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The effect of object contact on pre-reaching infants' causal perception.

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Abstract

The Sticky Mittens (SM) paradigm is an object manipulation task that provides infants the opportunity to explore objects through active experience before they have the necessary motor skills to do so on their own. Positive cognitive outcomes like increased attention to objects, object engagement, object exploration, and causal perception have been shown to result from active SM experience (Libertus & Needham, 2010; Rakison & Krogh, 2012). Researchers are interested in understanding which aspects of SM training are important for infant learning. Although there have been many SM studies looking at different variables, such as active vs. passive experience and parent encouragement, the role of infant contact with the toys has received little focus. The present study investigates the role of infant contact with toys during the SM experience. Holt (2016) investigated the effects of active vs. passive SM experience and parent encouragement vs. no parent encouragement on infants' learning and found that infants in the active, no parent encouragement group exhibited causal perception whereas infants in the active, parent encouragement condition did not. The present study includes a secondary analysis of Holt (2016), comparing infants' physical contact during the active SM sessions. I hypothesized that infants in the active, no parent encouragement condition exhibited causal perception due to a longer duration of physical contact with the toys. Videos from Holt's (2016) active, parent encouragement and active, no parent encouragement conditions were coded to compare the overall proportion of object contact across conditions. No difference was found between the two conditions for proportion of object contact, suggesting that other factors in the SM training led to infants' learning.

Introduction

For several decades, developmental researchers have been interested in the role that active experience plays in young infants' learning (Libertus & Needham, 2010; Needham et al. 2002; Rakison & Krogh 2012). As infants develop, physical experience like reaching and grasping for objects becomes increasingly important in cognitive development and learning (Rakison & Woodward, 2008). Reaching and grasping for objects are among the earliest emerging physical skills that allow infants to actively interact with the environment around them. Prior to four months of age, infants do not have the ability to reach and grasp for objects because they do not possess the fully developed motor skills that are necessary for such action (Rochat, 1989). This has led researchers to develop the Sticky Mittens (SM) training paradigm to study the cognitive effects of reaching, grasping, and object manipulation for inexperienced, pre-reaching infants (Needham et al. 2002). In the SM task, pre-reaching infants wear Velcro covered mittens to interact with other objects covered in Velcro, allowing the infants to manipulate objects before they have the physical skills to grasp on their own. Positive cognitive outcomes like increased attention to objects, object engagement, object exploration, and causal perception have been shown to result from active SM experience (Libertus & Needham, 2010; Rakison & Krogh, 2012). Underlying mechanisms of SM experience is helpful for infant cognition and learning, which is what the present study hopes to address.

In the original SM study by Needham et al. (2002), three-month-old infants were assigned to one of two conditions: an experimental SM condition and a control condition. The experimental SM condition involved an experimenter visiting the infants' homes and training the parents in facilitating the SM sessions with the Velcro-covered toys and mittens. During these play sessions, parents were instructed to tap and draw attention to the objects if the infant did not

swat at the objects spontaneously and to remove the toys from the mittens and reset the toys if the infant made contact with them. Infants in the experimental SM condition participated in daily 10-minute SM play sessions for two weeks. Infants in the control condition did not receive any SM experience. Infants in both conditions were then brought to the lab for test trials assessing their looking and reaching behavior to Velcro-covered objects with and without SM and object exploration skills using novel objects. Needham et al. (2002) found that infants in the experimental SM condition had higher exploration time and exhibited more intentional swats compared to infants in the control condition. The researchers concluded that the SM experience was beneficial to pre-reaching infants' object exploration ability.

