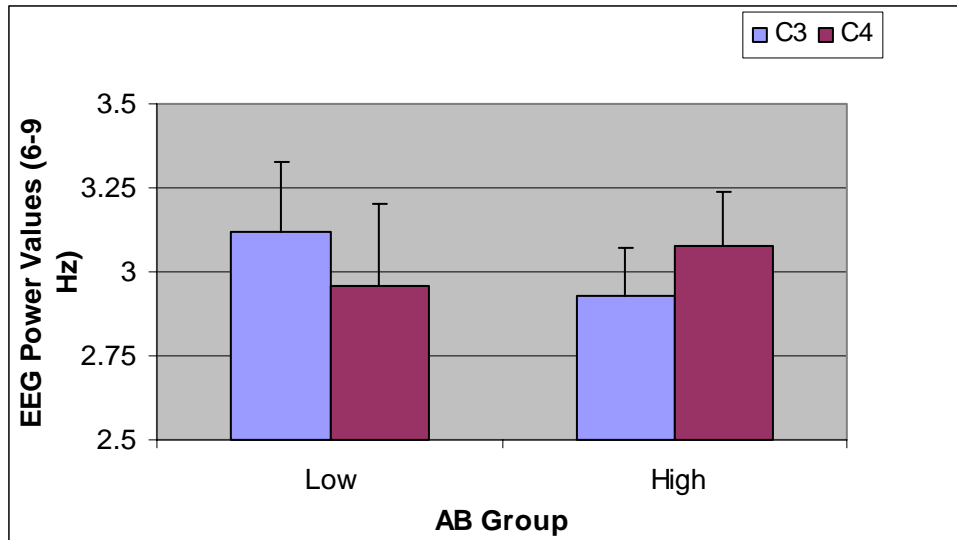


Figure 4. EEG power values (ln 6-9 Hz) from parietal (P3, P4) scalp locations for low and high AB groups.

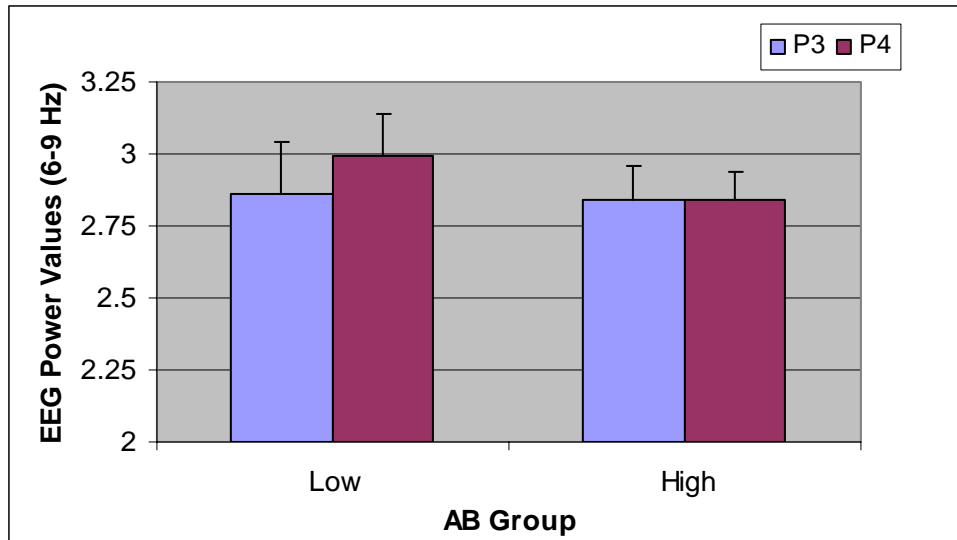


Figure 5. EEG power values (ln 6-9 Hz) from frontal pole (F1, F2) scalp locations for low, intermediate and high OR groups.

