Impact of Environmental Cues and Functional Tool Use on the Grasp of Transitioning Infants: A Pilot Study

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Abstract

Occupational therapy addresses fine motor skills throughout the lifespan, but there is limited evidence for how understanding a functional tool's purpose and the presence of environmental cues impact a transitioning infant's grasp pattern. Therefore, the researchers sought to determine if transitioning infants alter grasp on a functional object with the presence of an environmental cue. In a quasi-experimental study of transitioning infants aged 12 to 16 months *(N*=13), researchers presented a marker to participants with and without the presence of paper to determine the impact of environmental cues on functional tool use and grasp patterns. While trends in data were seen, there are no statistically significant findings as a result of this pilot study. The results confirm a trend in overall right-handed preference for transitioning infants when using a functional tool. On average, the transitioning infants initially make contact with the marker faster, maintain functional use of the marker longer, and utilize a more mature grasp pattern with the presence of an environmental cue. Future research is needed to confirm the impact of environmental cues on the development of transitioning infant grasp patterns. When working with transitioning infants, occupational therapists need to consider all environmental factors that may impact fine motor skills as they relate to functional tool use.

Impact of Environmental Cues and Functional Tool Use on the Grasp of Transitioning Infants: A Pilot Study

Occupational therapists work to increase engagement and participation in occupations throughout the lifespan by improving an individual's body functions and performance skills, altering tasks and activities, or adapting the environment (American Occupational Therapy Association [AOTA], 2014). A primary focus of occupational therapy is to assess and provide intervention for fine motor skills by targeting client factors such as control of voluntary movement and performance skills including gripping, manipulating, and coordinating (AOTA, 2014). Grasp is used in everyday functioning throughout all stages of life for engagement in occupations. By definition, grasp is opening, shaping, and closing the hand on an object based on the features of the object (Thomas, Karl, & Whishaw, 2015). The development of grasp has typically been seen as a sequential pattern (Cronin & Mandich, 2016), originating with an ulnar palmar grasp and progressing to a dynamic tripod by 12 months of age (Butterworth, Verweij, & Hopkins, 1997; Cronin & Mandich, 2016; Sgandurra et al., 2012). External factors, such as object orientation, symmetry, and environmental cues, have been found to influence grasp patterns from infancy to toddlerhood (Barrett & Needham, 2007; McCarty, Clifton, & Collard, 2001).

Researchers have examined various factors affecting grasp development in infancy including body scaling (Huang, Ellis, Wagenaar, & Fetters, 2013), visual perception (Berthier & Carrico, 2010), and object orientation (Claxton, McCarty, & Keen, 2009). Prior research has also examined how an infant perceives the functional use of objects (McCarty et al., 2001) but not how understanding the use of a tool impacts the infant's choice of grasp pattern. Adults easily perceive affordances and environmental cues, which leads to the use of a variety of functional

grasp patterns (Huang et al., 2013). The perceived information can be termed "body scaling," which is the foundation of functional actions (Huang et al., 2013). Body scaling is using the perceived size and shape of objects to adapt grasp patterns in relation to the size of the infant's hand (Huang et al., 2013). Contaldo et al. (2013) reported that by 10 months old, an infant is able to select a correct grasp for an object and plan for future action of a tool. By 13 to 15 months, infants begin performing functional tasks that have been modeled by their environment (Contaldo et al., 2013). However, the extent to which transitioning infants, defined as infants between 12 and 16 months of age, functionally alter grasp patterns due to external, environmental cues remains unknown. For the purpose of this research, a functional tool is an instrument that has a designated purpose to achieve specific task objectives, and an environmental cue is an external factor that provides meaning and stimulates understanding of functional tool use. In this case, the functional tool was a marker, and the environmental cue was paper. Therefore, the purpose of this research was to determine if transitioning infants alter grasp and the functional use of a tool with the presence of an environmental cue. It was hypothesized that transitioning infants would grasp the marker faster and maintain a functional writing position longer, as measured by percent of time the tip of a marker was maintained on a surface, when an environmental cue of paper was present. It was also hypothesized that transitioning infants would utilize more mature and functional grasp patterns with paper present.