In a follow up study, Libertus and Needham (2010) replicated the Needham et al. (2002) SM play sessions to look at the role of active versus passive SM experience on infants' object exploration. In this study, three-month-old pre-reaching infants were randomly assigned to either an active or passive condition. The active condition involved SM experience where the parent demonstrated how the Velcro-covered objects attach to the mittens, followed by the infants having independent interaction for the remainder of the session. In the passive condition, the parents were instructed to move the toys (non-Velcro covered) around on the table for the entire duration of the play session. Infants in the passive condition had the same exposure to the mittens and toys but the mittens prevented them from engaging in self-produced reaching and grasping because the mittens covered their fingers, and the toys did not stick to the mittens. Libertus and Needham (2010) concluded that infants from the active condition had increased reaching and grasping and showed changes in their visual attention to objects compared to infants in the passive condition.

SM experience has also been used to investigate how infants' interaction with the world around them may facilitate their cognitive development and causal perception. Causal perception, or physical causality, is a fundamental component of infants' ability to understand their surroundings (Piaget, 1954). Infants do not typically show evidence of causal perception until 6 or 7 months of age, but active SM experience has been shown to promote causal perception in younger, pre-reaching infants (Cohen & Amsel, 1998). Causal perception in infants is typically evaluated using a visual habituation paradigm in which infants are shown a causal (e.g., Ball 1 rolls into Ball 2 and Ball 2 immediately rolls away) or a non-causal (e.g., Ball 1 rolls into Ball 2, followed by a 1-second delay before Ball 2 rolls away) Michottian launching event. The infant's duration of visual attention is measured over repeated exposures of the event. Infants have been "habituated" to the event once the duration of their visual attention to the repeated event significantly decreases. Once infants have been habituated, they are expected to have increased visual attention to a novel stimulus, presented in test events. Test events include the same event the infant is habituated to along with novel variations of the launching event (e.g., if the infant was habituated to a causal event, they would also be shown two non-causal events). The infants' durations of visual attention during these test events are then compared. An infants' understanding of physical causality can be inferred if the infants' visual attention times during the test phase for the habituated event are significantly lower compared to the two novel events. This indicates that the infant can differentiate between causal and non-causal events.

Causality was investigated in relation to SM training in a 2012 study by Rakison and Krogh. In this study, pre-reaching infants were provided SM training followed by an infant visual habituation task to assess their understanding of physical causality (e.g., one ball rolling into another ball, causing the second ball to move). The researchers hypothesized that active SM

experience may promote infants' development of causal perception because the SM experience mimics infants' interaction with real world causal events. In this study, infants were seated on their parent's lap behind a table and parents were instructed not to talk or interact with their infant. The infants were randomly assigned to either an active or passive condition. In the active condition, the infants wore Velcro-covered mittens and interacted with four Velcro-covered balls. In the passive condition, the infants wore mittens with no Velcro attached and interacted with four balls that were glued and anchored down, meaning they were unable to move the balls around but could still move themselves in the same way as infants in the active condition.

Once the SM session concluded, infants in both the active and passive conditions participated in a causal perception habituation task. Infants were habituated to a causal Michottian launching event (e.g., Ball 1 rolls into Ball 2, and Ball 2 immediately rolls away) before being shown three test events: a familiar causal event, a novel causal event, and a novel non-causal event. Rakison and Krogh (2012) hypothesized that because infants in the active condition had experience with SM, they would look at the novel causal event and the novel non-causal event for a longer duration compared to the familiar event, reflecting causal perception of the events. Results confirmed that the infants in the active SM experience condition did exhibit causal perception in the habituation task, whereas infants in the passive condition did not, indicating that causal perception was facilitated by infants' early active experience.

The previously described research shows that active SM training produces positive cognitive results in pre-reaching infants such as increased visual attention, ability to reach and grasp objects, and causal perception. However, the question remains as to why active SM training leads to these positive outcomes. In 2016, a study was conducted in the University of Louisville Infant Cognition Lab to address this question by looking at the role of parent

encouragement, in addition to active SM experience. In a replication and extension of Rakison and Krogh (2012), Holt (2016) explored the effects of active vs. passive experience and parent encouragement vs. no encouragement during SM training on pre-reaching 4-to-5-month-old infants' causal perception. In this study, infants were randomly assigned to one of five conditions: a control condition (no SM play session) or one of four experimental SM training conditions from a 2x2 design (active vs. passive; parent encouragement vs. no encouragement). In the active condition, parents were instructed not to interfere with the movement of their infant. In the passive condition, however, parents were instructed to guide their infants' hands to the balls. In the parent encouragement condition, parents were instructed to verbally encourage their infant during the SM task. In the no encouragement condition, parents were instructed not to talk to their infant during the session.