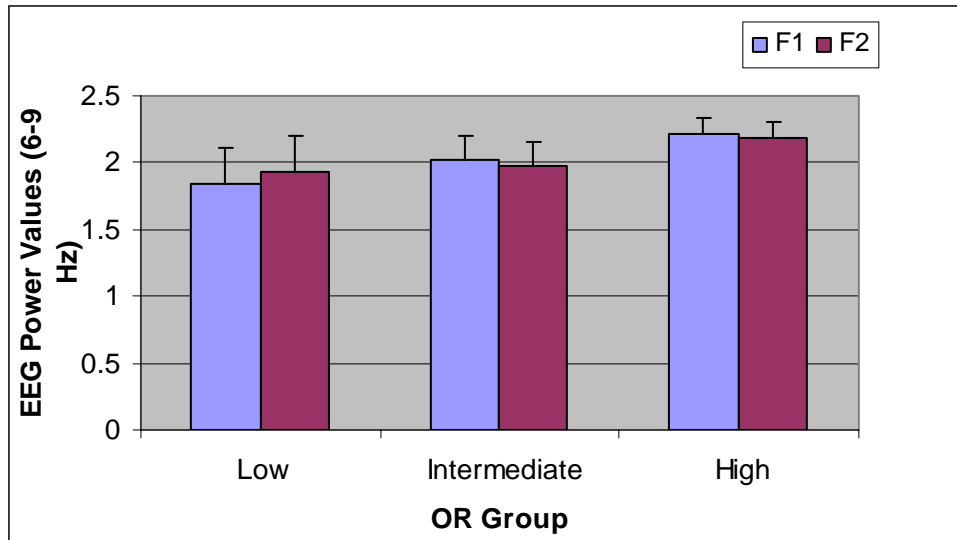




Figure 6. EEG power values (ln 6-9 Hz) from medial frontal (F3, F4) scalp locations for low, intermediate and high OR groups.

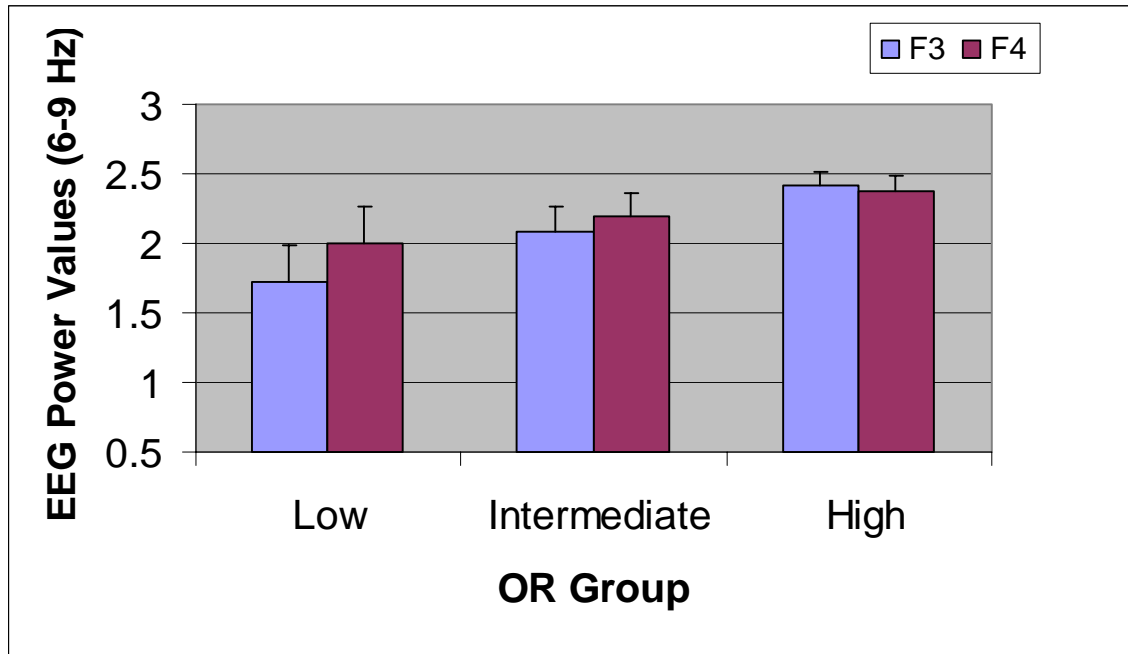


Figure 7. EEG power values (ln 6-9 Hz) from central (C3, C4) scalp locations for low, intermediate and high OR groups.

