When Less Can Be More: Evaluating the Impact of Animated and Interactive Demonstrations in Voice-Assisted Counting Games for Young Children

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(ABSTRACT)

Early experiences with counting form a critical foundation for children's numeracy development. Despite the increasing use of voice assistants in young children's math learning, the effectiveness of different levels of demonstration—animated and interactive—accompanied by these assistants remains unclear. This study examines how different demonstrations in touchscreen devices, combined with voice assistants, supported children's developing counting skills. We developed a tablet counting game for children aged 2-4 years, incorporating voice assistant counting. In a user study with 32 children, we compared two conditions (animated and interactive demonstrations), with each condition also being evaluated against a baseline. We found that animated demonstrations improved math performance compared to the baseline, while interactive demonstrations did not. These findings suggest that counting with voice assistants has the potential to support early counting experiences and highlight the importance of designing educational technology with appropriate levels of demonstration to engage young learners without increasing cognitive overload.

When Less Can Be More: Evaluating the Impact of Animated and Interactive Demonstrations in Voice-Assisted Counting Games for Young Children

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(GENERAL AUDIENCE ABSTRACT)

Counting is an important foundation for young children's math skills. As voice assistants become increasingly common in educational technologies, we explored levels of demonstrations such as animated and interactive accompanied by voice assistants on children aged 2-4 to learn how it affects counting. We developed a tablet-based counting game with a voice assistant to explore these different levels of demonstrations. In a study of 32 children, we compared the two approaches: animated and interactive demonstrations, with each condition also being evaluated against a baseline. Interestingly, the animated condition improved counting abilities more than the interactive condition, suggesting that too much interaction might overwhelm young children. These findings can help designers create better educational games that balance interactions and learning without increasing cognitive overload.

Dedication

This work is dedicated to all who have helped me throughout my master's journey. It wouldn't have been possible without all your help.

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Chapter 1

Introduction

Early numeracy skills are foundational and have a significant influence on later academic achievements and everyday life skills. Research indicates that these early skills are reliable indicators of future progress and success in mathematical performance [42]. Understanding numbers and quantities begins in early childhood. However, learning math, especially understanding exact numbers, is challenging for young children because it requires grasping an abstract and objective concept and involves building a new way of understanding that may conflict with young children's previous intuitive and inexact understanding of numbers [47]. For example, young children may initially think about spreading a set of objects farther apart to increase the number of objects, rather than the total remains the same regardless of the spatial arrangement.

Previous work has found that children begin to count at about two and a half years of age, but they often lack an understanding of the meanings behind the number words and the quantities they represent [58]. Another study found that children failed to extend relatively large number words, such as "five," "eight," and "ten", from one set to another [50]. This failure to map number words to specific quantities, even when presented with examples of sets of objects, demonstrates the challenge children face in mapping number words to exact quantities. Counting with parents, which involves parents making deictic gestures to objects during counting, has been shown to be helpful for young children in developing their counting skills [26]. Despite the critical role of parental input in children's early numeracy

development, the counting experiences that parents provide for their children vary according to various social and cultural contexts, including socioeconomic factors as well as parental beliefs and comfort with math [10, 22].

As with high-quality interactions with human partners, young learners may benefit from interactions with technological sources. Existing research on educational applications (apps) has suggested the importance of physical and verbal interactions in young children's learning [1, 9, 17, 19, 40]. Emerging research reveals that learners benefit from meaningful social interactions with technological sources, such as voice assistant technologies [61, 63]. Previous studies have shown that young children enjoy interacting with voice assistants [21, 36] and gain linguistic and scientific knowledge from these assistants [61]. Therefore, voice assistants may hold promise for support math learning by incorporating interactivity in counting apps.

The increasing use of voice assistants in children's math learning through digital technologies is accompanied by various levels of demonstrations, including visual, animated, and touch-based interactive formats. Such demonstrations also have the potential to expand the range of modalities that children can use to interact, rather than relying solely on speech-based interaction. However, most studies on voice assistance focus on speech-based interactions [63] and human-AI collaborations [5, 54], leaving the impact of integrating voice assistants with different levels of demonstrations on children's learning and engagement remain largely unexplored. A growing body of research suggests that interactive media technologies are not always beneficial for young children's learning [19, 33]. This highlights the importance of considering various factors, such as specific design features (e.g., level of interactivity), individual differences (e.g., child age and cognitive characteristics), and the demands of specific tasks (e.g., math) [9]. Therefore, it is important to examine the impact of technology design features (levels of demonstration) on children within a specific age range, taking into account both general and domain-specific cognitive characteristics.

This study aims to address this gap by investigating the impact of different types of demonstrations along with a voice assistant on touchscreens on children's early numerical skills, with a focus on young children's counting skills. We developed a tablet counting game for children aged 2-4 years that incorporated voice assistant counting. A user study using a within-subjects design with 32 children specifically compares children's engagement and performance between two levels of counting demonstrations along with a voice assistant: *animated demonstration condition*, in which the voice assistant counts aloud while the child watches and *interactive demonstration condition*, in which the voice assistant asks a child to press each object and speak aloud the number. Each condition was also evaluated against a *baseline* (visual only, no demonstration). By examining how different levels of demonstration affect early math learning with a voice assistant, this study contributes to the understanding of how to design effective educational technology that supports young children. Such understanding is expected to provide an important foundation for shaping future learning environments where collaboration between humans and AI will play a key role.

