INFANT TOOL USE AND EXECUTIVE FUNCTION

By

Ashley Detherage

Vanderbilt University

Professor Amy Needham

Abstract

How do toddlers' executive function skills relate to abilities to use familiar tools in unfamiliar ways? What method might encourage infants to employ executive function skills to override their prepotent, or automatic, responses to familiar tools? Fourteen-to 18-month-olds attempted to activate a lightbox using a familiar (spoon) and unfamiliar (novel) tool (see Barrett, Davis, & Needham, 2007). Toddlers' initial grasps were restricted on half of the trials.

Our behavioral data revealed that type of tool and methods of presentation were reliable predictors of infants' abilities to solve the lightbox task. One item on an executive function questionnaire reliably predicted toddlers' success, suggesting a positive correlation between 14- to 18-month-olds' emerging executive function and tool use.

Keywords: tool use, executive function, inhibitory control

Is Infants' Tool Use Affected by Their Executive Function Skills?

Tool use is pervasive in many aspects of human life and is, therefore, a widely researched topic in the field of infant development. Even young infants are exposed to everyday tools like spoons, toothbrushes, handrails, and they watch as adults engage in common actions with these items. At the same time, they engage in hands-on learning about how to use the objects around them to help them succeed in various tasks. For example, they begin to learn that spoons and forks are used to feed themselves. Toddlers might also begin to use objects like a play stroller or other push toy to balance when they are first learning how to walk.

The ability to use tools not only allows for greater independence for infants, but it also provides infants with new opportunities for social interaction and connections. The ability to use a tool to accomplish a given task sets up scenarios to further social engagement by providing opportunities for joint attention, shared focuses, and more (McEvoy et al, 1993; Miller & Marcovitch, 2015). Moreover, tool use can reveal pertinent information about how infants develop and learn about the world around them.

Literature Review

Spoons are some of the most basic and earliest-used tools in infancy; infants typically begin gaining hands-on experience feeding themselves and using spoons between 9 and 14 months of age (McCarty, Clifton, & Collard, 2001). Through observational and hands-on experience, spoons quickly become one of the most frequently experienced tools for infants. While there has been a considerable amount of research done on infant tool use and social development, few studies focus specifically on infants between the ages of 14 and 18 months—the period in which spoon use is being established and refined (Connolly & Dalgleish, 1989). Connolly and Dalgleish's 1989 study used a longitudinal design to examine the patterns and series of behaviors that are typically exhibited, as infants become skilled spoon users. Researchers made multiple visits over a 6-7 month period to observe and compare infants' spoon grasp patterns, trajectory of the spoon, and anticipatory behaviors. Their findings indicated that between 11 and 18 months of age, the process of using a spoon to feed one's self is perfected and becomes more natural: the grip on the spoon becomes more sophisticated and advantageous and the path from bowl to mouth more direct.

McCarty, Clifton, and Collard (1999) also investigated tool use by examining the use of action planning—identifying a goal and steps to achieve that goal before acting—in infancy. By observing how infants grasped and used spoons loaded with food presented in different orientations, the authors observed that that 14-month-olds corrected their grasps of a spoon mid-action while 19-month-olds were able to change their grasp or understand that they needed to use their non-preferred hand *before* picking up the object. These findings suggest that action planning is a skill that is developing rapidly during this age range (McCarty et al., 1999).

A major component of action planning in infancy is dependent on an infants' understanding of the object that they are using. Previously, researchers hypothesized that infants have prepotent or automatic responses to tools or objects that are familiar (like spoons), in that infants have observed them being used. However, more recent literature suggests that an action can be prepotent regardless of its association (or lack thereof) with the object being acted on. For instance, toddlers' ability to perform or inhibit actions in which the action may or may not be related to the object was examined using a method consisting of a series of go/no-go trials (Simpson, Carroll, & Riggs, 2014). In one kind of trial, researchers asked toddlers to draw with a hammer. The authors expected that only actions that are prepotent, or automatic, would be performed on no-go trials. However, they found that toddlers sometimes performed unassociated actions, like drawing with a hammer, on no-go trials, indicating that those actions can become prepotent with experience. These results suggest that perhaps specific experience, rather than general familiarity, creates prepotency or automatic response of an action.