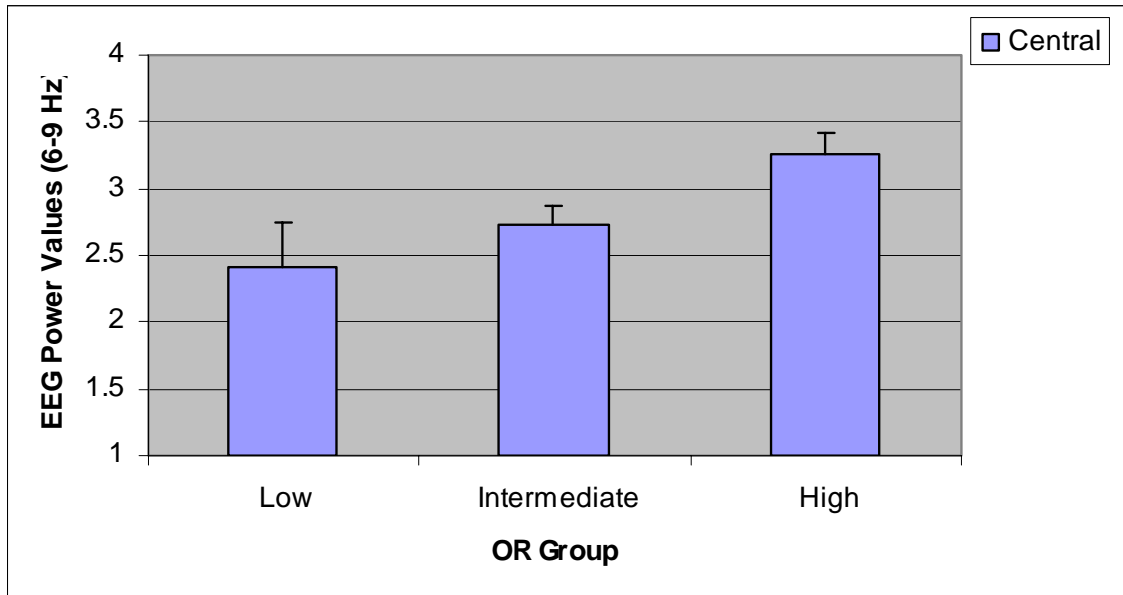


Figure 8. EEG power values (ln 6-9 Hz) from parietal (P3, P4) scalp locations for low, intermediate and high OR groups.

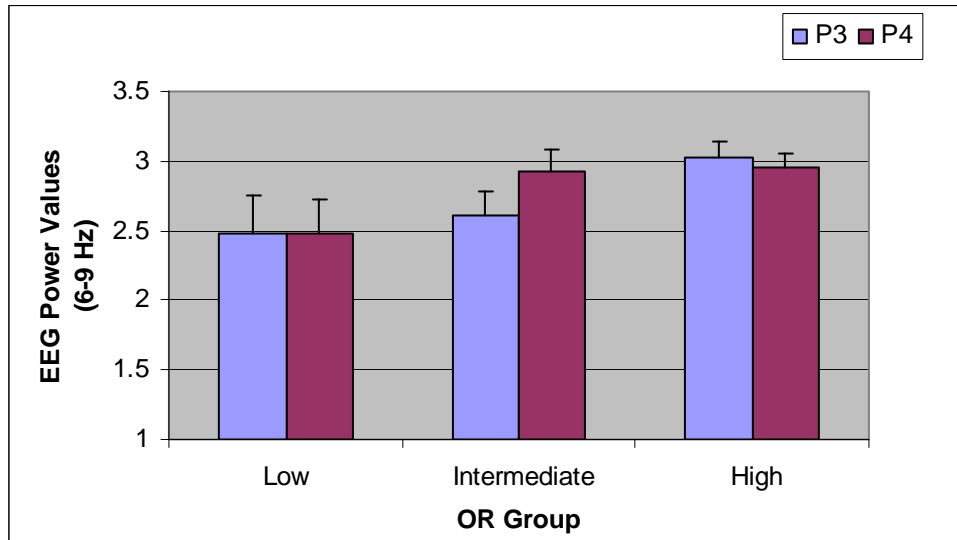


Figure 9. EEG power values (ln 6-9 Hz) from frontal pole (F1, F2) scalp locations for non-walkers, novice walkers, and experienced walkers.