Once the SM sessions concluded, infants in all five conditions completed a visual habituation task modeled after that described in Rakison and Krogh (2012). The visual habituation task was used to assess infants' ability to differentiate between causal and non-causal Michottian launching events through one of two non-causal events, either a delay (Ball 1 rolls into Ball 2 with a temporal delay before Ball 2 moves) or gap event (Ball 1 rolls near Ball 2 without contact but ball 2 moves as if the first collided). After infants were habituated to either the delay or gap event, they were shown three test events in a random order: a familiar event (the same non-causal event they were habituated to), a novel non-causal event (the other non-causal event they were not habituated to), and a novel causal event (infants had not seen). If an infant exhibits causal perception, they should respond visually to the test events on the basis of causality, meaning that infants should look longer only at the novel causal event they had not seen previously compared to the non-causal event that was familiar. In contrast, if infants do not

have causal perception, they should look at the novel causal and novel non-causal events longer compared to the familiar event since they are both novel events. Holt (2016) concluded that only infants in the active/no encouragement condition showed evidence of causal perception, which is consistent with findings from Rakison and Krogh (2012) and other previous SM studies showing the importance of active experience.

Holt's (2016) findings are unique, however, because infants in the active/encouragement condition did not show any evidence of causal perception. Previous SM research has shown causal perception from infants in an active and "encouragement" condition where the parent can interact with their infant naturally (Libertus & Needham, 2010; Needham et al., 2002). This suggests that parents' behaviors during training is also an important factor in infant learning, but the underlying mechanism for this finding is still unclear.

One possible explanation is that infants' visual attention during the SM play session may have been negatively affected by the parents' behaviors in the active/encouragement condition. A study by Mason et al. (2019) investigated how infants' attention to objects can be affected negatively by parent interactions. In this study, a group that had parents redirect their infants' attention a high proportion of times showed to increase the infants' gaze shifting during the play session, which was classified as distraction (Mason et al., 2019). To further explore this, a secondary analysis of Holt's two active conditions was conducted by Olesen (2021), where parents' physical interactions and infants' visual attention were coded and compared across conditions. This secondary analysis was used to investigate whether the parents' interactions disrupted the infants' attention, therefore inhibiting the infant from developing casual perception. Olesen (2021) found no significant differences between the active/parent encouragement and active/no parent encouragement conditions on infants' visual attention to objects and the amount

of parent interaction. However, Olesen (2021) did find that infants in the active/parent encouragement condition were significantly more likely to go off task following a parent interaction compared to infants in the active/no parent encouragement condition, which suggests that parents in the active/parent encouragement condition distracted their infants from the SM session.

A second potential explanation for Holt's (2016) findings is that infants in the active/no encouragement condition had more physical contact with the balls during the SM session, promoting causal perception. Rochat (1989) explains that infants' exploratory activities are refined in the first year of life through the coordination between the different perceptual systems including visual, haptic, and oral. When infants are exposed to early motor, sensorimotor, and action development they show increased strength of hand-eye and hand-mouth coordination in addition to the development of grasping of objects. A study by Gibson and Walker (1984) found that after oral haptic familiarization, one-month-old infants can detect and recognize the substance of objects, which indicates that haptic experience of the hands and mouth helps infants learn information about objects. It follows that the physical contact (haptic experience) infants practice during SM may help explain their development of causal perception.