Because grasp is a crucial component of daily independent occupational performance, infants who experience difficulties with grasp will be delayed in fine motor skills, greatly impacting their ability to engage in developmentally-appropriate activities in all areas of occupations (Libertus, Sheperd, Ross, & Landa, 2014). Early intervention with a focus on fine motor skills has been shown to be effective in establishing proper development throughout

childhood (Cameron et al., 2012). It is important for occupational therapists to understand all factors that impact functional grasp development for infants. If there are more factors affecting grasp patterns such as the presence of environmental cues, then occupational therapists need to incorporate a multi-faceted approach to fine motor intervention with infants and young children.

Literature Review: The Development of Tool Use

The purpose of this literature review is to explore research examining grasp development of transitioning infants. Specifically, research will be presented on the development of tool use and the functional use of a tool for typically-developing transitioning infants. Factors contributing to infant grasp patterns, such as tool function, orientation of objects being grasped, and infant visual perceptual skills will be explored to determine the current understanding of the impact of environmental cues on an infant's method of grasping an object. Some of the contributing factors include how understanding a tool's function, orientation of the tool, and visual perception impact grasp of a tool.

Development of Grasp Patterns

Gesell (1928) was one of the first researchers to acknowledge that as infants develop foundational grasp patterns, more advanced grasp patterns are able to form and build upon preceding patterns. The most primary form of grasp is the power grasp, which uses the entire hand in a fisted position to manipulate an object (Yakimishyn & Magill-Evans, 2002). According to Park (2006), infants begin grasping objects in their environment around 4 months of age using an ulnar palmar grasp to hold the object; this then progresses to radial palmar grasp. By 6 months, infants begin to demonstrate precision grasp patterns, such as raking and lateral grasp (Frankenburg et al., 1992). As infants get older, their use of power grasps continues to decrease, and the use of precision grasps increases (Butterworth et al., 1997). Around 7 to 9 months of age,

radial digital grasps begin to emerge (Cronin & Mandich, 2016). The consistent use of a radial grasp with various orientations of tools indicates advanced planning of function and accomplishing a goal (Claxton et al., 2009).

By 12 months of age, infants have observed grasping, manipulating, and controlling of a functional tool for at least six months as they are spoon-fed (Barrett, Davis, & Needham, 2007). At this stage, infants have also observed that a radial grasp is the most effective way to hold a spoon to accomplish the goal of transporting food to the mouth (McCarty et al., 1999; McCarty et al., 2001). Twelve-month-old infants are typically able to feed themselves with a spoon (Achard & von Hofsten, 2002), demonstrating that development of fine motor skills at this stage allows functional tool use.

As infants age, they are also able to manipulate and use environmental feedback to determine the type of grasp needed to functionally use a tool. McCarty et al. (1999; 2001) found that 14-month-old infants will make corrections in grasp before transporting a spoon to their mouth if it is necessary for the goal to be accomplished. The 14-month-old infants' ability to understand the need to make corrections demonstrates the presence of feedback control, as shown by the infants reaching with their preferred hand and making corrections to accomplish the goal (McCarty et al., 1999).

Grasp Skill Classifications

There are numerous methods to classify grasp patterns, from simple to detailed and complex systems. It may be argued that simple-classification categories of grasp do not include the vast array of grasp patterns utilized on objects of various sizes and shapes. If grasp is only classified in simple methods, misunderstanding of the exact grasp may occur and prehension of tools may not be accurately described (Kamakura, Matsuo, Ishii, Mitsuboshi, & Miura, 1980).

Kamakura et al. (1980) utilized a detailed classification of grasp that included four major categories, with 14 identified grasp patterns. These grasps included standard power, hook power, index finger extension power, extension power, distal power, lateral, tripod, tripod variations 1 and 2, parallel mild flexion, surrounding mild flexion, tip prehension, parallel extension, and adduction. Other researchers have classified clenched grip, ventral clenched grip, transverse digital radial grip, transverse digital ulnar grip, clenched transverse digital radial grip, clenched transverse digital ulnar grip, transverse palmar radial grip, transverse palmar ulnar grip, interdigital grip, and digital palmar grip (Archard & von Hofsten, 2002; Connolly & Dalgleish, 1989) as observed adult grasp patterns. Yakimishyn and Magill-Evans (2002) combined the developmental progression of pencil grasps, as identified by Schneck and Henderson (1990) and Tseng (1998), to classify grasp patterns into a developmental sequence of prehensile grasps that included 14 types of grasps. Yakimishyn and Magill-Evans (2002) then utilized a five-point scoring system to quantify these grasps based on level of maturity. The grasp patterns consisted of radial cross palmar, palmar supinate, interdigital (variations 1, 2, and 3), digital pronate (only index finger extended), brush, grasp with extended fingers, cross thumb, static tripod, four-finger, lateral tripod, dynamic tripod, and quadruped (Yakimishyn & Magill-Evans, 2002). Even though some of these grasp patterns are described in literature exploring grasping of infants and children, they are predominantly observed in research describing mature adult grasps.