Chapter 2

Review of Literature

2.1 Early Number Sense

Preverbal infants and older children can distinguish large quantities, such as discriminating 5 and 10 or 10 and 20 without counting [12, 59, 60]. Despite their ability to approximate large quantities to distinguish them, young children often fail to accurately interpret the meaning of large cardinal number words (e.g., “ten”), even when these number words are presented with concrete examples and contrasts that can be easily distinguished perceptually. For example, when presented with an example image of five turtles along with a pair of choices between another image of five turtles and a distractor image of ten turtles, young children often have difficulty accurately identifying the number words (e.g., ”five,” ”ten”) with the corresponding images [50].

One possible explanation for children’s failure to extend the number word from one example image to another is that children do not tend to attend spontaneously to numerical information, especially when numerical features are contrasted with shape or color [15]. Recent evidence suggests that verbal counting may help to direct children’s attention to numerical quantities. One source of evidence comes from research with 3- to 6-year-old children, showing that children who spontaneously count objects are better at interpreting large number words [43].

However, children who have less access to language input containing exact number words, such as 'one', 'two', 'three', tend to perform poorly on symbolic math tasks compared to those who are exposed to exact number words [49]. Therefore, counting with parents or teachers further helps young children overcome these limitataions and successfully attend to quantities [55, 56]. For example, observing verbal counting helps 18-month-old infants overcome their spontaneous bias to represent a set of objects as individual "object files" [23]. Instead, counting helps infants to focus on the approximate quantity of the whole array and become able to keep track of large sets of objects [55]. Therefore, it was expected that animated demonstrations of counting would similarly improve children's interpretation of cardinal number words by supporting their numerical attention.

It is possible that interactive demonstrations, which require children's active engagement and manipulation of objects, might help solidify these early quantitative abilities into more formal counting skills. However, there has been no direct causal evidence of how counting, especially an active experience of pointing at and counting objects, impacts children's numerical attention or their interpretation of cardinal number words. Therefore, in this study, we explored an open research question as to how such touch-based interactive demonstration would impact children's interpretation of cardinal number words.

2.2 Interactivity in Educational Apps

Interaction refers to two entities influencing each other's behavior over time. In the Human-computer Interaction (HCI) context, these entities are computers, including input devices and systems, and humans, ranging from end effectors to tool users [28]. Therefore, interactivity in touch-based educational apps refers to the degree to which users can actively engage with the content through various means, such as tapping, dragging and more.

Young children's learning primarily occurs through immersive interactions such as play and experiencing [27]. Therefore, it is important to understand what types of learning could be achieved through interactive devices, such as touch screens and voice agents, and how to create interactions to achieve them. These interactions should be designed to engage children actively and meaningfully with the educational content, fostering their understanding and skill development. A previous work proposes a learning taxonomy with three levels, one of which is active learning [16]. The paper defines active learning as engaging in an activity (typically involving physical movement) while learning.

In the context of educational apps, activity can take many forms. For instance, children can interact with the device in various ways, such as touching the screen, moving it, using the microphone, and listening to sounds—these encompass different types of interactions [27]. The authors discussed a concept of active learning known as "active minds on" learning, where activities are designed to engage students and shape their thinking and understanding as a natural consequence of their experiences and interactions within learning environments [27]. They provide an example of a mathematics app aimed at building skills in understanding quantity, which may present analog representations of physical objects (such as photos of red rubber balls) while allowing direct manipulation of these virtual objects. Additionally, the app may provide verbal labeling of quantities ("You found 5 balls!") and numerical representations ("5"). This study extends these insights by examining the impact of varying levels of demonstrations that incorporate different levels of interactivity, such as animated demonstrations and interactive demonstrations, on improving young children's understanding of cardinal number words compared to a baseline (visual only no demonstration) through supporting their counting skills.

2.3 Impact of Interactive Features on Learning Outcomes

While interactivity has the potential to enhance children's mathematical learning, it is important to recognize that not all forms of interaction are equally effective [33]. Some interactions can facilitate learning by promoting a sense of agency, increasing engagement through relevant responses, and directing visual attention to key information on the screen. On the other hand, interactions that require excessive cognitive demands, such as complex planning and motor responses while navigating tasks may hinder learning [33]. Therefore, understanding how to effectively combine levels of interactivity and match interactions with specific tasks is essential for optimizing learning outcomes.

Several studies have explored the relationship between interactions and learning outcomes in young children. Prior studies have demonstrated that animated demonstrations in screen media can successfully support young children's learning. For instance, research on learning from animated videos indicates that features like engaging animations and child-directed speech can help children develop expectations that the content is both understandable and worth paying attention to [30]. Mares and Pan's [37] meta-analysis of a children's educational program targeted at preschoolers, Sesame Street, indicated positive effects on cognitive outcomes (quantity) and learning about the world (environment and science). It was also found children between ages 3 to 7 have shown effective vocabulary gains by consistently watching educational programs like Sesame Street, which uses these engaging elements [46]. Longitudinal studies have found that educational television exposure during the preschool years predicts readiness at school entry [2] and academic achievement at least as far as high school [2].

When it comes to research on learning from interactive media, The impact of learning from

interactive media varies depending on several factors. These factors include design features (e.g., levels of interactivity), individual differences (e.g., child age and cognitive abilities), and the demands of specific tasks [9]. For example, it was found that the specific conditions that lead to learning vary with age among 2-4 years. For instance, young 2-year-olds learn new information more efficiently when videos require them to interact with the screen in a contingent manner compared to passive viewing of non-interactive videos [34]. That is, young 2-year-olds learned best from touch-screen applications that guided attention through touch-based interactivity, but not from applications that were more flexible (e.g., letting them touch anywhere on the screen to continue) or from non-interactive video [34, 48]. On the other hand, some of the existing studies reveal that older 2-year-olds and children between the ages of 3 and 5 learn better from watching digital games rather than actively playing them [1, 48].

