STICKY MITTENS EARLY MOTOR INTERVENTION AFFECTS INFANTS' OBJECT PREFERENCES

By

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Thesis

Submitted to the Faculty of the

Graduate School of Vanderbilt University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

in

Psychology

August, 2014

Nashville, Tennessee

Approved:

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ACKNOWLEDGEMENTS

This research was supported by National Institute of Health grant HD05120 to Amy Needham. A special thanks to my fellow graduate student Jane Hirtle and former lab manager Carrie Kocot for helping to run this study, to the research assistants in the Infant Learning Lab for their help with recruitment, and to the parents who generously donated their time and energy by bringing their infants in to participate in this study. I am also grateful for the patience and stamina of our former research assistant, Sophie Krefft, who spent endless hours helping me to code this data. And last but certainly not least, a huge thank you to my advisor, Dr. Amy Needham, for designing this study and providing support and guidance.

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CHAPTER I

INTRODUCTION

Infants' reaching and grasping abilities support opportunities to engage manual, oral, and visual object exploration. Young infants' object exploration skills have been linked with later outcomes such as attention, intelligence, and school performance. In particular, a 14-year longitudinal study by Bornstein, Hahn, & Suwalsky (2013) linked motor competence and object exploration skills at age 5-months to intelligence at 4 years of age, and to both intelligence and academic achievement at ages 10- and 14-years. Individuals' skills during infancy support further opportunities to learn and thus have far-reaching, cascading consequences across development.

Infants' Visual Preferences

Much research has established that young infants prefer to look toward objects that take up more of their visual fields. For example, Salapatek (1968) found that newborns preferred to look toward larger geometric figures rather than smaller geometric figures. Slater, Mattock, & Brown (1990) found that babies preferred to look toward objects that had a bigger retinal image. Lastly, Bruner & Koslowski (1972) presented infants between 8- and 22-weeks of age with one of two balls, one large and one small. On average, infants preferred the large ball and spent more time exploring it. However, these authors found that older infants were more willing to spend time exploring the smaller ball. This suggests that older infants, who are likely to have more experience

reaching and grasping for objects, may recognize smaller objects as more manageable targets of manual and oral exploration.

Early Object Exploration

The ability to coordinate one's hands in order to move toward and grasp a target of exploration progresses gradually across development. Evidence of this progression can be found in Piaget's detailed observations of his infants' behaviors (Piaget, 1963). Around 2.5 months of age his daughter, Lucienne, began noticing and appreciating her hands. Piaget noted that Lucienne, lying on her back, smiled as she gazed at her raised hand. Soon after infants begin to pay attention to their hands, around 3-months of age they begin to practice their reaching and grasping skills. Initially, infants tend to be clumsy, and small movements require concentration and effort. Piaget described his daughter's attempts to contact objects at this age as only sometimes successful, equally likely to result in "chance and coordination" (Piaget, 1963, p. 99). Infants quickly gain competence with practice, and by around 4 or 5 months of age, they are able to transport objects to their mouths, and successfully switch between and coordinate their visual and oral exploration of objects. Of course, some infants are more precocious in accomplishing this skill level. For example, Piaget also recorded an observation of his daughter Jacqueline, at 4 months of age, inadvertently whacking herself in the face with a rattle and reacting with surprise. Piaget stated, "her hand still does not belong to her!" (Piaget, 1963, p. 103).

Object Preferences and Reaching Experience

Research findings demonstrate that older infants with more advanced reaching and grasping skills are more likely to prefer smaller objects that are easier for them to manually explore than younger and less experienced infants. With age and experience, infants gain the ability to overcome their initial bias to attend to objects that occupy a greater portion of their visual fields. In addition, infants appear to gain sensitivity to the graspability of objects. Graspability refers to the potential for infants to successfully manipulate and interact with objects. Smaller objects tend to be more manageable targets for exploration for infants who have tiny hands and are inexperienced in coordinating their actions to manipulate objects.

A study by Newman, Atkinson, Braddick (2001) used a similar paired reaching and looking preference paradigm to examine factors influencing infants' object preferences. This study also presented infants with pairs of various sized cylinders and recorded their looking and touching preferences. Infants' looking behaviors revealed that they preferred to look toward the larger cylinder first, but infants between 8.5- and 12-months consistently reached toward the smaller object first.

Libertus and colleagues examined how visual salience and graspability influenced infants' object preferences between 4- and 6-months of age (Libertus, Gibson, Hidayatallah, Hirtle, Adcock, & Needham, 2013). Infants in this study were presented with pairs of cylinders of various sizes, and their visual and manual preferences were measured. Overall, infants showed a strong preference for looking at the larger cylinder first when the two objects were first presented to them. This preference was to be expected given the findings of past research showing that infants like to look at larger,

more visually salient objects. Although infants' looking was initially captured by the larger cylinder, older infants who were more skilled reachers overcame this initial preference and spent approximately equal amounts of time looking toward each of the two cylinders. In contrast, less skilled and younger infants spent more time visually examining the larger cylinder compared to the smaller cylinder. In this study, we see the sensitivity to size emerge around 5 months. In contrast, the study by Newman et al. (2013) found that infants began attending to the graspability of objects around 8.5-months of age. This discrepancy in findings may be related to the size of the cylinders presented to the infants in these two studies. The smaller cylinders presented by Newman and colleagues (2001) may provide a more sensitive measure of how graspability influences reaching decisions across infancy.