More commonly, researchers have classified grasp patterns with simple-classification methods based on the position of forearm, wrist, palm, and digits in relation to the item being grasped (Schneck & Henderson, 1990; Tseng, 1998). The most basic categories of grasp can be radial or non-radial grasp (McCarty & Keen, 2005), as determined by the object's orientation to the radial side of the hand (Achard & von Hofsten, 2002; Claxton et al., 2009; McCarty et al.,

1999; McCarty et al., 2001). Additional types of grasps in these simple categories include ulnar grasp (Achard & von Hofsten, 2002; Claxton et al., 2009; McCarty et al., 1999; McCarty et al., 2001), digital/fingertip grasp (Claxton et al., 2009; Connolly & Dalgleish, 1989:Keen, Lee, & Adolph, 2014), and goal-end grasp (Claxton et al., 2009; McCarty et al., 1999; McCarty et al., 2001). Researchers have further broken down radial and ulnar grasps into categories such as transverse palmar radial (Archard & von Hofsten, 2002), overhand radial, underhand radial, and overhand ulnar (Keen et al., 2014). Some other types of simple-classification categories include power, intermediate, precision, and adduction grasps (Kamakura et al., 1980); primitive, transitional, and mature grasps (Yakimishyn & Magill-Evans, 2002); flexible and non-functional grasps (Achard & von Hofsten, 2002); or developmental and handwriting (Edwards, Gallen, McCoy-Powlen, & Suarez, 2018). Many of the simple-classification methods are used because researchers agree that while grasp can be broken down further, the more detailed classifications still fall within a smaller number of general grasp categories.

Because the purpose of this study was to identify differences in the grasp patterns of transitioning infants, it was important to utilize a grasp classification system that could capture the varied developmental grasps that transitioning infants might use on a writing instrument. Therefore, the researchers used the classification system identified by Edwards et al. (2018), which divides grasp patterns into the primitive developmental grasps and the more mature handwriting grasps (See Table 1).

Table 1

Classification of Developmental and Handwriting Grasp Patterns

Developmental Grasps	Handwriting Grasps
• Reflex Squeeze • Crude Palmar • Palmar • Radial Palmar • Raking Grasp • Radial Digital • Developmental Scissors • Inferior Pincer • Three Jaw Chuck • Pincer • Neat Pincer	• Radial Cross Palmar • Palmar Supinate • Digital Pronate • Brush Grasp • Grasp with Extended Fingers • Static Quadrupod • Cross Thumb • Static Tripod • Lateral Tripod • Dynamic Quadrupod • Lateral Quadrupod • Dynamic Tripod • Interdigital Tripod

Orientation and Hand Preference

Object orientation is another component to examine when looking at grasp because the way an individual visually perceives the length and shape of an object will influence how he or she grasps the object (Claxton et al., 2009). Researchers in multiple studies alternated between left and right object orientation when presenting objects to the infant in order to control for bias (Barrett et al., 2007; Claxton et al., 2009; McCarty & Keen, 2005; Yakimishyn & Magill-Evans, 2002). Researchers have placed objects in midline in either the upright position or facing toward or away from the infant for a more neutral orientation approach (Achard & von Hofsten, 2002; Fagard & Lockman, 2005). In a study by McCarty, Clifton, and Collard (1999), the 9- and 14-month-old infants consistently reached for a spoon in any orientation with their preferred hand.

Fagard and Lockman (2005) discussed that although not always consistent at a young age, the majority of infants are right-handed, as most subjects over the age of 12 months used a predominantly right hand strategy across all trials. Claxton et al. (2009) agreed with prior

research findings that the majority of infants have a right-hand preference, saying that there was a faster preparation when using the right hand in grasp tasks. Cox and Smitsman (2006) found that children under the age of two years old do not tend to use goal-directed information such as the functional use of an object in deciding which hand they will use to grasp an object. In this study the researchers consistently presented the marker in midline to allow for greater variability of grasps for a functional purpose and to decrease bias for hand preference.