While the participants in Simpson et al.'s 2014 study were toddlers in an older age range (average age was 40 months), the concept of using familiar and unfamiliar objects has been studied in much younger populations as well. Barrett, Davis, and Needham's 2007 findings suggest that infants between 14- and 18-months old struggle to use a familiar tool in an unfamiliar way. In other words, infants had trouble utilizing the handle of the spoon to complete the task because it required them to grasp the bowl of the spoon (as opposed to the handle of the spoon, which is normally what is grasped). Infants were presented with a lightbox that was activated by inserting a tool into a small hole on one side of the box. The study presented infants with a familiar and an unfamiliar tool and "easy" and "hard" trials of the lightbox task: during the "hard" trial, the lightbox could only be activated using the skinny handle of a tool, which forced infants to hold the novel tool or the spoon by the bowl in order to complete the task. Infants performed better on the lightbox task when they were presented with an unfamiliar or novel tool as compared to their performance when they were presented with a spoon, a familiar tool that they had previously learned to use by grasping the handle. To succeed in the lightbox task with the familiar tool, infants must plan their action before grasping the spoon and inhibit their automatic reaction, which is to grasp the handle of the spoon.

This key to success is known as inhibitory control. It is a component of a larger skill set that is just beginning to develop during the 14- to 18-month-old age range: executive function. Executive function encompasses working memory, attentional skills, inhibition, and more (Miller & Marcovitch, 2015). Miller and Marcovitch (2015) examined the associations among newly developing executive-function skills and simultaneously emerging skills in 14- to 18-month-old infants, such as social skills and language development, by administering a verbal-skills test as well as a series of executive-function tasks and tasks involving social skills. The authors found a significant relationship between the number of executive function tasks an infant succeeded in and the extent to which infants responded to joint attention with an experimenter. Despite the fact that this significant relationship was limited to older participants (around 18 months), the limited findings here are important because they demonstrate the early development of an important skill set in infants. There is limited research on executive function during this period of rapid development; however, executive function skills are beginning to emerge in infant behavior alongside tool use development, social milestones, and more.

Miller and Marcovitch's (2015) finding on the association between toddlers' responses to joint attention (RJA) and executive-function skills is of particular interest for the proposed research because it suggests an early connection between social- and executive-function skills. RJA involves an infant maintaining eye contact with another individual and following gazes or gestures. It is one of the earliest social skills to develop, usually emerging when infants are between 8 and 15 months of age (Beuker et al., 2012). Not only are early joint attention skills important for social development and perhaps play a role in the development of executive function skills; but, research suggests that early joint attention skills can be predictive of language skills later in life (Mundy et al., 2007).

Current Research

With the understanding that more complex tool usage, such as the lightbox task in Barrett et al.'s study (2007), requires higher-level skills like action planning and inhibitory control, it is logical to expect that executive function skills would play some part in infants' success with the lightbox task. This study examines the factors that affect infants' performance in the lightbox task, specifically investigating the relationship among executive function, social development, and success with this tool use task. The presentation of the lightbox task was modified so that infants' options for how to pick up the spoon were constrained. Infants were forced to make their initial grasp of the spoon on the bowl instead of the handle. This constraint acts as a physical representation of inhibitory control for infants. Inhibitory control is the aspect of executive function that allows an individual to pause, inhibit their automatic response, understand that the lightbox task requires different behaviors than what would normally be enacted with the familiar tool presented, and consider how best to approach the task before *actually* acting (Diamond, 2012). Essentially, inhibitory control would allow a prepotent response to be suppressed. Because executive function skills are just beginning to develop in 14- and 18-month old infants, and infants might struggle to employ executive function skills during the lightbox task, our goal was to provide a proxy for actual initial inhibitory control. We did this by making the prepotent grasp of the spoon (by the handle) unavailable, via our manipulation of the tool presentation. The goal of making a specific grasp option unavailable was to increase infants' success. Additionally, by manipulating the physical presentation of a tool so that infants are restricted from grasping the spoon handle, we can investigate whether or not it is possible to change an infants' prepotent response.

The manipulations and small changes made to Barrett et al.'s initial study are important because they have the potential to reveal something very interesting about the lightbox task: where does the tool use error occur? It is possible that infants' lack of executive function and inhibitory control make it difficult for them to plan their actions: in this case it would seem that the error occurs within the initial grasp of the tool. On the other hand, it is possible that even despite having a correct initial grasp, infants may adjust their grasp of the tool to what is more familiar. This readjustment behavior would suggest that perhaps the problem has less to do with higher-level thinking and more to do with past experience and familiarity with an object.

With this study we intended to investigate infants' behaviors when their behavioral response options were restricted their behavioral response options and whether we could succeed in overriding their prepotent or automatic responses to familiar tools. We also investigated the role that social cues, including eye contact and joint attention, play in the success of tool-use tasks and encouraging executive function. We hypothesized that by restricting an infant's options for initial grasp of a tool, the infant would be more likely to employ inhibitory control and try to perform an unfamiliar action with the tool in order to solve the given task. Based on previously mentioned research by Miller and Marcovitch (2015), we hypothesized the infants who would be more successful at employing executive function skills would also likely respond more frequently to joint attention with experimenters and attempt to make eye contact with experimenters. By manipulating the conditions under which infants perform the tool-use task effectively and by encouraging social engagement with a more knowledgeable adult, we attempted to gain insight into what is helpful for infants to produce successful actions.