These two studies are consistent with prior research showing that infants have a visual preference for looking at larger objects rather than smaller objects. Together, they show that both age and ability influence infants' preferences when it comes to selecting objects for exploration. While these studies establish that infants who have more skill and coordination as reachers also prefer smaller, more potentially graspable objects, it is not clear whether this relation is causal, and if so, what the direction of causality is. For example, infants might begin to prefer smaller objects after they begin reaching because these objects are easier for them to manually and orally explore. On the other hand, there may be another explanation for the change in infants' preference for smaller objects such as improvements in infants' visual acuity. One way to answer this research question is to provide infants with reaching experience prior to the time they would normally obtain it

on their own. If this experience induces a change in infants' visual preferences, it would provide clear evidence that the onset of reaching is the origin of this change.

Sticky Mittens Early Motor Intervention

Would an early motor intervention lead to immediate changes in infants' preferences for different sized objects? Fortunately, the sticky mittens paradigm offers a convenient method of introducing young infants with the ability to interact with lightweight toys (Needham, Barrett, & Peterman, 2002). Velcro loop covering the palms of custom infant mittens allows pre-reaching infants, between 2.5- and 3.5-months-of age, to "pick up" lightweight toys covered in strips of velcro hook by merely swatting at them. Two weeks of mittens training has been shown to increase infants' object exploration skills, reaching, and preference for faces when compared to an age-matched group of infants who either did not receive mittens training or who participated in a passive experience in which parents manipulated the toys to create a similar visual experience for their infants (Needham et al., 2002; Libertus & Needham, 2010, 2011). In these studies, parents took the mittens and lightweight toys home and were responsible for training their babies with the mittens for ten minutes per day over a period of two-weeks.

Shorter, experimenter-led sessions of sticky mitten training, however, have also proven to have wide-ranging affects on pre-reaching infants' cognitive skills. For example, after just ten minutes of sticky mittens training, infants' looking and touching directed toward a teether increased in comparison to a group of infants who participated in passive mittens training (Needham, Gibson, Libertus, Wiesen, & Christopher, 2013).

It is important to note that during pre- and post-training assessments, infants were bare-handed, and the stimuli used in these assessments were unrelated to the objects that infants interacted with during training. In fact, studies have shown the effects of just 3 minutes of mittens training can lead to immediate improvements in infants' goal understanding (Sommerville, Woodward, & Needham, 2005), causal understanding (Rakison & Krogh, 2012), action understanding (Gerson & Woodward, 2013), and sensitivity toward the efficiency of others' actions (Skerry, Carey, & Spelke, 2013). Additionally, just 4 minutes of sticky mittens training has been found to improve infants' mental rotation abilities (Krogh & Johnson, 2013). These findings support the potential utility of sticky mittens early motor intervention in advancing infants' cognitive skills. Thus, the current study investigates whether sticky mittens training might increase infants' sensitivity toward the graspability of objects.

Current Study

Are infants able to immediately adjust their motor decisions based on their current bodily dimensions and abilities? A study by Adolph & Avolio (2000) found that infants immediately adjusted their decision-making based on their current motor capacities in the domain of locomotion. This study examined infants' decisions whether to proceed down or avoid slopes of various angles while wearing either (a) a heavy vest loaded with lead weights or (b) a lightweight vest stuffed with down feathers. They found that infants tailored their walking decisions according to their current bodily dimensions. The current study looks at whether infants also take into consideration their current ability-levels

during a different developmental period and motor domain, during early infancy during the transition to successful reaching and grasping.

CHAPTER II

EXPERIMENT

Method

Participants

Thirty-eight healthy, full-term infants between 2 months, 15 days and 3 months, 15 days of age participated in the current study (M_{age} = 91.76 days, SD_{age} = 9.03 days). We randomly assigned 19 infants (females = 10) to participate in the Active mittens training condition (M_{age} = 92 days, SD_{age}= 9.4. days). We randomly assigned the other 19 infants (females = 8) to participate in the Passive mittens training condition (M_{age} = 91 days, SD_{age} = 8.6 days). Data from 11 additional infants were collected, but were not included in the analyses for the following reasons: fussiness (n = 6); procedural or technical problems (n = 3); emergency diaper change during the study (n = 1); and a side bias which prevented us from determining object preference (n = 1).

Participants were recruited via public birth records that provided infants' and parents' names and addresses. Research assistants used Whitepages.com to obtain home telephone numbers and searched for parents' names in the university database to obtain email addresses for parents who were associated with the university. Thirty-two of the infants who participated in this experiment were white, four were Asian, and one was American Indian.