Together, the results from the existing body of research on interactive media for young children highlighted that the success of interactive educational apps is closely related to the deliberate selection, arrangement, and integration of interactive modes, based on an understanding of young users' cognitive capacities, physical capabilities, and preferences [11]. Thus, the present study focused on the varying levels of demonstrations during voice assistant counting as a key design feature, and systematically assessed their effects in children's understanding of cardinal number words within a specific age group (2-4 years), while also considering children's individual differences in cognitive abilities (memory, numeracy). Specifically, we compared the following two experimental conditions for voice assistant counting: 1) animated demonstration condition resembling video or television viewing, and 2) interactive demonstration condition having touch activities. Additionally, we included a baseline that provided only visual input without any demonstration to compare children's pre-post differences in each condition.

Chapter 3

Study Design and Development

Our system consists of four key components: a touchscreen interface, the integration of familiar characters, a voice assistant, and counting tasks with the two demonstration conditions and the baseline. The goal is to create an engaging research tool to effectively measure our research objectives. We developed our system using React/JavaScript for the frontend, Node.js for the backend, and MongoDB for data storage and management.

3.1 Touchscreens

We chose to design a tablet app because touchscreens have introduced a new level of interactivity to educational apps, allowing users to interact with apps using their hands. This tactile engagement enables even the youngest children to interact with digital devices. Because our age range is children aged 2 to 4 years, it is difficult for them to use external input devices like keyboards and mouse, due to their developing motor abilities [35]. The tablet eliminates the need for such devices. Also, tablets have become widely available to kids recently. Furthermore, previous research has shown that touchscreen usage promotes learning by providing interactive content [18, 33, 39]. Their findings showed that children as young as 24 months old performed better when actively engaged with touchscreen interfaces rather than passively observing them. Young children may be better able to navigate a simple, intuitive touchscreen interface than a game controller or computer mouse [44]. The design

of the app was guided by the TIDRC (Touchscreen Interaction Design Recommendations for Children) framework, which provides guidelines for creating tablet-based apps targeting children 2-11 years [51].

3.2 Familiar Character Integration

Research has shown that children often develop strong parasocial relationships with media characters, which can significantly enhance their learning and social development [13]. For example, Piotrowski [41] found that familiarity with Dora the Explorer, a preschool show, improved learning outcomes for children aged 3-5 years. We used a Sesame Street theme featuring familiar characters such as Cookie Monster and Big Bird in conjunction with a voice assistant, we aim to foster these parasocial relationships and interactions. Additionally, previous research indicates that cartoon images in touchscreen media can improve children's learning experiences [64]. By integrating these well-known and beloved characters, we create a relatable and engaging environment that further aids in learning.

3.3 Development of Voice Assistant

Voice assistants have become a strong alternative to developing human-computer interfaces that provide more human-like interactions between children and the system [62]. The voice assistant in our system was designed to provide support to children as they navigate the system by guiding them throughout all tests and helping them learn counting by responding to their touch gestures such as continuous and tapping motions on the screen. Selecting a voice for the assistant was an important decision, as most AI voices are designed for adult conversations and tend to sound robotic, which is not suitable for engaging young children.

We selected the voice for the assistant through the Google Text-to-Speech API. Children are more likely to listen to a voice that sounds like a female adult with lively music and sound effects [7]. To make the AI voice more child-friendly, we selected a female voice with a higher pitch, which is generally more appealing to young children. The voice was made to speak more slowly, emphasizing keywords and phrases to enhance comprehension and maintain the child's attention. We also used exclamation marks and varied punctuation to make the speech sound more natural and engaging. In future work, we plan to enhance the voice agent's capabilities to recognize speech input and respond to users using generative AI systems, making interactions even more dynamic and engaging. Thereby increasing the social aspect of the interactions.

3.4 Designing Interaction-Based Conditions

When developing the animated and interactive conditions, we focused on creating interactions that would reinforce Gelman and Gallistel's counting principles [24]: one-to-one correspondence, stable order, and cardinality. These principles are central to improving children's understanding of counting and helping them grasp the concept of larger cardinal numbers. The one-to-one principle emphasizes the importance of matching each item in a collection to a distinct spoken or written word, ensuring a clear and accurate correlation. The stable order principle emphasizes the need to keep a consistent sequence of number names, as any change interrupts the counting process. Finally, the cardinal principle states that when the one-to-one and stable order principles are applied, the final number in a count represents the total number of items in the collection. We'll talk more about the particular interactions intended to support these principles below.

3.5 Experimental Design

The baseline represents a static image, such as an audiobook with visuals, where there is no animation and no interactivity. For example, the voice assistant asks the child the question, "Cookie Monster has 10 cookies. Can Big Bird also have 10 cookies? Which tray has 10 cookies? Green or purple?" Subsequently, Big Bird appears on the screen with his green and purple trays, and the child is asked to select the correct tray (See Figure 3.1.). This condition aims to assess the child's performance in an environment without interactive elements.