Method

Participants

Forty-seven 14- to 18- month old infants participated in the study (26 male, 21 female). Infants and their families were recruited to participate at the Infant Learning Lab via phone and/or email outreach. Seven of the participants were excluded from the final data set for the following reasons: experimenter error (n = 2), solving the lightbox task during the baseline phase (n = 2), participating in a previous research study utilizing similar stimuli (n = 1); and parents reporting their infants had developmental delays (n = 1). The final data set included 40 infants (20 male, 20 female). All infant participants included in the final data set were healthy and born full-term. The mean age for participants with usable data was 15 months 8 days of age (SD = 38 days; age range = 13 months, 29 days to 18 months, 1 day). The demographics of the sample can be found in Table 1. Information about participants and their condition assignment can be found in Table 20. Names and addresses of new parents were obtained from the State of TN birth records, and their phone numbers were obtained from online phone records. Email addresses were obtained for those parents associated with Vanderbilt University through an online database for the Vanderbilt community. Infants' families were not compensated for their participation but infants were given a small toy as a thank you.

Apparatus and Measures

Data were collected using two video recording devices: infants were recorded using a security camera system and also a handheld video camera while in the procedure room. The security system allowed coders to view the infant and researcher from multiple angles. The procedure was simultaneously recorded by the small handheld video camera to provide an auditory recording, which was not picked up by the security camera system. The auditory recording was important for coding infants' vocalizations and ensuring fidelity to the procedures among experimenters. All other data were collected via parent-report questionnaires. Parents completed a spoon-experience questionnaire and the Early Childhood Behavior Questionnaire (ECBQ) Very Short Form to examine executive functioning. The ECBQ was developed by Gartstein, Putnam, and Rothbart (2006) as a temperament measure for toddlers and includes dimensions that explore emotions, motor control, self-regulation abilities, and more. Although the ECBQ was originally designed for slightly older infants, was chosen as the most appropriate measure for this study based on previous studies and the questionnaire's inclusion of inhibitory/effortful control measures.

Infant participants sat on their caregiver's lap in the procedure room. Parents were seated at a semi-circular table facing the experimenter, who sat directly across from them. The table measured 1.75 m across. Infants were presented with two different tools during the experiment: a silver table spoon measuring 15.88 cm and a "novel tool," measuring 13.65 cm similar the tool used in Barrett et al. (2007). In both studies, the novel tool was designed to have the same shape and size as the spoon. Infants were presented with a lightbox that measured 13.97 x 13.97 x 12.7 cm.

Design

The study used a 2x2 within-subjects design. The two independent variables were the order in which the two tools were presented to the infant (spoon first or novel tool first) and the method with which the tool was presented to the infant (upright in the tool holder or flat on the table with the bowl toward the infant). The sequence of the tools (spoon then novel or novel then spoon) and the method of tool presentation were counterbalanced between-subjects. The experiment itself was brief in duration; however, infants experienced one baseline trial and four test trials, which gave them five opportunities to solve the lightbox task using two different tools, which were each presented in two different ways.

Procedure

Infants and parents were brought into the procedure room to complete the experiment. First, infants' hand preferences were assessed using three animal bath toys. The experimenter used both hands to present each toy, one at a time, to the infant at the infant's midline. The infant's hand preferences, based on their grasps, were recorded (left, right, or both). Following the hand-preference assessment, infants were presented with a 30-s baseline test to verify that they did not already know how to solve the behavioral task. Data from infants who solved during this baseline trial were eliminated from the final sample because the goal of the current study was to teach infants who didn't already know how to solve the task on their own. During the baseline testing, the experimenter presented the spoon on the table next to the lightbox with the bowl of the spoon closest to the infant. The only requirements during the baseline testing were that the infant touch or hold the spoon in some way. If necessary, the experimenter placed the spoon in the baby's hand at the end of the 30-s interval to fulfill this requirement.

After the baseline testing, the experimenter demonstrated how to complete the behavioral task with the first tool. Depending on the condition, the experimenter demonstrated the task to the infant using either the spoon or the novel tool two times. The experimenter started the demonstration with the table cleared and the box and tool under the table. Both items were placed on the table and the experimenter called the infant's name to catch their attention, saying, "[**Baby's Name**], watch this!" The experimenter made an attempt to initiate joint attention by making eye contact with the infant and calling their name up to two times. Then, the experimenter held the given tool by the bowl. They held the tool in front of the infant for five seconds and instructed, "hold it like this," before inserting the handle into the lightbox to activate the light. The experimenter held the tool in the lightbox for 5 seconds while commenting, "Look! The light turns on." Then the lightbox and tool were removed from the table. After 5 s, the demonstration was repeated using the same tool.