Visual Perception and Feedback

Schneck and Case-Smith (2015) described visual-motor skills as an individual's "ability to integrate the visual image of letters or shapes with appropriate motor response" (p. 500). Infants use their visual-motor skills to help refine grasp based on visual feedback. Once an infant develops the ability to integrate visual input with the motor skills of reaching and grasping, they can successfully and functionally grasp objects (Dankert, Davies, & Gavin, 2003). Visual perception allows infants to see a tool and purposefully reach for and grasp it (Berthier & Carrico, 2010). The infant does this by using his or her improved vision to create more precise motor movements of the hand (Berthier & Carrico, 2010). With this improved motor precision and understanding of their hand, infants must use their haptic feedback to manipulate their grasp on the functional tool (Berthier & Carrico, 2010). During the late part of the first year of an infant's life, refinements with respect to motor planning and use of haptic feedback transform less stable initial grasps into more stable grasps (Barrett & Needham, 2007).

Understanding of Function

If there is a known function for an object, infants are more likely to grasp the object in a way that is helpful to the execution of the function (Barrett et al., 2007; Claxton et al., 2009; Keen et al., 2014). When knowing the functional use of an object, an infant tends to grasp the

correct area that enables proper use of a tool, such as the handle of a hairbrush instead of the head of the hairbrush. However, when there is an unknown function or absence of function, an infant will grasp any part of the tool (Claxton et al., 2009). Infants aged 12 to 18 months old who were presented with a spoon tended to grab the handle of the spoon; however, if they were presented with a novel tool that resembled a spoon in appearance, they grasped varying parts of the tool (Barrett et al., 2007).

McCarty et al. (2001) used four different objects to determine when infants began to functionally use the tools, representing understanding of function. McCarty et al. (2001) found that at around 14 months of age, infants were more likely to effectively use the tools in the correct functional manner. The researchers also found that infants were more effective in using the tools and performing tasks that were self-directed rather than other-directed or object-directed (McCarty et al., 2001). Researchers have found that infants as young as 6 to 10 months old recognized object properties and the surface on which the object lies and utilized these properties to adapt their haptic exploration and manipulation of the object (Bourgeious, Khawar, Neal, & Lockman, 2005; Morgante & Keen, 2008). Thirteen-month-old infants obtained objects faster than 11-month-old infants, possibly due to greater ability to understand function as well as having greater motor control (Barrett & Needham, 2007).

Functional Tool Use: Crayons

Infants tend to begin to make marks on paper with a writing instrument shortly after their first birthday (Bayley, 2006); therefore, it is important to understand the best writing instrument to enhance maturity of grasp development. Morgante and Johnson (2011) found that while 12-month-old infants are able to grasp a crayon and show the emergence of object manipulation to influence function, it was more prominent and effective in 18-month-old infants. This shows that

the understanding of functional objects and grasp develops early and progresses with age. Simple mark-making with a crayon emerges around 12 to 14 months of age, and the progression to line drawing emerges around 15 to 24 months (Dunst & Gorman, 2009).

Young children are more interested in colored tools than standard pencils (Yakimishyn & Magill-Evans, 2002). Infants produce larger quantity and better quality of scribbling when there is visual feedback from the utensil (Berefelt, 1987; Dunst & Gorman, 2009). In terms of size of the utensil, standard-sized crayons and magic markers, as opposed to primary-sized, are typically associated with more mature and complex marking (Dunst & Gorman, 2009). A standard-sized marker was used in this study based on the belief that transitioning infants would have experience with markers. Because it only has one functional end, the marker was also used to encourage the infant to use a more purposeful grasp on the marker toward the functional end, as opposed to a crayon that can be used functionally from both ends.