Design

All infants first participated in a pre-training assessment of object preference. This was followed by about 8 minutes of either active or passive mittens training. Lastly, infants participated in a post-training assessment of object preference. Throughout the study, infants were seated on a parent's lap at a kidney-bean shaped table. The table was 180 cm across at its widest point. The experimenter was seated on the opposite side of the table, about 74 cm, from the infant. The half-circle cutout where the infant was seated was 63.5 cm in diameter. Infants' arms were placed on the table. Parents were offered a pillow to place under their infants if infants' arms were not level with the tabletop.

Materials

Pre- and Post-Training Assessment of Object Preference

Two clear plastic cylinders, one big and one small, decorated with stripes of colorful electrical tape were used in pre- and post-training trials (see Figure 1). The big cylinder was 18 cm in diameter and 24 cm tall. The small cylinder was 5 cm in diameter and 3 cm tall. Apart from their dimensions, the appearances of the cylinders were nearly identical. Please note that these cylinders were only presented to infants during pre- and post-training assessments; different toys were presented to infants during the mittens training, which we will describe shortly. We would also like to emphasize that infants were not wearing mittens during pre- and post-training assessments. Infants were barehanded during these portions of the study.

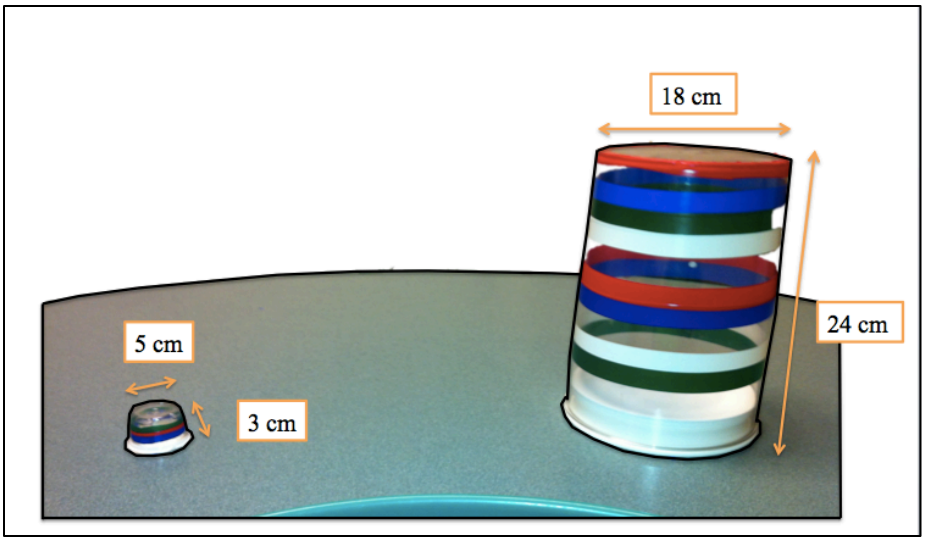

Figure 1. These two cylinders were presented to infants during pre- and post-training assessments of object preference.

Mittens Training

All infants wore purple fleece mittens during training (see Figure 2). Infants who were assigned to the Active condition wore mittens with the soft loop side of Velcro sewn onto the palms. Infants who were assigned to the Passive condition wore mittens with white ribbon sewn onto the palms to mimic the appearance of the Velcro. All infants were presented with a variety of small, lightweight toys including foam letters and numbers, small plastic Duplo blocks, and rubber bath toys shaped like animals. Infants in the Active condition interacted with toys that had strips of the hook side of Velcro on them. Infants in the Passive condition interacted with toys that had strips of black electrical tape highlighting their edges to mimic the appearance of the Velcro.

Figure 2. An infant participates in Active mittens training.

Measures and Coding

Pre- and Post-Training Assessment of Object Preference

Infants' looking toward each of the two cylinders was coded to the nearest tenth of a second. Two coders, one of whom was blind to the hypothesized outcomes of the study, coded infants' looking toward the cylinders. One coder pressed a button to indicate looking toward the small cylinder, and the second coder pressed a button to indicate looking toward the big cylinder. Later, the coders switched roles and coded looking toward the opposite cylinder. Reliability between coders was high, with agreement at 99.2%.

Mittens Training

Two research assistants coded the duration of mittens training. Research assistants viewed a video of the mittens training session. They paused the video when the experimenter fastened the second mitten on the babies' wrist and recorded the timestamp on the video. Reliability between the two coders was 99.96%. The research assistants coded the end of mittens training when the experimenter began to remove the first mitten from the infants' hand. Two research assistants also coded how many toys that infants

interacted with during the mittens training. Reliability between coders across the two conditions was 92.49%. Lastly, two research assistants coded the number of warm-up trials infants in the Active condition participated in. Warm-up trials consisted of the experimenter demonstrating how toys stuck to the mittens. The coders agreed on 94.74% of warm-up trials.