Infants were given two opportunities to solve the lightbox task after the experimenter's demonstration. The tool was presented in two different ways. Each test trial was 45 s long for a total of 1.5 min. Presentation A restricted the infant's ability to grasp the handle of the tool by presenting it in an acrylic toothbrush holder (7.62 x 7.62 x 10.16 cm) so that infants could see the tool in its entirety but were forced to pick it up by the bowl (but infants were free to adjust their grasp after they had the tool in their hands). The holder had three openings at the top: two of the openings were taped in an attempt to minimize the appeal of the holder for infants. Presentation B allowed infants to grasp the tool however they wanted; the experimenter set the tool on the table next to the lightbox with the bowl facing the infant. Regardless of presentation method, experimenters placed the lightbox and the tool on the table at the same time, within arm's reach of the infant, and prompted, "Now it's your turn!" If infants did not attempt to pick up the tool, the experimenter prompted them further. After the two test trials, the experimenter completed a second demonstration with the lightbox task using the alternate tool. Demonstration and test phases followed the same protocol as above, using the second tool. The presentation of the tools during test phases remained consistent. See Figure 1 for a flow chart depicting each phase of the experiment.

Coding

The behavioral data were coded using a program called Datavyu (www.datavyu.org). The video coding focused specifically on two categories: grasping activities and social interactions. Grasping activities included infants' grasp pattern, latency to grasp, and grasp adjustments during the test trials. Coders recorded the number of attempts to solve the task as well as number of solves and details about each attempt. Social interactions that were considered particularly important were eye contact, vocalizations, and response to/initiating joint attention during the demonstration and test phases. Specific instructions on how to code RJA and other social interactions were based on the "Early Social Communication Scales (ESCS)" by Mundy et al. (2003). The coded data were analyzed in conjunction with the Early Childhood Behavior Questionnaire (ECBQ) Very Short Form, a parent questionnaire. The ECBQ provided measures of a wide scope of aspects of childhood temperament: the dimension primarily used in this study was inhibitory control, a facet of executive function (Garthstein et al., 2006). Three of the questions on the questionnaire were identified to be further analyzed further using the scoring information for the questionnaire (found in Table 3).

All video coding was performed by an undergraduate research assistant and checked for reliability by a different research assistant. To confirm reliability, the secondary coder coded one test trial from each participant (n = 40) and compared their coded number of attempts and solves for participants. Reliability for number of attempts and solves was calculated using the intraclass correlation coefficient (ICC) to compare our coders' quantitative measurements of how many attempts and solves infant participants made for each test trial (**ICC** = 0.968, **p** < 0.001, **CI** [0.951 – 0.979]). There were some limitations for the social interaction coding: six participant videos were excluded because the videos were not clear enough to code.

Results

Based on the data collected during the experiment, we aim to investigate the associations among executive functioning, success in completing the given task, tool grasp placement and pattern, and social skills such as response to joint attention and eye contact.

The coded behavioral data and parent-report questionnaire data were analyzed using a Generalized Estimating Equation (GEE) in R. We chose to analyze our data using the GEE because it accounts for correlated data from each participant across all four test trials and allowed us to examine multiple factors. The factors analyzed were type of tool, type of presentation, interaction between type of tool and type of presentation, and the variables included were the scores of the ECBQ questions pertaining to inhibitory control. Previous research indicated that order of tools did not systematically affect infants' behavior at test and this fact was also confirmed in a preliminary GEE analysis ($\boldsymbol{\beta}$ =0.08851, $\boldsymbol{\chi}^2(1)$= =0.41738, **p**=0.8321, **CI** [-0.72954 – 0.90656]) (Barrett et al., 2007).

Our initial hypothesis that infants would be more likely to solve the lightbox task when the tool was presented with a constrained grasp option was supported by the data collected. The GEE analysis found that the presentation of the tool was a reliable predictor of infants' ability to solve the lightbox task ($\boldsymbol{\beta}$ =0.67523, $\boldsymbol{\chi}^2(1)$=0.29520, **p**=0.022, **CI** [0.09664-1.25382]). As we expected from previous research, the GEE analysis also found that the type of tool used was also a reliable predictor of infants' ability to solve: infants were significantly more likely to solve the task when presented with the novel tool ($\boldsymbol{\beta}$ = -0.63342, $\boldsymbol{\chi}^2(1)$=0.29063, **p**=.0293, **CI** [-1.20304 - -0.06381]) (Barrett et al., 2007). The GEE analysis found no interaction between type of tool and type of presentation ($\boldsymbol{\beta}$ =0.08851, $\boldsymbol{\chi}^2(1)$=0.41783, **p**=0.8321, **CI** [-0.72954 – 0.90656]). See Figure 3 for a representation of infants' behaviors in each test trial condition.