Environmental Cues

It has been found that infants change the speed in which they reach for an object and the grasp pattern they use to pick up an object based on what they intend to do with the object after retrieving it (Claxton, Keen, & McCarty, 2003). Barrett et al. (2007) found that infants were faster at grasping an object when they understood the function because they were motivated to produce the function. This shows that infants are able to use cognitive planning skills to adjust their grasp patterns based on environmental cues, their perception of the object's properties, and their perception of the object's function. Keen et al. (2014) determined environmental cues changed the way four-year-old children grasped a spoon to accomplish the task of feeding. The four-year-old children used a radial fingertip grip for self-feeding; however, they used an ulnar grip when the feeding task was externally directed, specifically toward a puppet (Keen et al.,

2014). These children modified the grasp based on the environmental cue of the puppet. In the current study, the addition of a piece of paper was similar to the presence of the puppet. Because the impact of environmental cues on functional grasp patterns in transitioning infants is still unclear, research was conducted to determine the change in functional use of a writing instrument with and without the presence of an environmental cue.

Methods

Study Design

The researchers used a quasi-experimental, repeated measures study design to examine the impact of an environmental cue such as paper, on the grasp patterns and functional tool use of transitioning infants. Using this design, the researchers completed two trials with each participating infant. In each trial, the transitioning infant was presented with a marker. However, on the second trial, the primary researcher also supplied the infant with paper to determine if the transitioning infant used a more mature grasp on the marker, grasped the marker quicker, or maintained the marker on the surface longer when paper was provided.

Recruitment Procedures

Following Human Research Protections Program (HRPP) approval, the researchers distributed informational flyers to daycare facilities in Indianapolis, Indiana. The informational flyer provided a brief description of the study and included researchers' contact information. Additionally, a packet of information including the informational flyer, informed consent documents, and a brief questionnaire was given to the guardians of infants who would be between the ages of 12 and 16 months at the time of the study. The researchers were also available during predetermined times at the daycare facilities to provide additional information about the research study and answer any questions. At that time, if guardians wished to include

their infant in the study, the researcher reviewed the informed consent document with the guardian and obtained consent.

Participants

Participants included 12- to 16-month-old infants at the time of testing who attended approved daycares in Indianapolis. Infants with a diagnosed developmental delay or who had an injury or impairment affecting the use of their upper extremity were excluded from the study.

Procedure/Data Collection

The instruments needed to conduct the study included one piece of white 8.5”x11” paper per participant, clear tape, and a standard-sized, non-toxic, dried out red marker. Guardians completed a brief questionnaire about their infant’s experience using a writing instrument such as a crayon, pencil, pen, or marker and to ensure their infant met the inclusion criteria (See Appendix A). On the day of testing, the infant’s classroom teacher also completed a short questionnaire about the typical writing experiences in the classroom (See Appendix B). An iPad or iPhone encrypted with a passcode was used to record the intervention sessions.

Prior to data collection, the principal investigator trained all researchers on the appropriate procedures to conduct the intervention in a consistent and reliable manner. Consistent with past research, the trials took place in the infant’s daycare classroom to maintain ecological validity (Fagard & Lockman, 2005). This allowed the infant to be in a comfortable, familiar environment where the infant may have previously engaged in the activity of coloring with markers (Fagard & Lockman, 2005). The infant was seated at a child-sized table in the daycare classroom with a primary researcher seated across from the infant throughout both trials. A second researcher was located behind the primary researcher and recorded the session with an

encrypted iPad or iPhone. In the view of the camera, a label identifying the participant number was included to reduce risk of error during transfer of videos for storage.

Video recording began approximately five seconds before initiation of the first trial and continued through the end of the second trial. The primary researcher performing the trials presented an uncapped, non-toxic, dried out marker at the infant's midline using a fingertip grasp. Transitioning infants have had minimal experience with this type of grasp (Claxton et al., 2009; Connolly & Dalgleish, 1989); therefore, presenting the marker in this way minimizes the learned effect. As the researcher presented the marker on the table within reaching distance of the infant, the researcher only used the verbal phrase "here you go" to begin the trial. After the uncapped marker was presented to the participant, the infant was given one minute to make contact with the marker. If the infant did not make any contact with the marker within the first 10 to 15 seconds, the researcher cued the infant by pointing to the marker and repeating the phrase "here you go" to attempt to initiate the infant's grasp of the marker. No more than five cues were used during each trial. Regardless if the infant contacted the marker or not, the researcher removed the marker from the infant's hand and visual field after one minute.