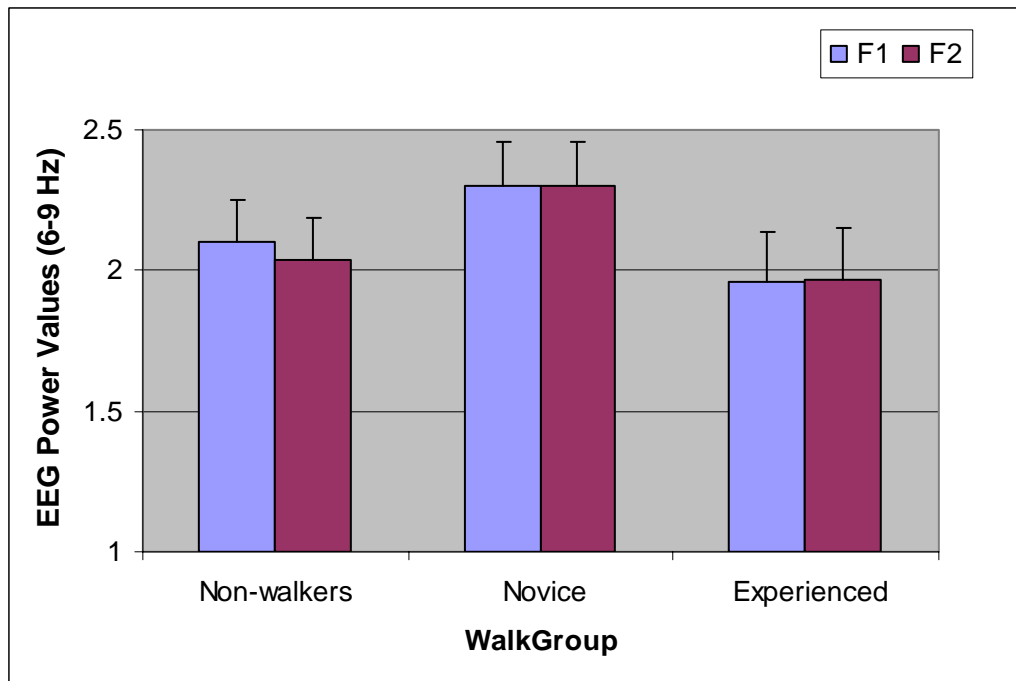


Figure 10. EEG power values (ln 6-9 Hz) from medial frontal (F3, F4) scalp locations for non-walkers, novice walkers, and experienced walkers.