The purpose of the present study was to investigate this possibility by comparing the proportion of time infants spent in physical contact with the balls in the active/no parent encouragement and active/parent encouragement conditions during SM play sessions. It was hypothesized that infants in the active/no parent encouragement condition exhibited causal perception due to a longer duration of physical contact with the balls, suggesting that infants' haptic experience is an important factor in SM training and infant learning. To test this hypothesis, a secondary analysis was conducted on SM training videos of infants in Holt's

(2016) two active groups (encouragement/no encouragement). Infants' contact with the balls was coded offline and proportion of total time spent in contact was compared across the two conditions.

Method

Participants

The current study is a secondary analysis of recorded SM videos from Holt (2016). The participants included 35 4-month-old infants (16 females and 19 males, *Mage* = 4.27, *SD* = 0.49, Range = 3.54 – 5.29). Only infants in the active/parent encouragement (AE) condition (*N* = 18; 10 females; M_{age} = 4.34, *SD* = 0.51, Range = 3.61 – 5.26) and active/no parent encouragement (AN) condition (*N* = 17; 6 females; M_{age} = 4.18, *SD* = 0.48, *Range* = 3.54 – 5.29) were included in the analysis. All the participants were considered healthy and full-term (i.e., gestational age of >36 weeks and weight >5 lbs.) with normal hearing and vision. The caregivers self-reported the race and ethnicity of the infants. Thirty infants were White/non-Hispanic, two were multiracial/non-Hispanic, two were multiracial/Hispanic, and one was Black/African American/non-Hispanic.

Participants in the pre-recorded SM videos were recruited through flyers, social media postings, university listservs, and word of mouth. Additionally, letters of invitation were sent to families from a list of infants born in the Louisville area within the 4-month-old age range provided by the Kentucky Cabinet for Health and Family Services of infants (Holt, 2016). Upon the completion of the study, participants were given a small gift (e.g., a t-shirt for the infant).

Procedure

In the SM play sessions from Holt's (2016) original study, infants were seated on their parent's lap across a small table from an experimenter. Infants wore a pair of custom-made

mittens with Velcro sewn onto the palms. In front of the infant on the table were four yellow balls covered in Velcro on a white tray. In the play session, the Velcro on the balls would stick to the Velcro on the mittens when infants reached for the balls. Once infants were in contact with the balls for about 10 seconds either the parent or experimenter removed the balls from the mittens, reset the balls on the table, and readjusted the infant's mittens. Parents in the AE condition were given instructions to encourage and praise their infant during the play session whereas parents in the AN condition were instructed not to talk to their infant at all during the play session. SM play sessions typically lasted around 10 minutes but ended early if an infant became too fussy to continue.

Coding

The infant behavior in the SM session was coded frame by frame by a trained experimenter using Datavyu (2014). Infant physical contact was coded into one of three categories: "contact" (C; when the infant is in physical contact with the balls), "no contact" (NC; when the infant is not in contact with the balls), or "ambiguous" (A; when physical contact cannot be clearly determined), seen in Figure 1. These codes were mutually exclusive and exhaustive for infant contact. The onset and offset times of each code began when the infant started the behavior and ended when the infant stopped the behavior or started a new behavior.

Figure 1

Example Views of SM Sessions

Contact No Contact Ambiguous

Data Processing

The durations of each behavior were calculated using the onset and offset times (in milliseconds) from Datavyu. A minimum bout duration was set, meaning if a behavior lasted less than one second, it was interpolated into the preceding behavior bout instead of being thrown out (Ruff, 1986). For example, if a "contact" behavior bout that lasted for 3 seconds was followed by a "no contact" behavior bout that lasted for 0.5 seconds, the "no contact" behavior bout would be recorded as "contact" and the length of the first "contact" behavior would be recorded as lasting for 3.5 seconds. Proportion of overall contact was calculated as the total duration of infant contact divided by the combined total of time the infant was in contact or not in contact with the toys during SM play session (duration of ambiguous activity was not included in the total duration).