We also hypothesized that ECBQ questionnaire scores would be a predictor for lightbox task success. We compared questionnaire information with behavioral data instead of examining a relationship between age and behavioral data to explore our hypothesis that executive function is a predictor of tool use success. After data collection we found that infants' task success was variable and we saw no trend between age and task success (see Figure 4). Out of the three inhibitory control questions, one was shown to be a reliable predictor of success according to the GEE analysis (**β** = -0.16490, $\chi^2(1)=0.6930$, **p**=0.0173, **CI** [-0.30073 – -0.02908]). See Figure 5 for a distribution of scores for this item. The only question to systematically predict success was "When asked to wait for a desirable item (such as ice cream), how often did your child wait patiently?" The questions, "When told 'no' how often did your child stop the forbidden activity" (**β** =0.02681, $\chi^2(1)=0.07618$, **p**=0.7249, **CI** [-.12250 – 0.17612]) and "When asked to do so, how often was your child able to be careful with something breakable" (**β** =0.01887 , $\chi^2(1)= 0.05821$, **p**=0.7459, **CI** [-0.09522 – 0.13295]) were not reliable predictors of the infants' ability to solve the lightbox task.

Our final hypothesis was that infants would be more likely to solve the lightbox task if they responded to joint attention and took part in social interactions with the experimenter. Upon examining the coded data for social interactions, we found that there was a ceiling effect on eye contact and joint attention. The coding criteria for social interactions was that infants made eye contact with the experimenters and responded to their name being called. All 34 infant participants that were coded looked at least once during each demonstration phase (shown in Figure 2), so we were not able to confirm the hypothesis that RJA and social interactions correlate with success on the lightbox task.

Discussion

The study revealed important insight into how infants plan tool use actions and how executive function could be related to that action planning process. As predicted, the constrained grasp presentation of the tool led to success more often among infants in the 14- to 18-month range. This finding is important because it could shed more light on exactly how infant action planning happens. We now know that interfering early, before infants can even grasp the tool, seems to be the most successful.

It is interesting that only the ECBQ item asking about infants' ability to wait patiently was a systematic predictor of task success. The other questions addressed infants' abilities to "stop a forbidden activity" and "be careful with something breakable." There could be a few different explanations for this finding: it is likely that the infants in this age range had limited exposure to breakable items, which would make this item difficult to answer. 19 of the 40 participants did not provide and answer for this item on the ECBQ. Based on reports from participant parents, it seems unlikely that all infant participants had exposure to fragile or breakable objects. Fewer responses on this item make it less likely that it would result in statistical significance. Additionally, there is a lot of variability in the category "forbidden activity" so it could be that factors other than inhibitory control, like discipline style, are at play and make that question a less reliable measure of inhibitory control.

The significant difference in ECBQ scores between the participants that were able to solve the lightbox task and those that were not suggests that the ability to solve the task is in fact related to the early stages of executive function development in infants. This suggests that developmental ability and experience are good predictors for action planning and tool use success in this infant age range; it could be that in some cases, these are better predictors than numerical age. Despite the fact that we could not further analyze our social interaction data, the ceiling effect shows that by this age range, eye contact and RJA are “the norm.” Further coding of our data could look into any differences in how many times infants look at experimenters, if they look away and how long they look away, etc. to see if these more specific details could be predictors of tool use and action planning success.

Like any study, there are multiple limitations to our findings. Infants’ behaviors and capabilities span a wide range during the dynamic period of growth between 14 and 18 months old. Another limitation is that our sample size was relatively small, with a total of 40 infant participants and only ten participants in each condition. Additionally, we had limited diversity represented in our study: over 80% of the infants were Caucasian. There also could have been a sample bias from the lab’s recruiting methods: an unrepresentative proportion of participant families were recruited from Vanderbilt University, 52% of participant mothers had post-doctorate degrees, and 55% of participant fathers had post-doctorate degrees. Because our data came from such an unrepresentative sample, it is possible that we over-estimated infants’ abilities. Follow-up research should look at new recruiting methods that are more representative of the population.