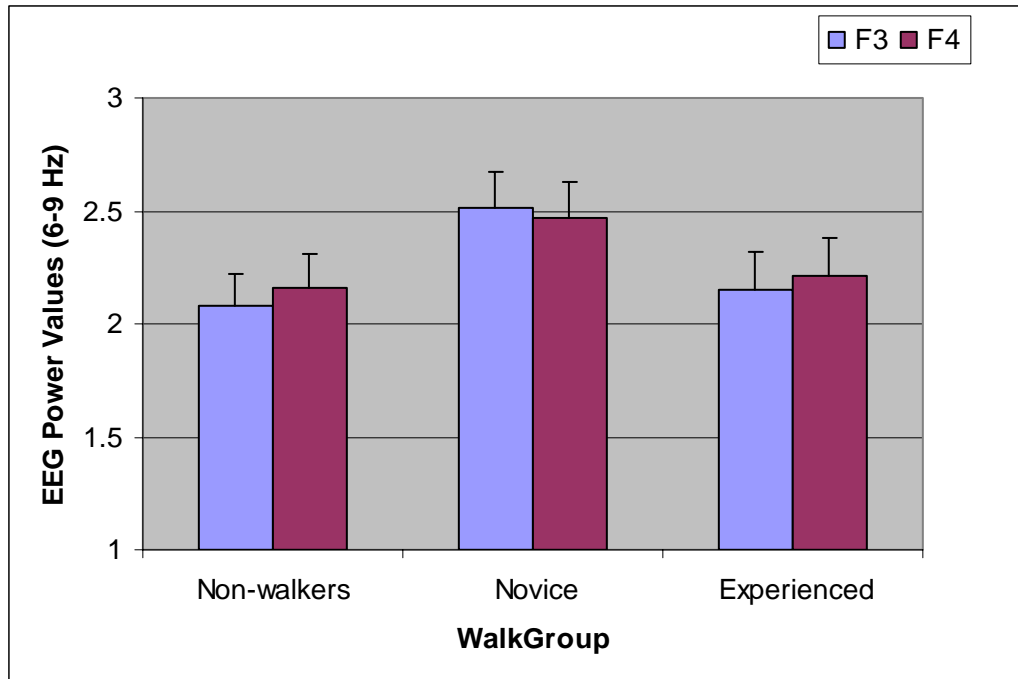


Figure 11. EEG power values (ln 6-9 Hz) from central (C3, C4) scalp locations for non-walkers, novice walkers, and experienced walkers.

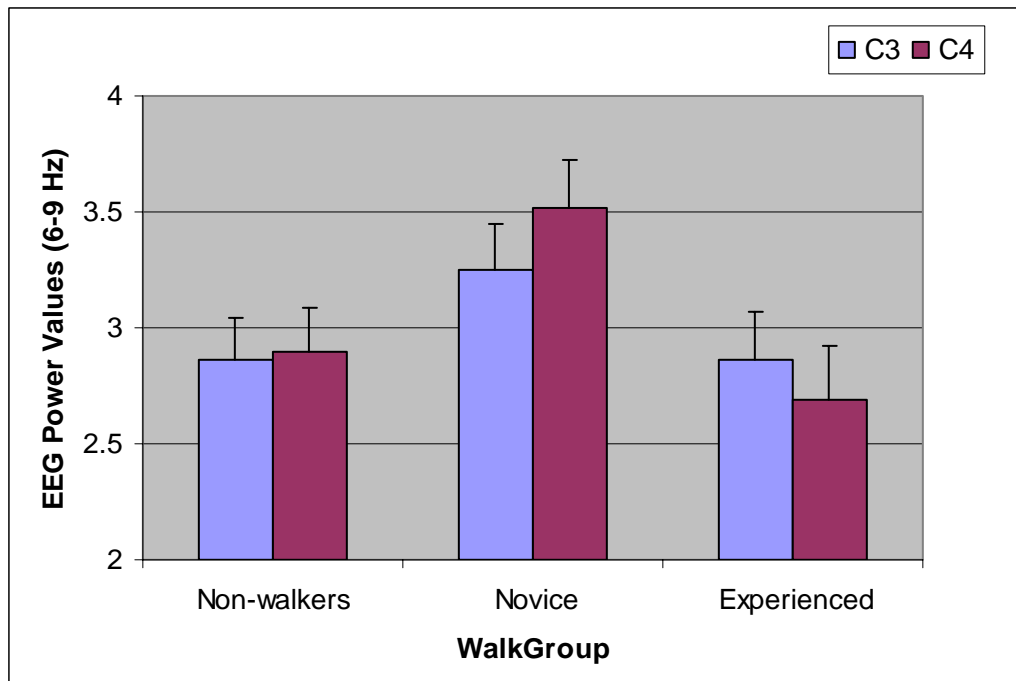
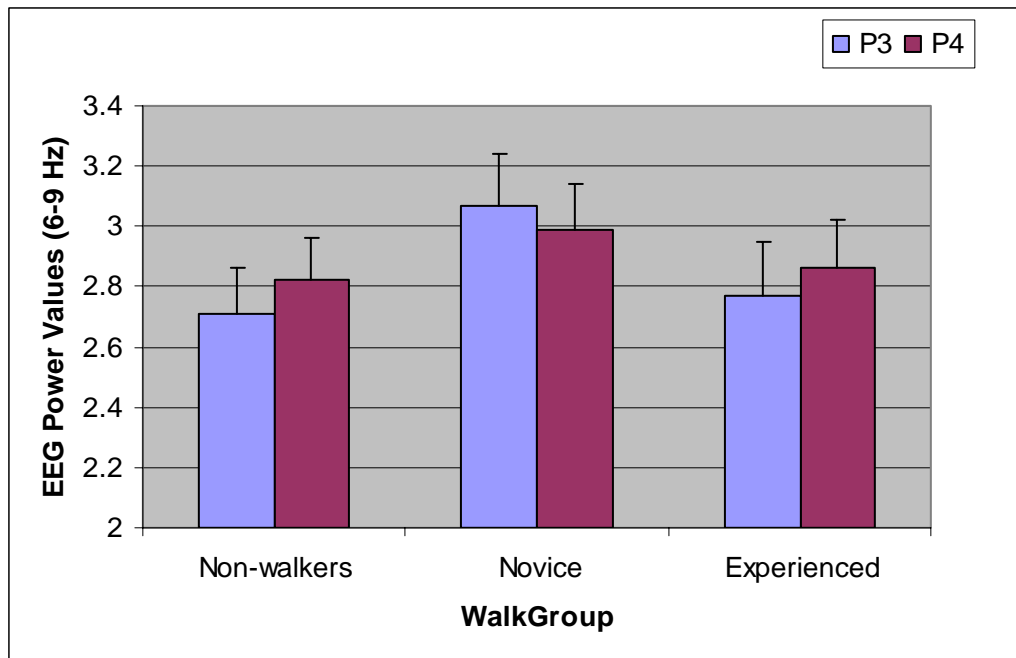