Reliability

To check the reliability of the coding, 25% (9 total) of the coded videos were re-coded by an additional expert coder. In the reliability coding, the expert coder was blind to the participants' condition. Reliability coding was performed on the entirety of the nine randomly

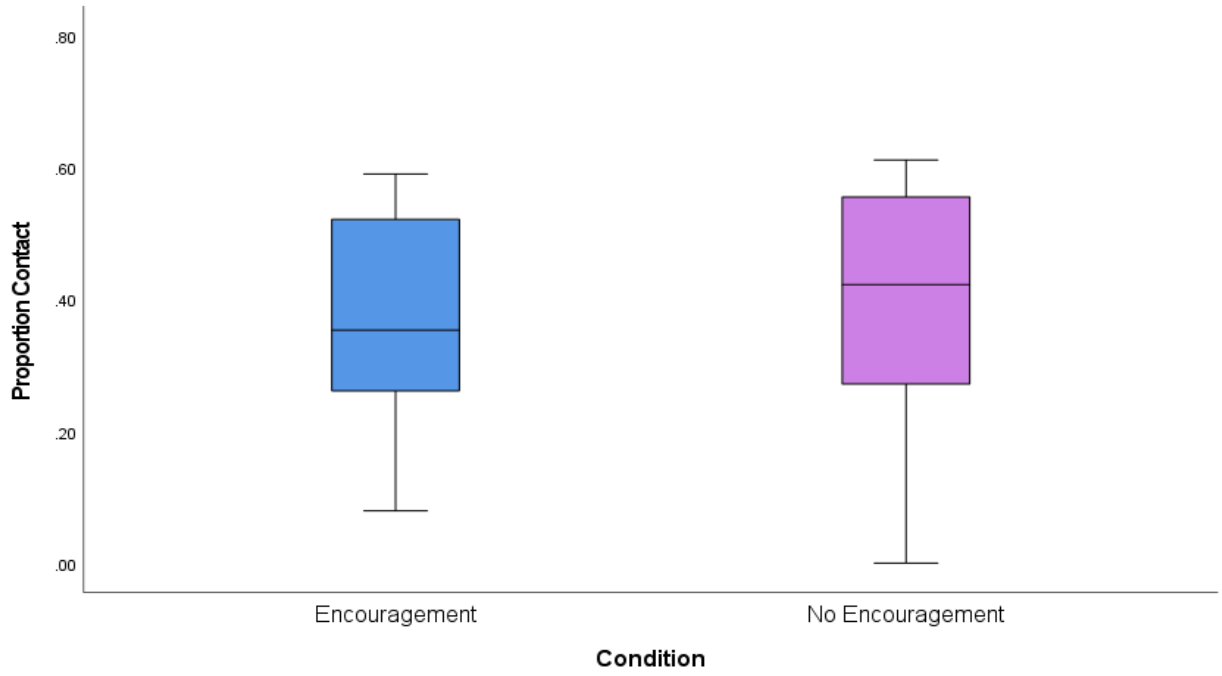
selected videos. The coding was deemed reliable if the original experimenter and expert coder had an overall agreement of at least 90%. Percent agreement between the original experimenter and the expert coder for the infant contact ranged from 83.33% to 100% with a mean of 96.51%.

Results

Nonparametric tests were used due to the limited sample size of the study. Outliers in the data were defined as values that did not fall within three standard deviations of the mean. There were no outliers detected. Proportion of overall contact was determined by calculating total time infants were in contact with the balls during the play sessions divided by the total SM play session duration to account for different play session lengths (see boxplots for each condition in Figure 2). A Mann-Whitney U test was conducted to determine if there was a difference in the proportion of contact between groups. There was no significant difference found between the proportion of time in contact with the balls for infants in the encouragement condition (*Mdn* = 0.35, *IQR:* 0.26 – 0.53) and those in the no encouragement condition (*Mdn* = 0.42, *IQR:* 0.23 – 0.57), $U = 168.00$, $z = .495$, $p = .636$, $r = .08$.