While the study focused on a simple lightbox task, the findings can be broadened to reveal information on how to help infants develop executive-function skills, encourage action planning early in development, use tools effectively, and create successful and meaningful interactions with caregivers. One specific set of skills, pattern of behaviors, or timeline of events cannot characterize infant development. It is more likely that the development of behaviors we observe is a product of many different intersecting pathways of development that come together to enhance how an infant learns about and experiences the world around them. Recent literature supports this theory of intersecting pathways: for example, one of the latest studies by Libertus et al. (in press) provides evidence that two weeks of “sticky mittens” training at 3 months of age is related to increased object exploration at 15 months of age, a full year after training ended. They found a significant difference between the active and passive training groups in the amount of visual engagement with a novel toy and the amount of distraction demonstrated. This could indicate higher levels of attentional skills. These results consistent with the finding that infants with active training showing more of an ability to engage in longer periods of focused attention. This association itself is evidence that development is a synergistic process.

The findings of this study suggest that proxies for executive function can be useful for infants that are beginning to develop this set of skills. Caregivers that can help redirect or refocus attention on an important object, make infants “pause” before beginning a task so that they can plan their action, and more. Providing initial assistance to infants can not only encourage executive function but also help them succeed in tool use and learning about their surroundings.

Further analysis of the data collected for this study could look at other dimensions of the ECBQ to see if there are other executive function skills that are more rapidly developing during this age range. Additionally, it could be beneficial to re-examine the social interaction data to try to find interesting implications between social interactions and tool use success or action planning. For example, perhaps infant participants look at the experimenter more before grasping the tool if they are planning to use a familiar tool in an unfamiliar way.

This study revealed important insight on how two developmental pathways—tool use and executive function—came together to produce a certain level of success in a particular task. Insofar as the research on executive function in infants younger than 18 months is limited, this study provides valuable and necessary insight into the development of these important skills in early childhood. Future research should continue to investigate the developmental pathway of executive function in young infants (14-18 months old). While this study provides a solid start, there is still much more to be explored in the realm of executive function development in young infants.

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Table 1
Infant & Family Participant Information

Demographics	
Caucasian	38
African American/Caucasian	1
Asian/Caucasian	2
Pacific Islander/Caucasian	2
Asian/African American/Caucasian	1
African American	1
Asian	2
Mother/Parent 1 Education	
Some College	3
Technical or AA Degree	3
College Degree	15
Postgraduate education	23
Father/Parent 2 Education	
Some College	4
Technical or AA Degree	1
College Degree	14
Postgraduate education	23

Table 2
Age Distribution Among Assigned Conditions

Condition	**Average Age**
Spoon first; Presentation A, B	M = 16 months, 5 days (SD = 39 days)
Spoon first; Presentation B, A	M = 16 months, 3 days (SD = 36 days)
Tool first; Presentation A, B	M = 15 months, 20 days (SD = 43 days)
Tool first; Presentation B, A	M = 15 months, 25 days (SD = 37 days)

Table 3

ECBQ: Inhibitory Control Questionnaire Items Analyzed

ECBQ Number	**Question**
21	When told "no", how often did your child stop the forbidden activity?
27	When asked to wait for a desirable item (such as ice cream), how often did your child wait patiently?
31	When asked to do so, how often was your child able to be careful with something breakable?

Table 4

Summary of GEE Analysis for Variables Predicting Infant Success in Solving Lightbox Task (N = 40)

Variable	*β*	*SE β*	*X^2 Value*	*CI (odds)*
Tool Type **	- 0.58873	0.34660	7.8964	- 0.99936 - -0.17810
Tool Presentation ***	0.71889	0.20951	11.7618	0.30805 – 1.12974
Order of Presentation	0.15122	0.20962	0.3900	- 0.32338 – 0.62581
Question #21	0.04018	0.07948	0.2556	- 0.11560 – 0.19597
Question #27 *	- 0.19130	0.07972	5.7584	- 0.34756 - -0.03505
Question #31	0.02415	0.05847	0.1706	- 0.09045 – 0.13876
NOTE: GEE = General Estimating Equations; CI = confidence interval. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$				

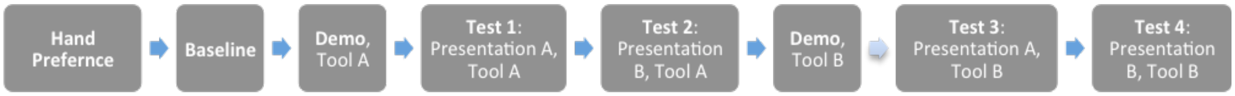

Figure 1. Flowchart for full procedure.