Pre- and Post-Training Assessments of Object Preference

The two cylinders were presented for 30 seconds before and after the mittens training experience. The side on which big and small cylinders were presented to infants from pre- to post-training was counterbalanced. For example, if infants saw the big cylinder on their left sides and the small cylinder on their right sides during pre-training, then during post-training the big cylinder would be on these infants' right sides and the small cylinder would be on these infants' left sides. Ten infants in the Active condition and 8 infants in the Passive condition saw the big cylinder on their left side during pre-training and right side during post-training.

The distance between the two cylinders was 46 cm throughout the study. The two cylinders were first presented in the far position for ten seconds. In this position, the front surfaces of the two cylinders were approximately 50 cm from the edge of the table in front of infants. Two discreet marks on the table allowed the experimenter to keep this distance the same across participants. Next, the experimenter placed one hand on each cylinder and pushed the cylinders closer toward the infants, within their reach. In this position, which we refer to as the near position, the front surfaces of the two cylinders were approximately 12 cm from the edge of the table where infants were seated. Again,

small marks on the tabletop allowed the experimenter to place the cylinders in precisely the same position across participants. The two cylinders remained in this position for 20 s, which concluded this part of the study.

Mittens Training

Mittens training procedures differed depending on whether infants were randomly assigned to the Active or Passive mittens training condition.

Active mittens training

The experimenter demonstrated how the mittens worked two or three times for each infant in the Active mittens training condition. The experimenter placed a toy in front of the infant. Then, the experimenter held the infant's wrist and gently pressed the mitten to the toy so that the Velcro loop on the palm of the mitten stuck to the Velcro hooks on the toy. The experimenter lifted the infant's wrist, showing the infant how the toy dangled from the mitten. After these demonstrations, the experimenter simply presented toys one at a time to the infants, and allowed them to play with the toys. The experimenter referenced a stopwatch, placed on her lap out of view of the infant. Toys were presented for between 30 and 60 s, depending on the infants' interest in the toys. If infants were engaged with the toys (looking and moving them), the experimenter did her best to remove the toy at an optimal time so as not to upset the baby.

Passive mittens training

The experimenter moved the toys through infants' visual fields to provide a similar visual experience for infants in the Passive condition. First, the experimenter tapped the toy on the table. Then, the experimenter briefly rested the object on the table

within infants' reach. Next, the experimenter touched the toy to each of the infant's palms. Then she moved the toy slowly to the left side of the infants' visual field at eye level, moving in an arc in front of the infant over to the right side of his/her visual field. This procedure was repeated for each of the toys. Each toy was presented for between 30 and 60 s. The speed and length of time the experimenter rested the toys on the table were adjusted according to infants' abilities to track the objects as they were moved.

Data Analysis

Hybrid t-tests on the difference scores (post-training looking durations minus pre-training looking durations) were used to assess whether infants' looking preferences changed from pre- to post-training. Paired hybrid t-tests on the difference scores (for infants in the Active mittens training condition compared to infants in the Passive mittens training condition) were used to assess whether the changes in looking durations from pre- to post-training between the two conditions.

One-tailed binomial tests were used to assess whether more infants either increased or decreased their looking toward each cylinder than would be expected by chance. We elected to use one-tailed tests because we had prior hypotheses that infants who participated in Active mittens training would increase their looking toward the small cylinder. While we did not expect that Passive mittens training would influence infants' visual preferences, we thought that if there were to be a change in their visual preferences, it would be toward looking more at the large cylinder.

We created graphs to help illustrate the changes in infants' looking behaviors from pre- to post-training. Figures 4 and 5 were inspired by William Cleveland's multi-

way dot plots used to show barley crops from one growing season to the next (Cleveland, 1993).

We performed two analyses to determine whether the number of toys presented to infants during the mittens training accounted for the differences in infants' looking preferences. We first used a MANCOVA with the number of toys infants saw entered as a covariate. The purpose of this analysis was to determine if (a) number of toys was significant as a covariate and (b) to see if entering the number of toys as a covariate would lead to different findings that if it was not included in the model. Thus, our second analysis, a MANOVA, was performed so that we could compare the findings with our previous findings from the MANCOVA analysis.

Results

Mittens Training

The average duration of training for infants in the Active mittens training condition was 8 minutes, 22 seconds (*SD* = 48 s). The average duration of training for infants in the Passive mittens training condition was 8 min, 19 s (*SD* = 49 s). Infants in the Active condition were shown how the toy stuck to the mittens with an average of 2.05 toys (*SD* = .4). On average, infants in the Active training condition interacted with slightly more toys (*M* = 10.36 toys, *SD* = 1.95 toys) than infants in the Passive condition (*M* = 8.68 toys, *SD* = 1.53 toys).