Figure 12. EEG power values (ln 6-9 Hz) from parietal (P3, P4) scalp locations for non-walkers, novice walkers, and experienced walkers.



## Appendix A

### VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY Parental Consent Form

*Title of Project:* “Cognitive and Locomotor Development in Infants”

*Investigators:* Martha Ann Bell, Ph.D., Denise R. Adkins

#### **I. Purpose of this Research**

You and your infant have been invited to participate in a research project investigating the effects of walking experience on the development of memory at 12 months of age. Specifically, we are examining how brainwave activity is associated with infant task performance relative to the amount of walking experience your infant has incurred. The information we gather in this research study will further our knowledge of how infants develop important memory skills. A total of 50 infants and parents will be participating in this study. We are seeking infants with all levels of walking experience, from pre-walking, to new walkers, to experienced walkers.

#### **II. Procedures**

This study involves one 45-minute visit to the Infant Development Project Lab (Derring 5076-F) at Virginia Tech. The visit will occur when your child is 12 months of age. Your infant will sit on your lap throughout the visit. The entire session will be video taped. This study also involves a questionnaire (General Information Questionnaire). We had asked you to try to complete this brief form at home prior to your infant's visit to our research lab.

A little green cap that helps us to collect brainwave activity will be placed on your infant's head. This cap looks and fits like a little infant swim cap. In order to collect brain-wave activity, gel will be applied to your infant's hair through little holes in the cap. These procedures are similar to those used in a doctor's office and are not harmful to your infant. While brain-wave activity is being recorded for 2 minutes, your infant will be looking at an infant toy with colored balls being tumbled in it. We have found that 12-month-old infants like this toy and will sit quietly and watch it. After this recording, the cap will be removed and the gel will be washed from your infant's hair with warm water and a clean washcloth.

First, we will ask that you hold your infant while s/he reaches to grasp toys we are holding. Then, we will observe how your infant searches for a hidden toy by reaching to retrieve it. We will be making note of where your infant reaches to determine the strategy your child uses in searching for the toy. Then your infant will be asked to retrieve a toy from underneath a transparent box by figuring out where the box opening is. Last, we will ask that you use a toy to coax your infant to walk/crawl across the room to retrieve it from you.

#### **III. Risks**

There is minimal risk associated with this research project. The brainwave procedures are similar to that done in a doctor's office and are not harmful. All brain-wave equipment is disinfected after each use. Toys are disinfected after being handled by each infant. If your child has an allergy to skin lotions, please inform us so that we can discuss the allergy and determine if any procedural changes need to be made. Our EEG gels are water based, but do contain the same preservatives that are used in everyday skin lotions.

#### **IV. Benefits of This Research**

There are no tangible benefits for you or your infant. No promise or guarantee of benefits have been made to encourage you and your infant to participate in this study. In a scientific sense, however, this research study will give developmental specialists more information about the development of memory and locomotor skills during infancy. Upon completion of this study, we will send you a letter briefly outlining the findings of this research.