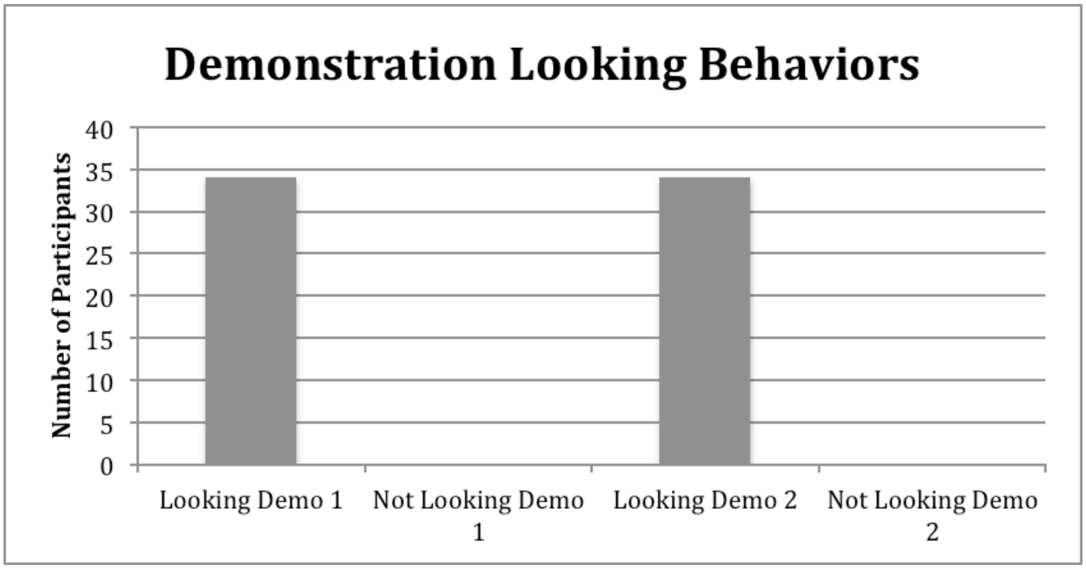

Figure 2. Coded data for infant participants (n = 34) for eye contact and response to joint attention (RJA) during demonstration phases.

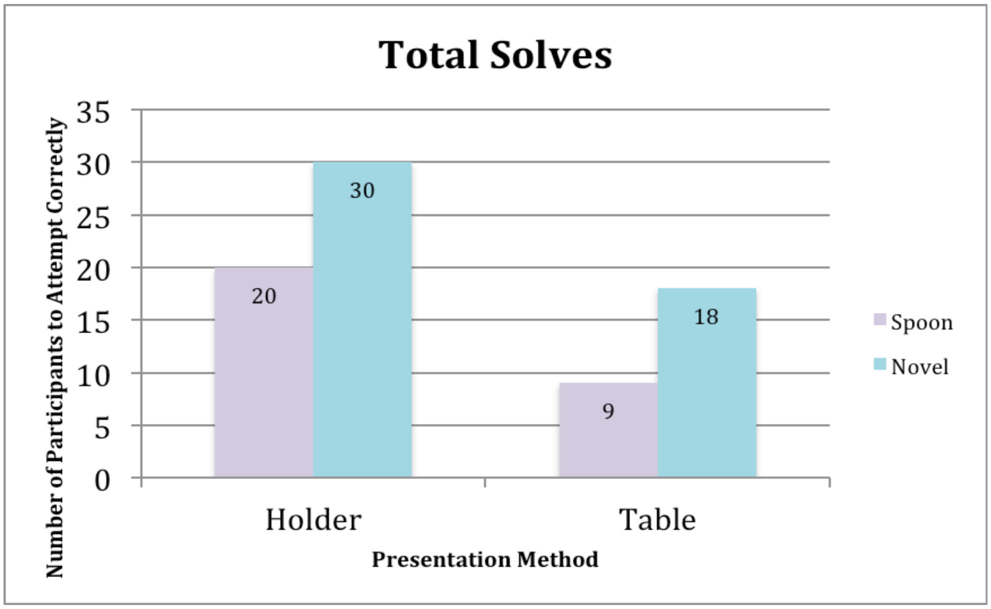

Figure 3. Total number of participants (n=40) able to solve the lightbox task when presented with the novel tool and spoon in two presentations.