For the second trial, the primary researcher placed a piece of white 8.5"x11" paper directly in front of the infant with clear scotch tape on the top edge of the paper to keep it from sliding. Immediately after the paper was taped down, the primary researcher placed the uncapped, non-toxic, dried out marker used in the first trial in front of the infant using the same procedures and instructions. The trial concluded one minute after the marker was presented. At this time, the primary researcher removed the marker and paper from the infant's hand and visual field, and videotaping ceased.

Data Analysis

The primary investigator and four members of the research team viewed the video of both grasping trials of the first participant. The researchers used the video to discuss the correct procedures for documenting the times and grasp patterns throughout each trial on the remaining participants. After the researchers demonstrated understanding and consistency with the documenting process, two researchers were paired and assigned to record each infant's precise movements when reaching, grasping, and manipulating the marker.

The two researchers independently viewed each infant's video in slow motion many times to record the infant's precise grasp and manipulation movements second by second. Recording movements second by second allowed the researchers to calculate the duration of each trial; the time from presentation of the marker to the initial grasp on the marker; the time from the initial grasp to the contact of the tip of the marker to the surface (table or paper); and the overall percent of time the infant maintained the tip of the marker on the surface. During this process, the initial grasp was identified as the time at which the infant held the marker in at least one hand and lifted the marker from the surface. Each pair of researchers also described in detail the infant's initial grasp on the marker and all alterations of grasp on the marker throughout each trial. They described the grasps by indicating the handedness of the grasp, the grasp location on the marker, and the exact finger and thumb placements on the marker. If the two researchers' times and/or descriptions of the grasps differed, then a third researcher reviewed the trial and the researchers discussed the observations until they reached a consensus. After the variables were documented, the principal investigator categorized the initial grasp and the grasp on the marker during the first contact of the tip of the marker to the surface as a developmental grasp or a handwriting grasp based on the descriptions of Edwards et al. (2018).

Researchers used descriptive statistics to explore the data and report the frequencies of nominal variables, such as hand use and type of grasps, and to calculate the means and standard deviations of continuous variables, including age and all measures of time. Tests of normality indicated that the data were not normally distributed. Therefore, Wilcoxon signed ranks were completed to determine if there was a difference between the time to initial grasp on the marker, the time from initial grasp of marker to tip of marker contact to the surface, and the percent of time the infant maintained the tip of the marker on the surface with and without paper. Researchers completed secondary analyses of Spearman's rho to determine any correlations between the variables.

Results

Guardian and Teacher Reports

Guardians reported their infant used markers or crayons at home typically one to two days per week. Additionally, most guardians reported that their infant observed use of writing utensils in the home on a daily basis. Teachers of older transitioning infants (14-16 months) reported using markers or crayons in the classroom three to four days per week, whereas teachers of younger transitioning infants (11-13 months) reported using markers and crayons in the classroom one to two days per week. A majority of teachers indicated they use techniques of demonstration and hand over hand when the infants use writing utensils in the classroom.

Grasping Trials

The researchers recruited 20 transitioning infants for this study. Seven participants were eliminated if they did not come to the table, grasp the marker, or bring the marker to the surface in either trial (See Figure 1). The remaining 13 infants ranged in age from 12 to 16 months old, with an average age of 13.92 months. Two infants did not bring the marker to surface in one

trial; because of this, researchers completed data analyses with a sample size of 13 or 11 participants, determined by the infant's actions during the trials.

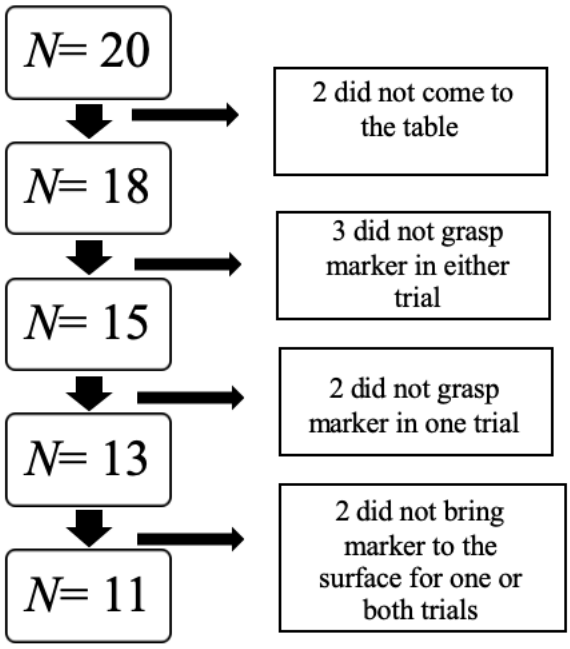

Figure 1. Flow chart depicting elimination of participants.