#### **V. Extent of Confidentiality**

Information gathered for this study will be confidential and the information from each individual baby will be identified by code number only. Information linking infant name and code number will be



kept in a card file and locked in a file drawer. Only Dr. Bell and her graduate Research Assistants will have access to the card file. Your infant will be videotaped during the lab procedure. This allows us to go back at a later date and code your infant's search behaviors. Videotapes will identify infants only by code number. Tapes will be stored in the research lab and will be accessible only to Research Assistants associated specifically with this research project. Dr. Bell will supervise the confidentiality of the videotapes. Tapes will be erased 5 years after publication of the results of this study. The research team will not give you direct information of how your infant compares with any of the other infants included in this study.

#### **VI. Compensation**

Your infant will receive a small "thank you" gift for participation in the laboratory visit for this research study.

#### **VII. Freedom to Withdraw**

You may withdraw your infant from participation in the lab visit portion of this research study at any time without penalty. Your infant will still receive the small gift.

#### **Approval of Research**

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at VPI&SU and by the Department of Psychology at Virginia Tech.

#### **IX. Parent's Responsibilities**

none

#### **X. Parent's Permission**

I have read and understand the Informed Consent and conditions of this research study. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for my infant to participate in this project. I understand that I may withdraw from participation at any time without penalty. I understand that I will be given a copy of this consent form.

\_\_\_\_\_

parent's signature

\_\_\_\_\_

date

*Should I have any questions about this study, I may contact:*

- 1) Martha Ann Bell, PhD  
Investigator, Associate Professor of Psychology, 231-2546
- 2) Denise R. Adkins  
Co-investigator, Graduate Student of Psychology, 231-2320
- 3) David W. Harrison, PhD  
Chair, Psychology Department Human Subjects Committee, 231-4422
- 4) David Moore, PhD  
Chair, IRB, CVM Phase II 231-4991

## Appendix B

Infant Development Project

General Information Questionnaire

Infant ID number \_\_\_\_\_

Date of visit \_\_\_\_\_

1. Sex of baby:     M     F

2. Date of birth \_\_\_\_\_

3. Weight at birth \_\_\_\_\_

4. What was the expected due date? \_\_\_\_\_

5. Did your child receive any oxygen at birth or soon thereafter?

\_\_\_\_\_ no  
\_\_\_\_\_ yes

6. Has your child experienced any serious illness or problems in development?

\_\_\_\_\_ no  
\_\_\_\_\_ yes-----brief explanation \_\_\_\_\_

7. Has your child ever had any neurological problems, such as epilepsy, or seizures of any kind?

\_\_\_\_\_ no  
\_\_\_\_\_ yes-----brief explanation \_\_\_\_\_

8. Has your child received any long term medication?

\_\_\_\_\_ no  
\_\_\_\_\_ yes-----brief explanation \_\_\_\_\_

9. Is your child ill or on any medications now?

\_\_\_\_\_ no  
\_\_\_\_\_ yes-----brief explanation \_\_\_\_\_

10. Has your child shown an allergic reaction to anything?

\_\_\_\_\_ no  
\_\_\_\_\_ yes-----brief explanation \_\_\_\_\_

11. Has your child ever had any skin irritations?

\_\_\_\_\_ no  
\_\_\_\_\_ yes

12. Age of parents at infant's birth:

**mother** \_\_\_\_\_  
**father** \_\_\_\_\_

13. Ethnic group of parents:

**mother** \_\_\_\_\_ Hispanic or Latino  
 \_\_\_\_\_ not Hispanic or Latino

**father** \_\_\_\_\_ Hispanic or Latino  
 \_\_\_\_\_ not Hispanic or Latino

14. Racial group of parents:

**mother** \_\_\_\_\_ American Indian / Alaska Native  
 Native

**father** \_\_\_\_\_ American Indian / Alaska

\_\_\_\_\_ Asian

\_\_\_\_\_ Asian

\_\_\_\_\_ Native Hawaiian or Other Pacific Islander  
 Pacific Islander

\_\_\_\_\_ Native Hawaiian or Other

\_\_\_\_\_ Black or African American

\_\_\_\_\_ Black or African American

\_\_\_\_\_ White

\_\_\_\_\_ White

15. Highest level of education completed: (please note any "in progress")

**mother** \_\_\_\_\_ high school  
 \_\_\_\_\_ technical school  
 \_\_\_\_\_ college  
 \_\_\_\_\_ graduate school

**father** \_\_\_\_\_ high school  
 \_\_\_\_\_ technical school  
 \_\_\_\_\_ college  
 \_\_\_\_\_ graduate school

16. Which hand do you prefer to use for each of these activities?

Please put **R** (right hand), **L** (left hand), or **E** (either hand).