Looking Durations in the Far Position

Across the two training conditions and pre- and post-training assessments, infants' looking behaviors did not change when the cylinders were presented in the far position for 10 seconds. Infants in the Active training condition spent an average of 4.62 seconds (*SD* = 4.02 s) looking at the big cylinder during pre-training, and during post-training they looked 3.93 s (*SD* = 3.79 s) toward the big cylinder. A t-test on the difference scores (post-training looking minus pre-training looking confirmed that this change in looking was non-significant, $t(18) = -.67$, $p = .512$, 95% CI [–2.88, 1.49]. There was also no change in looking toward the small cylinder from pre-training ($M_{pre} = 2.82$ s, $SD_{pre} = 3.89$ s) to post-training ($M_{post} = 2.29$ s, $SD_{post} = 2.40$ s) among infants in the Active condition, $t(18) = -.71$, $p = .49$, 95% CI [-2.09, 1.04]. Similarly, infants in the Passive condition did not change their looking toward the big cylinder from pre-training ($M_{pre} = 5.47$ s, $SD_{pre} = 4.10$ s) to post-training ($M_{post} = 5.54$ s, $SD_{post} = 3.27$ s), $t(18) = .05$, p=.957, 95% CI [–2.36, 2.49]. Infants in the Passive condition also looked about the same amount toward the small cylinder during pre-training ($M_{pre} = 2.71$ s, $SD_{pre} = 3.48$ s) and post-training ($M_{post} = 1.92$ s, $SD_{post} = 3.26$) assessments of object preference, $t(18) = -.81$, $p = .431$, 95% CI [–3.21, 1.43]. The difference between the changes in looking toward the big cylinder between infants in the Active and Passive conditions from pre- to post-training was non-significant, $t(36) = -.49$, $p = .628$, 95% CI [–3.91, 2.39]. Lastly, the difference between the two groups' looking toward the small cylinder from pre- to post-training was also non-significant, $t(36) = .27$, $p = .787$, 95% CI [–2.34, 3.07].

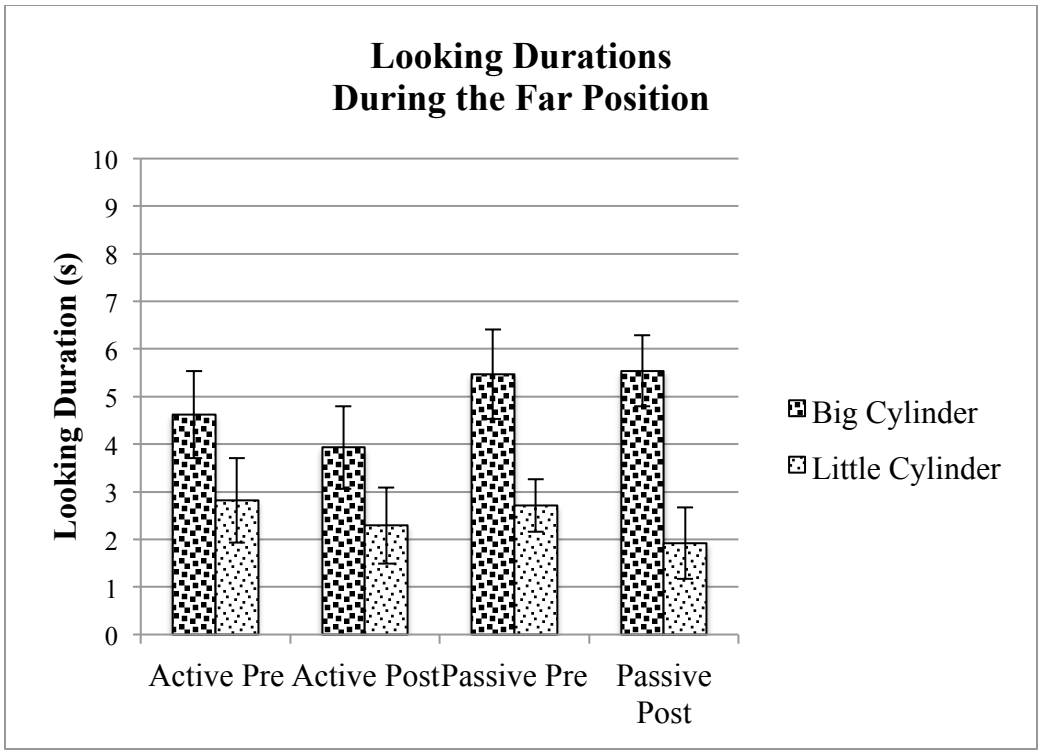

Figure 3. This bar graph shows the average durations that infants looked toward the large and small cylinders during the 10 seconds when the cylinders were presented in the far position outside of infants' reach.

Looking Durations in the Near Position

Looking Toward the Big Cylinder in Near Position

Difference scores were calculated for each infant to examine changes in the duration of looking toward the big cylinder from pre- to post-training. To calculate difference scores, we subtracted the duration of each infant's looking during pre-training from the duration of his/her looking during post training. On average, infants in the Active mittens training condition tended to look less toward the big cylinder during post-training (M_{post} = 6.08 s, SD_{post} = 6.71 s) than during pre-training (M_{pre} = 9.84 s, SD_{pre} = 3.46 s), $t(18) = -1.56$, $p = .137$, 95% CI [–8.84, 1.32]. Infants in the Passive training condition, on the other hand, significantly increased their looking toward the big object from pre- (M_{pre} =