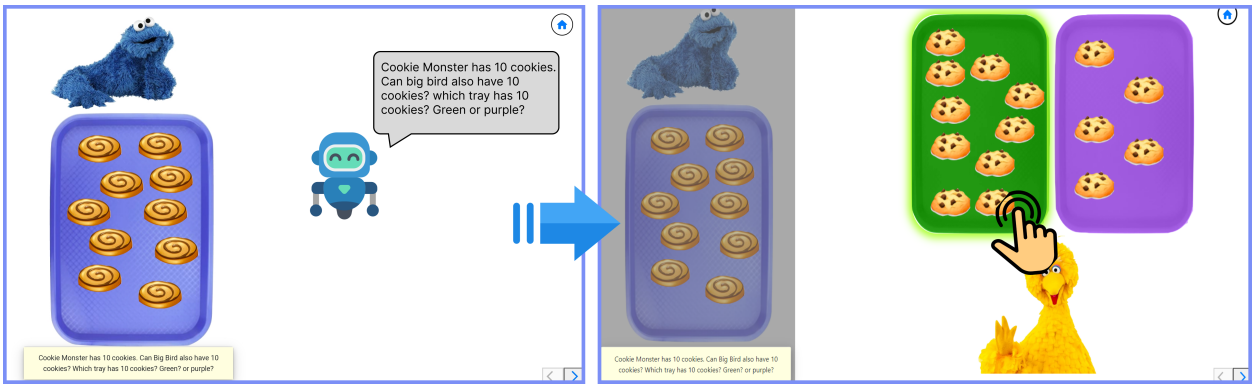

Figure 3.1: Baseline: Without animation or interactivity

The animated condition represents a video or traditional media, such as TV, where there is animation without interactivity. For example, the Cookie Monster appears with his cookie tray, and the voice assistant prompts, "Cookie Monster has 10 cookies. Let's count together!" The system then highlights and wiggles each cookie sequentially, counting them aloud. To emphasize the concept of cardinality, after counting, the total number of cookies is then enclosed in a circle through a circular animation [31]. The voice assistant then mentions the total number of cookies. Following this, Big Bird and his trays appear, and the voice assistant asks the child, "Can Big Bird also have 10 cookies? Which tray has 10 cookies? Green or purple?" The child then selects the correct tray(See **??**.). This demonstration introduces visual and auditory cues without requiring active participation from the child.

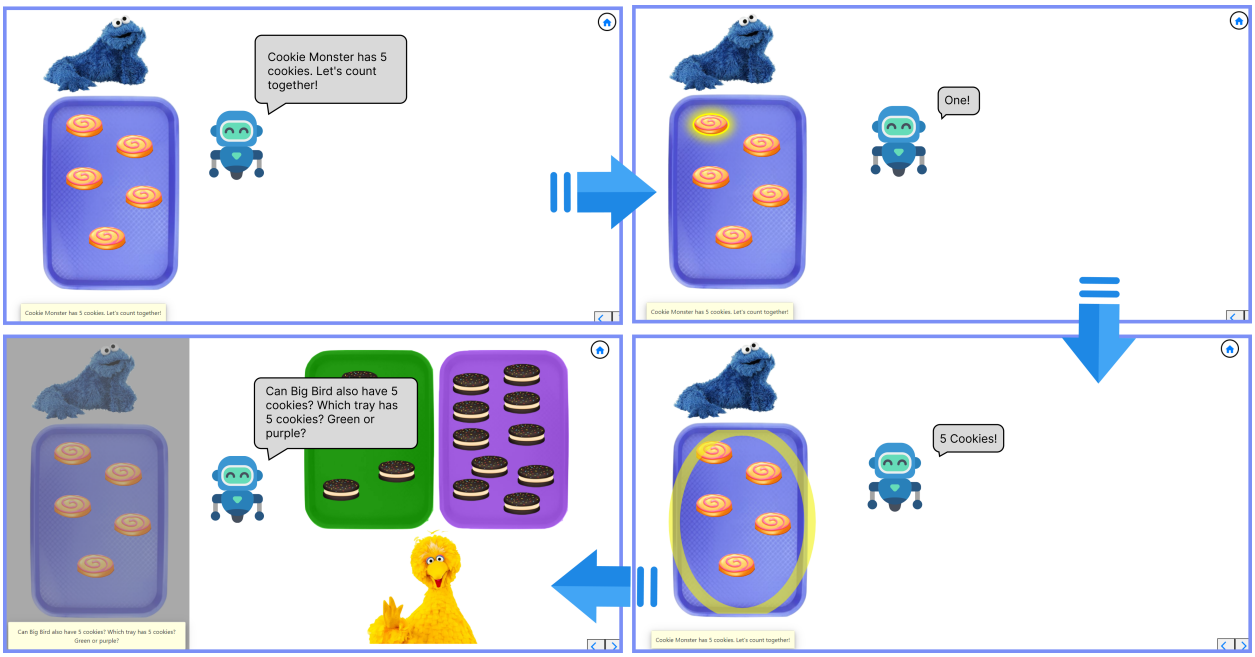

Figure 3.2: Animation Demonstration: Animated without interactivity.

The interactive condition represents a touchscreen task where there is animation and interactivity. The process is similar to the animated demonstration but with an addition of active engagement giving flexibility and control to the child. Prior research shows that providing preschool-aged children with control over the game can significantly enhance their attention, engagement, and interest in the task [14]. As each wiggling cookie is highlighted, the child must tap on it, prompting the voice assistant to count the cookie aloud in sync with the child's action (See Figure 3.3-A) After counting, the child is instructed to draw a circle around the total set of cookies, reinforcing the concept of grouping and cardinality [31]. It has been found that representing and highlighting sets by showing a circular, enclosed diagram around them helps children enhance their understanding of cardinality [31]. This visual representation reinforces the cardinal principle by making the total quantity more comprehensible to young learners. This active learning technique enhances engagement and improves counting skills through direct interaction and visual grouping.