Figure 2

Infant Contact with Toys by Condition



Discussion

In the current study, video files from Holt (2016) were used for a secondary analysis to investigate the effect of object contact on pre-reaching infants' causal perception. It was hypothesized that infants in the active/no parent encouragement condition exhibited causal perception due to a longer duration of physical contact with the balls. Infants' proportion of overall contact with the balls during the SM task was compared across an active/parent encouragement condition and an active/no parent encouragement condition. However, no significant difference between groups on proportion of overall contact was found. These results are surprising given the established connection between haptic experience and several aspects of cognitive development (Rochat, 1989; Gibson & Walker, 1984). The hypothesis followed that object contact may have been greater for the group that exhibited causal perception in the present

study. However, there is a general lack of literature on object contact during SM in relation to infants' causal perception, which underscores both the importance of the present study and the need for more research.

Several limitations of the present study may help explain why results did not align with what was hypothesized. First, it is possible that infant contact was influenced by parent interactions during the SM play sessions. Parents were given specific instructions about encouragement during a training period before the SM play session. Parents in the active/parent encouragement condition were instructed to talk and encourage their infant whereas parents in the active/no parent encouragement condition were instructed not to talk at all throughout the SM session. Even though parents were given these instructions, not all parents followed the instructions, which could have impacted the amount of time infants were in contact with the balls. Olesen (2021) found that parents in the active/parent encouragement condition distracted their infants during the SM task, which may have prevented them from experiencing the full effects that SM training has on causal perception. The SM videos do not have sound, so it is difficult to assess the extent to which parents followed the directions during the session.

Second, this study has a small sample size of only 35 infants, which is acceptable for the statistical tests used, but power could be improved with a larger sample. Additionally, the video files used were not intended to analyze these variables since they were taken from a previous study. There are some instances where infant contact cannot be determined because of the camera angle, necessitating the ambiguous code.

Future studies should continue to investigate the role of infants' haptic experience in their development of causal perception. It may be interesting to incorporate infant attention into these studies. It is possible that infant attention in combination with infants' physical contact with the

balls could contribute to the exhibited causal perception in the active/no parent encouragement condition in Holt (2016). Future research could also design a SM study specifically looking at infant contact using multiple camera angles and equipment with sound.

Overall, the current study plays an important part in understanding the role of infants' physical contact on the development of causal perception during SM experience. While there were no significant differences found, more research is needed to fully understand the effect of infants' physical contact on causal perception.

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Appendix

Coding Manual

Video coding will be conducted in Datavyu and the onset and offset times will be recorded for durations of infant contact. The coding will consist of timed-event recording for a mutually exclusive and exhaustive coding scheme. The coding scheme is considered mutually exclusive and exhaustive because only one code within each set applies (Bakeman & Quera, 2011). Video coding will include individual onset and offset times for each behavior listed below.

Coding Rules

- Coding in Datavyu will begin immediately following experimenter instructions and initial parent example. Parent example will involve parents' putting the mittens on their infants and then guiding their infants' hands to the balls and attempting to then draw their infants' attention to the balls/mittens (see Sticky Mittens Instructions for more details).
- Coding will end when it is clear the experimenter has ended the play session (i.e., the experimenter and parent begin talking and the parent moves the infant away from the table, removes the mittens, etc.) or until the video ends (these might coincide).

Codes in Datavyu:

Infant Contact	
Code	Definition
STOP	When the parent and baby leave the table – this ends when the parent and baby are back and prepared to play (mittens on, facing table, etc.). Note – this begins when

	parent takes mittens off in preparation to leave table, or picks baby up and leaves the table.
C	"Contact" - Infant is in contact with the balls (balls stick to mittens or mittens appear to touch balls).
NC	"No Contact" - Infant is not contact with the balls.
A	"Ambiguous" - It cannot be determined if infant is in contact with balls. This occurs when something is obstructing the view of the camera (e.g., a parent's arm, hair, etc.). This does not occur often.