6.93 s, SD_{pre} = 6.28 s) to post-training (M_{post} = 11.18 s, SD_{post} = 6.84 s), $t(18) = 2.52$, p = .022, 95% CI [.75, 8.29]. The change in durations of looking directed toward the big cylinder from pre- to post-training significantly differed between infants in the Active versus Passive training conditions, $t(36) = -2.66$, p = .012, 95% CI [–14.12,–1.91] (see Figure 4). Among infants in the Active condition, eleven out of nineteen decreased their looking toward the big cylinder from pre- to post-training. The results of a one-tailed binomial test indicated that the number of infants who decreased their looking toward the big cylinder did not significantly differ from what would be expected by chance, p=.324. In contrast, of the nineteen infants in the passive training condition, fourteen increased their looking toward the big cylinder from pre- to post-training. The results of a one-tailed binomial test indicated that significantly more infants increased their looking toward the big cylinder than would be expected by chance alone, p =.064.

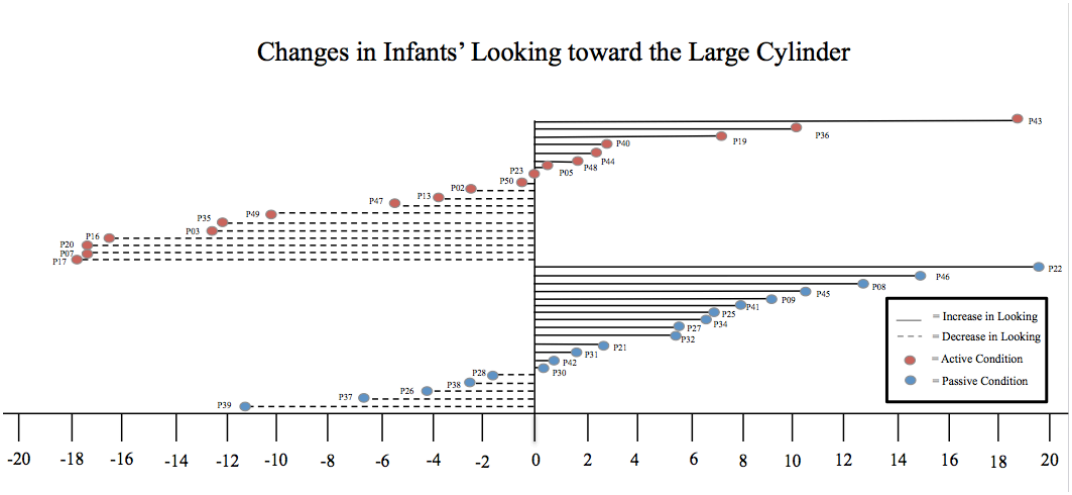

Figure 4. The overall pattern of changes in looking durations shows that infants in the Active mittens training condition tended to look less toward the large cylinder during post-training while infants in the Passive mittens training condition tended to look more toward the large cylinder during post-training.

In Figures 4 and 5, the lines represent difference scores (post-training looking minus pre-training looking). The vertical lines in the centers of the graphs represent zero

change in looking duration toward a cylinder from pre- to post-training assessments of object preference. Positive values (solid lines) indicate that infants increased their looking toward the cylinder from pre- to post-training. Negative values (dashed lines) indicate decreases in looking toward the cylinder from pre- to post-training. The red dots indicate the changes in looking durations of infants who participated in Active mittens training, while the blue dots indicate changes in looking behaviors among infants who participated in Passive training.

Looking Toward the Small Cylinder in Near Position

Difference scores were once again calculated as a measure of the change in infants' looking durations from pre-to post-training. Infants who participated in Active training tended to increase their looking toward the small cylinder from pre- (M_{pre} = 3.46 s, SD_{pre} = 4.59 s) to post-training (M_{post} = 6.66 s, SD_{post} = 6.48 s), $t(18) = 1.58$, $p = .132$, 95% CI [–1.07, 7.49]. In comparison, infants in the Passive training condition looked significantly less toward the small cylinder after training (M_{post} = 4.49 s, SD_{post} = 5.44 s) than before training (M_{pre} = 7.47 s, SD_{pre} = 5.59 s), $t(18) = -2.20$, p=.041, 95% CI [–5.83, –.13]. Changes in looking toward the small cylinder significantly differed between infants in the Active versus Passive training conditions, $t(36) = 2.53$, $p = .016$, 95% CI [1.22, 11.14] (see Figure 5). Twelve out of the nineteen infants in the Active condition increased their looking toward the small cylinder from pre- to post-training. The results of a one-tailed binomial test indicated that the number of infants who increased their looking toward the small cylinder did not significantly differ from what would be expected by chance, p=.18. In contrast, eleven out of the nineteen infants in the Passive

training condition decreased their looking toward the small cylinder from pre- to post-training. The results of a one-tailed binomial test indicated that the number of infants who decreased their looking toward the small cylinder did not significantly differ from what would be expected by chance, p=.324.