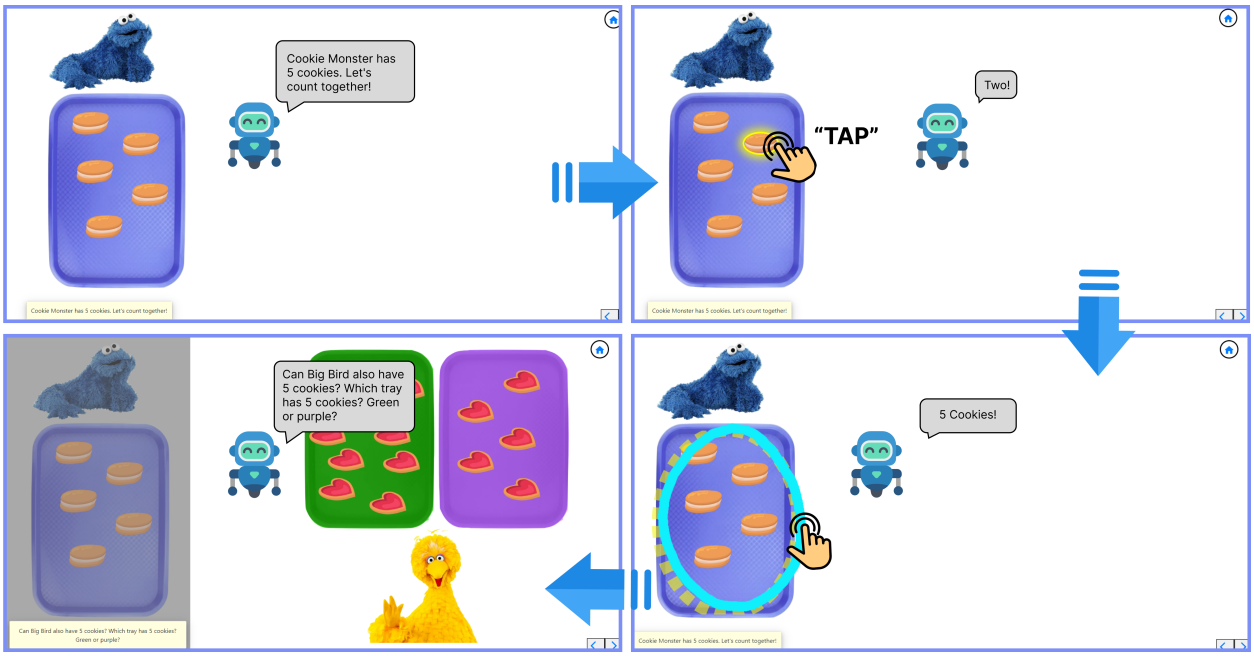

Figure 3.3: Interactive Demonstration: Animated and interactive.

3.6 Implementation

To evaluate the effectiveness of these three types of conditions, we developed a tablet app called "CountBuddy". We built the interface using React with a nodeJS backend service. CountBuddy begins with a sign-up page, after which users are directed to the main home screen. From here, users can select one of three conditions: baseline, animated, or interactive. Each condition consists of six tests—two training tests followed by four main tests. These counting tasks were adapted from the Word Extension task by Slusser and Sarnecka [50], where 2- to 4-year-old children often failed to interpret the meaning of large, cardinal numbers (e.g., 10).

The brief training phase was created to familiarize the child with each condition before the main test. For example, in the baseline, the training begins with a simple counting test: one cookie is displayed, and the voice assistant prompts the child with, "Cookie Monster has 1 cookie. Can Big Bird also have 1 cookie? Which tray has 1 cookie? Green or purple?" This is

followed by a second task showing two cookies to solidify the concept further. Similarly, the training phase in the animated and interactive conditions follows the same structure, using 1 cookie in the first test and 2 cookies in the second with the condition-specific interactions, before transitioning to the main tasks, which involve counting between 5 and 10 cookies.

3.7 Evaluation

We conducted an experiment using a within-subjects design to evaluate the impact of two demonstration types on children's numerical performance. We examined whether animated and touch-based interactive demonstration would lead to better numerical performance compared to the baseline.

Given the benefit of counting in children's numerical development [15, 43], we hypothesized that children's verbal engagement and performance in the animated condition would be higher compared to the baseline. Given the mixed evidence on the effectiveness of interactive media on young children's learning, we had an open research question regarding the effect of the interactive demonstration condition. If interactive counting experiences would support children's learning, we would expect to see an improvement in children's verbal engage engagement and performance in the interactive demonstration condition compared to the baseline and the animated condition. If interactivity would increase a load for children, we would not expect any condition difference in engagement and performance.

Thus, we propose the following hypotheses and research questions:

H1: Children's math performance scores would improve following the animated demonstration condition compared to their baseline due to counting.

H2: Children's verbal engagement would be higher in the animated demonstration com-

pared to the baseline.

Q1: Does the interactive demonstration results in different math performance scores compared to the baseline?

Q2: Does the interactive demonstration results in different levels of verbal engagement compared to the baseline?

Q3: Does interactivity affect children's math performance, evidenced by the difference between the animated and interactive demonstration conditions?

Q4: Does interactivity affect children's verbal engagement during counting, evidenced by the difference between the animated and interactive demonstration conditions?