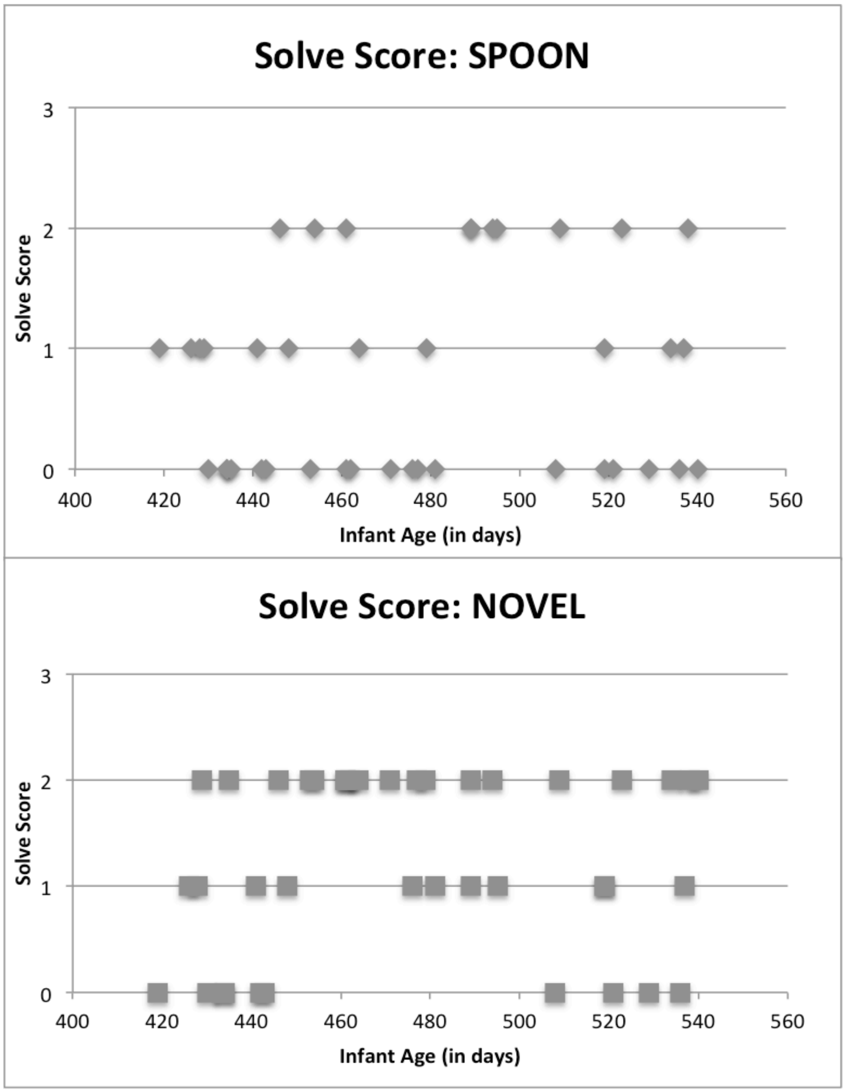

Figure 4. Scatterplots for infant age versus ability to solve lightbox task. Ability to solve was distinguished by solve score: 0=did not solve during any test trial, 1=solved one of the two test trials, 2=solved both test trials.

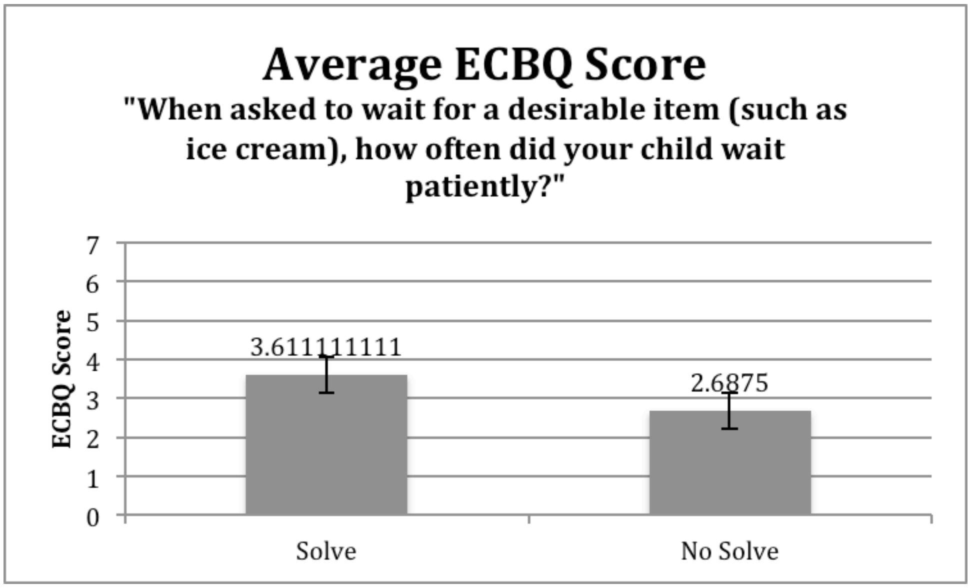

Figure 5. Distribution of item responses for ECBQ item found to be a reliable predictor of infant task success.