	<b>mother</b>	<b>father</b>
a. Writing	_____	_____
b. Drawing	_____	_____
c. Throwing	_____	_____
d. Scissors	_____	_____
e. Toothbrush	_____	_____
f. Knife (without fork)	_____	_____
g. Spoon	_____	_____
h. Broom (upper hand)	_____	_____
i. Striking match (to hold match)	_____	_____
j. Opening jar (hand on lid)	_____	_____
* * * * *		
k. Which foot do you prefer to kick with?	_____	_____
l. Which eye do you use when using only one?	_____	_____

17. Is your infant walking? \_\_\_\_\_ If so, on what day did your child take his/her first independent steps?

\_\_\_\_\_

18. How much experience has your infant had with the following:

	<b>None</b>	<b>Infrequent</b>	<b>Frequent</b>
Johnny Jump-Up	_____	_____	_____
Bouncer/Saucer	_____	_____	_____
Infant Walker	_____	_____	_____
Push-cart	_____	_____	_____

**DENISE RENE ADKINS****Office Address:**

Department of Psychology  
 306 Williams Hall  
 Virginia Tech (0436)  
 Blacksburg, VA 24061  
 (540) 231.7001  
 FAX (540) 231.3652  
 e-mail: [dradkins@vt.edu](mailto:dradkins@vt.edu)

**Home Address:**

706 Park Street  
 Christiansburg, VA 24073  
 Home (540) 381.4827  
 Cell (540) 641.2416

**Education:**

**M.S.**, May 2004, Virginia Polytechnic Institute and State University  
*major:* Psychological Sciences  
*emphasis:* Developmental Psychology  
*thesis:* Individual differences in spatial memory performance at 12 months of age:  
 Contributions from walking experience and brain electrical activity  
*mentor:* Martha Ann Bell, Ph.D.

**B.S.**, December 2001, Averett University, *Summa Cum Laude*  
*major:* Clinical and Counseling Psychology

**Professional Experience:**

2002- present	Research Assistant, Developmental Cognitive Neuroscience Lab, Virginia Tech
2002-present	Graduate Teaching Assistant, Department of Psychology, Virginia Tech
2000-2001	Psychology Lab Monitor, Department of Psychology, Averett University

**Publications:**

Adkins, D.R. (2003). Introduction to Development. In P.K. Lehman, C. Dula, J.W. Finney (Eds.), *Introductory Psychology Recitation Reader* (pp. 139-140). Boston, MA: McGraw Hill.

**Conference Presentations:**

Adkins, D.R., Clory, T., & Bell, M.A. (2004, May). Associations between locomotor experience and spatial search performance in 12-month-old infants. Poster presented at the International Conference on Infant Studies, Chicago, Illinois.

Adkins, D.R. (2001, March). Training a Long-Evans Hooded Rat to Perform a Heterogeneous Chain. Poster presented at Alpha Chi, Savannah, Georgia.

**Conference Attendance:**

- International Conference on Infant Studies (May 2004)
- Society for Research in Child Development (April 2003)
- Virginia Psychological Association (October 2002)

**Research Experience:**

- Individual Differences in Spatial Memory Performance at 12 Months of Age: Contributions from Walking Experience and Brain Electrical Activity; thesis topic
- The Psychological and Physical Barriers of Disabilities; literature review
- The Effects of Competition Type on Performance Quality Among Pairs of College Students; independent research study
- Training a Long-Evans Hooded Rat to Perform a Heterogeneous Chain; required research experience

**Teaching Experience:**

- Advanced Developmental Lab (Fall 2003, Spring 2004)
- Introductory Psychology Recitation (Fall 2002, Spring 2003)

**Student Membership:**

- International Society on Infant Studies (ISIS-----since 2003)
- Society for Research in Child Development (SRCDD-----since 2003)
- Virginia Psychological Association (VPA-----since 2000)

**Awards:**

- Graduate Research Development Project Award (Spring 2003)
- GSA Travel Fund Award (Spring 2004)