3.7.1 Participants

Participants were 32 children (21 female, 11 male) aged 2 to 4 years ($M = 42.56$, $SD = 10.24$) and their parents recruited through local preschools and mailing lists. Child participants consisted of 9 (2-year-olds), 13 (3-year-olds) and 10 (4-year-olds) children. All participants were from Virginia, USA and could speak English. Parents' average years of education were roughly equivalent to a Bachelor's degree (mean = 17.85 years, SD = 2.44 years, range = 14–22 years). Most parents (79%) identified their child as white/Caucasian and non-Hispanic. A majority of parents (83.87%) reported that their children mostly watched TV programs or videos on a stationary TV set, with only 9.68% indicating that their children primarily used mobile devices like tablets or smartphones. When it comes to playing digital games at home, parents reported that their children spent time playing both on weekdays and weekends, with all respondents indicating daily gaming activity. The reasons for allowing their children to play digital games varied, with the most common motivations being to

keep their child busy while they took a break (40.91%) and because their child enjoyed it (50%). Educational purposes were a factor for 31.82% of parents, while 27.27% played games together to connect.

3.7.2 Study Procedure and Design

The study was approved by the Institutional Review Board. After obtaining parental/-guardian consent and child assent, participants were introduced to a research assistant and the two-part study procedure began which consisted of counting activities in all two types of demonstrations: animated demonstration and interactive demonstration. There was a baseline (no demonstration) per each condition and a working memory task and a numeracy task. Details of the tasks are described in (Section:3.7.3).

While the children participated the counting tasks, parents were asked to fill out an online survey about demographic information such as the parent's education and the child's race and ethnicity. Parents also reported whether they allow their child to play digital games, which device they use for that purpose, and how much time their kids spend on each of the following: (1) Playing digital games, (2) Talking to a voice assistant, and (3) Playing digital counting games. Counting games involve finding out how many things there are. Digital counting games could be on on any device, including computers, tablets, smartphones, or consoles.

Children were randomly assigned to groups within a 2 (condition: animated vs. interactive) x 2 (order: animated first vs. interactive first), which condition as a repeated measures. To control for order effects, the order of the conditions was counterbalanced so that some of the children completed the first counting game with the animated demonstration first, followed by the second counting game with the interactive demonstration, while the remaining

children completed the order in reverse.

Each part took approximately 30 minutes to complete, yielding an approximately one-hour-long study (two parts). We divided the study into two parts with a short break in between because, for the younger children, it was difficult to maintain their attention span for a single, longer session. The parents were given the option to revisit again for the second part, and most of the 3-4-year-old children did both sessions in a day whereas the younger ones did it in two days. In addition, a break was provided between the two parts because the tasks were the same except for the difference in the types of demonstrations (animated vs. interactive).

In the first part, the child completed the baseline task and another counting task in one of two conditions (animated or interactive demonstration, randomly selected) along with the working memory task. In the second part, the child again performed the baseline task, followed by another counting task in the remaining condition (animated or interactive demonstration) and the numeracy task. The baseline was performed before both animated and interactive conditions (serving as pretest), to examine whether there had been an improvement after each counting condition. This design allowed for a comprehensive assessment of how different levels of demonstrations affect children's engagement and performance in the counting task. All parts of the procedure were video recorded for later coding of questions and behaviors.

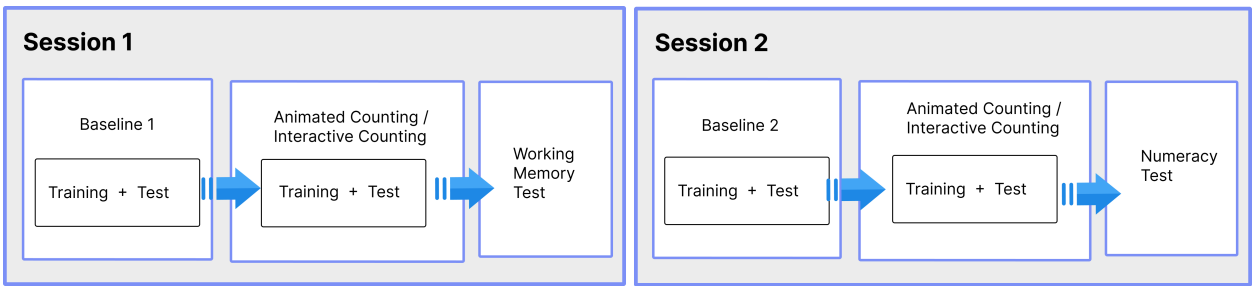

Figure 3.4: Study Flow

3.7.3 Measures and Instruments

In this study, our focus was on examining the impact of these varying levels of demonstrations in touch-based interfaces on young children's engagement and learning. Thus, we examined how children's performance in their cardinal number word extension task and verbal engagement behaviors during counting differ by the experimental conditions. Further, we examined each condition differed a baseline .

Cardinal Number Word Extension Task:The main dependent variable was children's performance in the cardinal number word extension task, adapted from the Word Extension task from Slusser and Sarnecka [50]. Children's performance was measured by the percentage of correct trials out of four trials. That is, each trial was evaluated for correctness, and the proportion of correct answers was then computed as the number of correct trials divided by the total number of trials completed. For example, we counted it as a correct answer if they choose a tray from green or purple trays on the right that has the same number of cookies on the example blue tray. This variable reflected how well the children can select the tray containing the correct cardinal number of cookies after engaging with each type of counting demonstration.

Verbal Engagement: The other dependent variable was the children's verbal engagement, which was measured by analyzing the behaviors of children from the video recordings of the experimental session. In both the touch-based and animated conditions, the voice assistant encouraged children to count by saying, "Let's count together!" whereas in the baseline, the counting task was presented without specifically asking the children to count aloud. We recorded a binary variable, with "1" indicating that the child counted along with the system, and "0" indicating that they did not. Children's verbal engagement was measured by the percentage of trials in which verbal counting responses were observed over four trials. That

is, each trial was evaluated for the presence of verbal counting, and the proportion of verbal counting responses was determined by dividing the number of verbally counted trials by the total number of trials completed.