Throughout all trials, 18 initial grasps were with the right hand, five initial grasps were with the left hand, and three initial grasps were with both hands. During each trial, the infants frequently changed grasp patterns on the marker, alternating between using the right, left, or both hands to ultimately manipulate the marker into a purposeful grasp and bring it to the surface. This occurred with final grasp using their right hand 18 times and left hand four times. There were no instances when the infants used both hands to bring the marker to the surface.

The infants also demonstrated an increased use of a mature, handwriting grasp with the presence of environmental cue of paper. Regardless of the presence of paper or not, the infants consistently used a more mature, handwriting grasp when bringing the marker to contact the surface (See Table 2).

Table 2

Frequency of Grasp Patterns With and Without Environmental Cue

Initial Grasp		
	Without Paper	With Paper
Developmental	9	4
Handwriting	4	8

Grasp when Contacting Surface		
	Without Paper	With Paper
Developmental	4	2
Handwriting	7	9

The resulting continuous variables associated with time were not normally distributed. Therefore, the researchers completed a Wilcoxon signed-rank analysis based on mean ranks to determine if there was a difference between the time the infants initially grasped the marker, between the time of initial grasp of the marker to the time of marker contact to the surface, and between the percent of time the infants maintained the tip of the marker on the writing surface with and without the environmental cue of the paper. Respectively, the results indicated Z= -1.55, Z= -1.69 and Z= -1.27, none of which were significant at p =.05. Although not statistically significant, when reviewing the means of the continuous variables associated with time, the infants initiated grasp on the marker quicker when paper was present than without paper (See Table 3). The infants also brought the marker to the table quicker and maintained the marker in a functional position longer when paper was present.

Table 3

Mean Performance of Transitioning Infants With and Without Environmental Cue

	Time to initial grasp no paper (N=13)	Time to bring marker to surface (N=11)	Percent of time marker on surface (N=11)
Without Paper	M = 4.72 *SD =6.68*	M = 11.74 *SD =14.44*	M = 27.44 *SD =29.75*

With Paper	*M* = 2.27 *SD =1.74*	*M* = 5.02 *SD =7.92*	*M* = 40.30 *SD =29.36*

Discussion

The researchers sought to determine if transitioning infants demonstrate a more purposeful and mature grasp on a functional tool (marker), increase the speed of initial grasp, and maintain a purposeful use of the tool longer when provided with an environmental cue, such as a piece of paper. Although the results indicate no statistical difference between the use of the functional tool with the presence of the environmental cue, trends were observed. Consistent with past research, the researchers found that the transitioning infants preferred their right hand to initially grasp the marker and bring the marker to the surface (Claxton et al., 2009; Fagard & Lockman, 2005). Also, a greater number of transitioning infants demonstrated a more mature, handwriting initial grasp on the marker with paper as compared to without paper. This is consistent with the findings of Contaldo et al. (2013), who reported that infants use appropriate grasps on tools and alter grasps according to the function of the tool. It is possible that the infants in this study used a more mature grasp with the presence of paper because it provided a cue that helped the infants better understand the purpose of the marker. In addition, based on the mean times, the transitioning infants grasped the marker quicker and maintained contact with the surface longer when an environmental cue was present compared to without. The small sample size may have limited the ability to find statistical significance. Researchers have found that infants' grasp patterns on tools are dictated by their perception of tool properties, the intended goal of tools, and their prior experience with tools (Barrett et al., 2007). When infants have more exposure to tool use, they demonstrate more functional grasp patterns because they have a better understanding of the purpose of the tool (Barrett et al., 2007). More often than not, infants are

exposed to writing with a marker on paper. More research needs to be done to determine if the environmental cue of paper adds to infants' understanding of the tool because it is associated with prior exposure to writing with a marker. Researchers could also examine the impact of experience with markers combined with paper on infants' functional grasp and use of the marker. McCarty et al. (1999) found that 14-month-old infants corrected grasp patterns on a functional tool, a spoon, to accomplish the specific goal of bringing food to the mouth. Similarly, the majority of infants in the current study demonstrated alterations in grasp to a handwriting grasp when bringing the marker to the surface, both with and without the paper. Interestingly, the researchers also observed when the infants manipulated the marker, they consistently moved the marker with one or both hands to manipulate it into a more functional, handwriting grasp in order to bring the marker to the surface. This was beyond the scope of this pilot study. However, future research could explore the number and variety of manipulations to determine if infants exhibit less alterations of grasp patterns with the presence of paper.