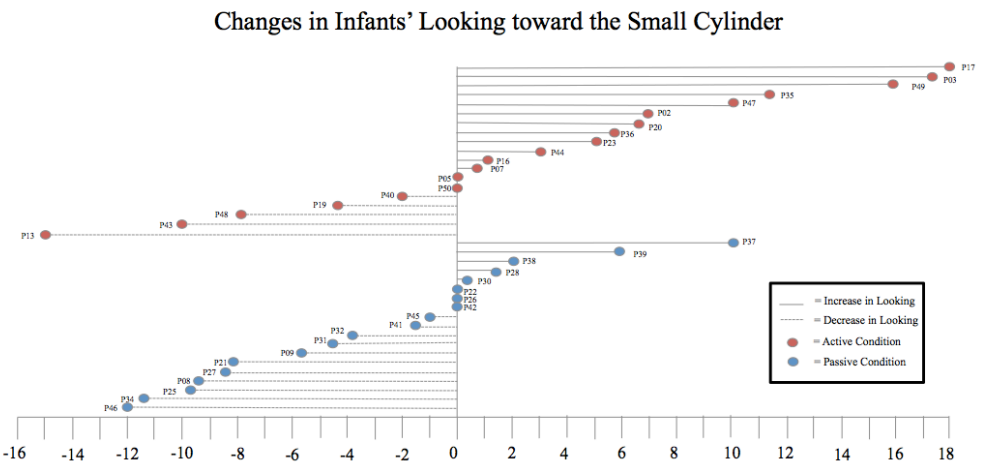

Figure 5. Infants in the Active mittens training condition tended look more toward the small cylinder from pre- to post-training, while infants in the Passive mittens training condition tended to look less toward the small cylinder.

It is important to note that although infants tended to look toward one of the two cylinders during pre- and post-training, Figures 4 and 5 are not mirror images of one another because infants may have looked elsewhere during pre- and/or post-training. For example, an infant might look less toward the large cylinder during post-training, but this does not necessarily mean that the infant was looking more toward the small cylinder during post-training. The infant may have been inspecting his or her hands, examining the video cameras in the experiment room, or attempting to engage the experimenter.

Number of Toys during Training

Next, to examine whether the number of toys infants were exposed to during mittens training influenced their looking behaviors, we conducted a repeated-measures MANCOVA. Phase (pre- or post-training) was entered as a within subjects factor, and condition (Active or Passive mittens training) was entered as a between-subject factor. The number of toys infants saw during mittens training was entered as a covariate. Two dependent variables, which both measured looking durations, were tested: looking toward the big cylinder and looking toward the small cylinder.

For looking toward the big cylinder, we found no evidence of main effects for phase ($F(1, 34) = 1.19$, $p = .283$, $\eta_p^2 = .03$), condition ($F(1, 34) = .63$, $p = .433$, $\eta_p^2 = .02$), or number of toys ($F(1, 34) = .005$, $p = .945$, $\eta_p^2 = .00$). As was expected, we found evidence of an interaction between phase and condition, although this effect was only marginally significant, $F(1, 34) = 3.71$, $p = .062$, $\eta_p^2 = .10$.

For looking toward the small cylinder, we found no evidence of main effects for phase ($F(1, 34) = .28$, $p = .598$, $\eta_p^2 = .01$), condition ($F(1, 34) = .871$, $p = .357$, $\eta_p^2 = .03$), or number of toys ($F(1, 34) = .244$, $p = .625$, $\eta_p^2 = .01$). We did, however, find evidence of a interaction between phase and condition, $F(1, 34) = 4.632$, $p = .039$, $\eta_p^2 = .12$.

Despite the number of toys being non-significant as a covariate in this analysis, we performed a second analysis, a repeated-measures MANOVA, to be sure that this covariate was not acting as a suppressor variable. In this second analysis, phase (pre- or post-training) was entered as a within subjects factor, and condition (Active or Passive mittens training) was entered as a between-subject factor. We looked at the same two dependent variables (looking toward the big cylinder and looking toward the small

cylinder), again to ensure that our findings held up without the number of toys being entered into the model as a covariate.

In our MANOVA analysis, for looking toward the big cylinder, we found similar results as in our first analysis. We found no evidence of main effects for phase ($F(1, 36) = .03$, $p = .872$, $\eta_p^2 = .00$) or condition, $F(1, 36) = .49$, $p = .490$, $\eta_p^2 = .01$. The interaction between phase and condition was significant ($F(1, 36) = 7.08$, $p = .012$, $\eta_p^2 = .16$), whereas with the number of toys entered as a covariate in our model this finding was only marginally significant.

Without the covariate entered into our analysis, we replicated our findings for looking toward the small cylinder. Once again, we found no evidence of main effects for phase ($F(1, 36) = .01$, $p = .927$, $\eta_p^2 = .00$) or condition, $F(1, 36) = .48$, $p = .491$, $\eta_p^2 = .01$. Just like before, we found evidence of a interaction between phase and condition, $F(1, 36) = 6.39$, $p = .016$, $\eta_p^2 = .15$.