Working Memory Task and Numerical Comparison Task: To measure and control children's general and math-specific cognitive skills, a working memory task and a numeracy task were administered. Working memory is the ability to hold and update information in mind for future tasks [8, 45]. Children age of two exhibit working memory ability [20], which improves rapidly between the ages of three and five [4, 29, 53]. The working memory task was adapted and a PowerPoint version was created from [32] where children watch identical objects being hidden in six different possible locations and then find the given object. The numeracy task was custom-designed based on a previous study on approximate number system [57], to measure children's numerical acuity, where children see different numbers of blue and yellow dots flash on the screen briefly and decide which array has more dots.

Chapter 4

Results

In this section, we present the results of the study and interpret findings with respect to our previously presented hypotheses and research questions. Results from counting tasks from the two conditions and their baselines are summarized in 4.1.

4.0.1 Children's Performance on the Cardinal Number Word Task

First, to examine whether children's performance scores in the animated condition (H1) and the interactive condition (Q1) differed from baseline, we fitted mixed-effects models to compare each condition (animated and interactive) with either the first baseline score (Model 1) or their own baseline (Model 2 and 3). We conducted multiple baseline comparisons because comparing both the initial baseline (at the very beginning) and the baseline before each condition provides a more nuanced understanding of performance. The initial baseline gives a general starting point for the child, while the condition-specific baseline allows for a more direct assessment of the immediate effect of each condition. Next, we directly compared the two experimental conditions (animated vs interactive) with the animated condition (Model 4) to address Q3. Covariates included child age and condition order in these models.

Table 4.1 represents the results from Model 1 where we compared each condition (animated and interactive) with the first baseline score as a reference category. In Model 1, child age was a significant predictor of performance, with older children performing better on the cardinal

Table 4.1: Model 1 Results

Predictors	**Estimate (SE)**	**t**	**df**	**p**
(Intercept)	0.241	1.643	31.663	0.110
Condition (Animated)	0.117*	2.197	60.444	0.031
Condition (Interactive)	0.015	0.295	59.986	0.768
Age (months)	0.010**	3.353	28.803	0.002
Order (Animated first)	-0.000	-0.010	28.389	0.992

Note. Two dummy-coded condition variables were included: Condition (Animated) and Condition (Interactive); the initial baseline was the reference category for each. Age (in months) was included as a continuous variable. Order was included as a dummy variable with the interactive condition first as the reference category. Interactions that are not listed did not significantly improve the fit of the model. $^{*}p < 0.05$, $^{**}p < 0.01$

number word task ($b = 0.01$, $p = .002$). This finding aligns with existing literature suggesting counting skills improve with age. There was no significant order effect ($b = 0.00$, $p = .992$), suggesting that order of the conditions did not influence the children's performance in this experiment. According to Model 1, as shown in Figure 5, children performed considerably better in the animated condition than at initial baseline ($b = 0.12$, $p = .032$). On the other hand, children's performance in the interactive condition did not differ significantly from initial baseline ($b = .016$, $p = .769$).

In Model 2 and Model 3, we compared each condition (animated vs interactive) with the condition-specific baseline as a reference category to examine the immediate effect of each condition, respectively. Neither condition significantly differed from its own baseline (Model 2: animated baseline vs animated: $b = 0.07$, $p = .153$; Model 3: interactive baseline vs interactive: $b = 0.00$, $p = 1.00$). Thus, the immediate effect of the animated condition was not observed with at baseline right before each condition despite the improvement observed in comparison to the initial baseline found in Model 1. In each of Model 2 and Model 3, child age was a significant predictor (Model 1: $b = 0.01$, $p = .019$; Model 2: $b = 0.01$, $p =$

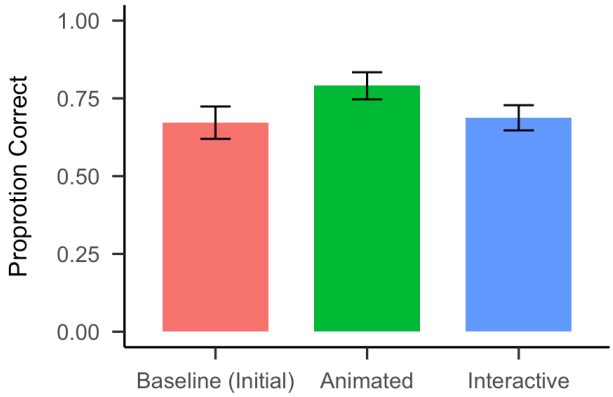

Figure 4.1: Average proportion of trials answered correctly during the cardinal number word task at baseline (initial) and in the animated and interactive conditions. Bars represent standard errors.

.003), but there was no significant order effect (Model 1: b = -0.01, p = .868; Model 2: b = 0.005, p = .948), consistent with Model 1.

In Model 4, we directly compared the two experimental conditions (animated vs interactive) with the animated condition as a reference category (Model 4). Children's performance was higher in the animated condition compared to the interactive condition (b = -0.10, p =.047). Children's performance was significantly predicted by child age (b = 0.10, p =.003) but not by order (b = -0.02, p =.807)

Overall, H1 was partially supported as the animated condition outperformed the initial baseline whereas the immediate effect of the animated condition was not observed at baseline right before each condition. Regarding our research questions involving the interactive condition (Q1 and Q3), the findings suggest that the interactive condition did not provide a significant improvement in performance compared to baseline (Q1) and animated condition (Q3), highlighting the need for further exploration into the appropriate levels of interaction for enhancing educational outcomes, which we discuss further in the discussion section.