Limitations

The current study had several limitations that impacted the overall results. The power and the generalizability of the results were impacted by the small, convenience sample. Participants were tested in a familiar environment to maintain ecological validity; however, within the classroom setting, there were a large number of environmental distractions including other infants, activities, and teachers. The environmental distractions provided decreased attention to task during testing for some of the transitioning infants and may have impacted time to contact results. Additionally, several teachers gave verbal cues to the infants during the trials despite researchers providing an explanation of the methods prior to testing. Verbal cues from teachers included "pick up the marker" and "color on the paper," which impacted the ecological validity

and biased the infants to perform the task in a specific manner. The researchers attempted to decrease visual feedback; however, due to the marker not being fully dried out during all trials, minimal visual feedback occurred when contact of the marker was made with the surface. The visual feedback may have impacted the length of time the infant maintained the marker on the surface. This effect was minimized because each infant was presented the same marker for both trials and thus received visual feedback in each trial. Due to the variations in infant personalities, not all infants were comfortable with researchers during testing. Although questionnaires were used to collect some preliminary data on the infant's experience with markers, the accuracy of answers provided by the guardian and teacher report cannot be confirmed.

Conclusion

The results of this pilot study were statistically inconclusive. The observed trends, however, support the need for more empirical research with a larger, more representative sample to determine the precise impact of environmental cues on functional tool use. Much of the research to date has explored infants' functional use of tools such as a spoon (Barrett et al., 2007; Claxton et al., 2009; Connolly & Dalgleish, 1989; McCarty et al., 2001), but limited research has been done to examine infants' functional use of writing instruments, such as crayons or markers. Despite limited understanding of transitioning infants' knowledge of the function of writing instruments, handwriting is a primary focus for occupational therapists working with children. Researchers have found that environmental cues have been related to increased functional tool use with a spoon (McCarty et al., 2001). Researchers have also found that indirect experience, such as observing spoon use and direct experience, such as being taught appropriate grasp resulted in infants using functional grasp patterns more consistently on the spoon (Barrett et al., 2007). It is difficult to know how much indirect or direct experience transitioning infants have

with writing instruments today, especially with the increased use of technology. It is also difficult to determine the frequency in which early childhood educators or guardians guide transitioning infants to using a more mature grasp on writing instruments. Future research needs to be done to explore the impact of all environmental cues, as well as the impact of indirect and direct experiences on transitioning infants' functional use of writing instruments. Occupational therapists can use this information to enhance early intervention, which may have a future impact on handwriting development.

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Appendix A

Demographic Questionnaire for Parents

Child's Name:_____

Child's Date of Birth:_____

Daycare Facility and Room (Class Name): _____

Does your child have an identified diagnosis resulting in developmental delays? **Yes** **No**

Does your child have experience at home with using markers or crayons for coloring? **Yes** **No**

If yes, approximately what age did he/she first start playing with crayons or markers? __

Approximately how often does your child currently use markers and/or crayons at home?

☐ Daily ☐ 5-6 days per week ☐ 3-4 days per week ☐ 1-2 days per week

In the last week, approximately how often has your child observed individuals writing or coloring at home?

☐ Daily ☐ 5-6 days per week ☐ 3-4 days per week ☐ 1-2 days per week

Appendix B

Demographic Questionnaire for Daycare Teachers

To be completed by Researchers:

Classroom Name: _____ *Day of Testing:* _____

Tested Participant Numbers: _____

_____

To be completed by teachers:

On average, how many times each week do the children in your classroom participate in activities that utilize crayons or markers?

☐ Daily ☐ 3-4 days per week ☐ 1-2 days per week

Do you demonstrate how to use a crayon or marker when they are used for activities?

☐ Yes ☐ No

Do you ever use a hand-over-hand technique with the children, to help them use the crayon or marker? ☐ Yes ☐ No