CHAPTER IV

DISCUSSION

Main Findings

The majority of infants in the Passive mittens training condition increased their looking toward the large cylinder from pre- to post-training, while the opposite pattern was seen for infants in the Active mittens training condition (see Figure 4). Additionally, the majority of infants in the Active mittens training condition increased their looking toward the small cylinder from pre- to post-training, whereas infants in the Passive mittens training condition tended to decrease their looking toward the small cylinder from pre- to post-training. Our analyses show that this effect was not driven by the number of toys that infants were exposed to during mittens training experiences.

We interpret these results to show that experience moving objects through their visual fields during Active mittens training led infants to become more sensitive to the graspability of the smaller cylinder. While the big cylinder likely initially caught their attention, after training, infants in the Active mittens condition appear to have overcome this bias to look toward more visually salient stimuli. On the other hand, infants in the Passive mittens training condition appeared to show a stronger preference for the large object after mittens training. It is possible that infants in this condition habituated to the size of the series of lightweight toys presented by the experimenter during the training procedure, and therefore, after training, these infants might have found the larger cylinder

more novel and interesting to look at. The Passive mittens training experience seems to have prompted infants in this condition to increase their preference for the large cylinder. This effect could potentially be detrimental to infants' object exploration opportunities if it were to be maintained in the long term, but due to the short duration of mittens training in this study, we do not foresee this as a valid concern. In light of this finding, however, we might recommend that parents and caretakers seek opportunities for infants to engage in active exploration rather than passive observation of adults interacting with toys.

How Our Findings Relate to Extant Research

The findings of the current study corroborate previous research showing that infants who are more skilled reachers tend to show a preference for smaller, more easily manipulated cylinders over larger, more cumbersome cylinders (Libertus et al., 2013; Newman et al., 2001). Our results indicate that just eight minutes of experience actively manipulating objects led three-month-old infants to increase their looking toward the small and decrease their looking toward the large cylinder. While previous sticky mittens research has established that infants show increases in object exploration after short durations of active mittens training, this is the first study to show that infants' sensitivity toward the properties of objects can be manipulated via this early motor intervention.

As Adolph & Avolio (2000) found that walking infants adjusted their decisions based on their current motor abilities when wearing heavy or lightweight vests, the current findings show that three-month-old infants consider their newfound abilities to interact with objects when deciding which objects to visually explore. Of course, we do not expect that this preference for smaller objects of exploration would be maintained

after such a short duration of mittens training. Rather, these findings are interesting because they hint that infants are rapidly learning about their abilities and the effects they have on their surroundings during sticky mittens training. Infants' visual preferences appear to be quite sensitive to improvements in motor abilities. Future work might explore whether sticky mittens training could also increase infants' sensitivity toward other affordances of objects.

Limitations

One limitation of the current study is that we only based infants' preferences solely on their looking behavior. Unfortunately, although sticky mittens training has been shown to lead to an earlier onset of successful reaching (Libertus & Needham, 2010), eight minutes of training was not sufficient to show such effects. The frequency of infants' reaching directed toward the cylinders was minimal in the current study. While this is not surprising given that the three-month-old infants in the current study participated in only one training session, a longer mittens training experience might allow us to more reliably assess infants preferences if we could measure both reaching and looking behaviors.

The external validity in the current study is another limitation. The striped cylinders used as stimuli in this study may not reflect the complexities of the visual scenes that infants experience on a daily basis when choosing which objects to explore. While the highly similar appearances of the two cylinders allowed us to control for other factors that may influence infants' preferences, future work might examine whether these

findings would also hold up in more realistic settings with objects that infants might encounter outside of an experimental setting.

Lastly, the demographic characteristics of infants who participated in this study are far from representative of the overall population of the United States. There was little ethnic diversity in this group, and the parents of these infants were highly educated. More than 90% of the parents of these infants reported obtaining a degree from a 4-year college, and more than 60% of parents had obtained or were pursuing a graduate degree. Given the unique demographic characteristics of the infants who participated in the current study, we hesitate to generalize our findings to the wider population. Rather, we would recommend that further studies investigate the effects of sticky mittens training among more diverse populations of infants. Extant sticky mittens research, conducted with typically developing infants from middleclass households, suggests that this early motor intervention has great potential to benefit infants who are at risk for motor delays.

Conclusion

This study adds to existing studies using the sticky mittens paradigm by showing that Active mittens training has the capacity to draw infants' attention toward the affordances of objects. Infants who participated in just eight minutes of Active mittens training looked more toward the small cylinder, which is potentially graspable, during post-training compared to during pre-training. On the other hand, infants in the Passive mittens training condition looked more toward the large cylinder during post-training compared to during pre-training. The experience of interacting with small toys and experiencing the contingency of moving toys through their visual fields appears to

increase infants' sensitivity to the size of objects. This early motor intervention led to patterns of looking more similar to older infants with more advanced reaching skills (Libertus et al., 2013). This is beneficial because infants are likely to be more successful in manipulating a smaller object rather than a larger one. The contributors to infants' object preferences are important because they determine infants' learning opportunities. The current findings show that developments in infants' own reaching abilities lead them to prefer different objects, thus influencing which objects infants learn about.

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