4.0.2 Children's Verbal Engagement during Counting

Next, we focused on children's verbal counting to examine whether children's verbal engagement in the animated condition (H2) and the interactive condition (Q2) differed from baseline. We fitted mixed-effects models to compare each condition (animated and interactive) with either the first baseline score (Model 5) or their own baseline (Model 6 and 7). Next, we directly compared the two experimental conditions (animated vs interactive) to address Q4 (Model 8).

Model 5 compared each condition (animated and interactive) with the first baseline score as a reference category. In Model 5, child age was not a significant predictor of verbal engagement ($b = 0.002$, $p = .590$). There was no significant order effect ($b = 0.02$, $p = .819$) on verbal engagement. Children's verbal engagement was significantly higher in the animated condition than the initial baseline ($b = 0.27$, $p < .001$). On the other hand, children's verbal engagement in the interactive condition was also higher than the initial baseline, but this difference was only marginally significant ($b = .13$, $p = .074$).

In Model 6 and Model 7, we compared each condition (animated vs interactive) with the condition-specific baseline as a reference category, respectively. Each condition significantly differed from its own baseline (Model 6: animated baseline vs animated: $b = 0.27$, $p = <.001$; Model 7: interactive baseline vs interactive: $b = 0.13$, $p = 0.035$). Thus, children engaged in higher verbal counting compared to the condition-specific baseline in each condition. In each of Model 2 and Model 3, child age was not a significant predictor (Model 6: $b = 0.001$, $p = .682$; Model 7: $b = 0.001$, $p = .658$), and there was no significant order effect (Model 1: $b = -0.05$, $p = .513$; Model 2: $b = 0.068$, $p = .295$).

In Model 8, we directly compared the two experimental conditions (animated vs interactive), with the animated condition as a reference category (Model 8) Children's verbal engagement

was higher in the animated condition compared to the interactive condition, but this difference was only marginally significant.(b = -0.14, p =.068). Child age (b = 0.002, p =.701) and order (b = 0.031, p =.787) did not significantly predict verbal engagement in this model.

Together, these findings support H2, which predicted that the interactive condition would lead to higher levels of verbal engagement compared to both the initial baseline and the condition-specific baseline. Regarding our research questions about the interactive condition (Q2 and Q4), the interactive condition appears to promote greater verbal engagement than the baseline (Q2), supported by its significant difference from the condition-specific baseline and its marginally significant difference from the initial baseline. With marginal significance, children's verbal engagement was higher in the animated condition compared to the interactive condition (Q5), suggesting that while the touch-based interactivity was designed to encourage physical engagement with objects by touching each object during counting, the animated demonstration may have reduced cognitive load, allowing children to verbally engage during counting.

Table 4.2: Summary of Test Correctness Average Across Conditions

Condition	**Mean (SD)**	**Median [Min, Max]**	**Missing (%)**
AC (N=32)	0.790 (0.242)	0.750 [0.250, 1.00]	1 (3.1%)
BL1 (N=32)	0.672 (0.294)	0.750 [0, 1.00]	0 (0%)
BL2 (N=32)	0.734 (0.273)	0.750 [0, 1.00]	1 (3.1%)
TC (N=32)	0.688 (0.229)	0.750 [0.250, 1.00]	0 (0%)
Overall (N=128)	0.720 (0.262)	0.750 [0, 1.00]	2 (1.6%)

Chapter 5

Discussion

This paper explored the various interaction levels in voice assistant counting demonstrations and how they affected children's math performance and engagement. This study improved our understanding of interactivity design specifically for children's early math learning experiences and provided insights into which types of interactive features are most effective in facilitating young children's math engagement and learning.

5.1 The Goldilocks Question: How Much is Too Much

The findings from this study offer insights into how different levels of interaction (such as touch-based gestures) in touch screens affect young children's understanding of large number words through counting, challenging the assumption that increased interactivity automatically leads to improved learning outcomes. This observation aligns with prior research, which indicates that passive viewing, in some cases, supports learning more effectively than interactive engagement [1, 48]. Our results support this, children's performance was higher in the animated condition, designed to provide counting experiences without requiring active physical counting, than the touch-based interactive condition.

In the interactive condition, children had to tap each cookie as it wiggled to actively engage in the counting process, which made the procedure more flexible and allowed the counting to be done at the child's own pace. Although this form of interaction was intended to

increase engagement and learning by active involvement, it is possible that it increased the task's cognitive demands. While children's verbal engagement during counting was higher in the animated condition compared to both the initial and condition-specific baselines, the benefit of the interactive condition in verbal engagement was less consistent. For example, six children started counting by saying "one" aloud but stopped when they started tapping the cookies. This suggests that the act of tapping may have shifted their attention away from verbal counting, as they focused more on the physical interaction with the touchscreen. This behavior shows a potential cognitive shift where the need to coordinate motor actions (tapping) and verbal actions (counting aloud) may have led some children to prioritize one task over the other. While children were still physically engaged, the drop-off in verbal counting might indicate that the touch interaction increased cognitive load, making it more difficult for them to keep track of the counting sequence which is more important [43]. For younger children, particularly those who are still developing their motor and cognitive skills, managing both tapping and counting tasks may have been too difficult.

On the other hand, the animated condition, which included visual and auditory cues without needing active tapping, appeared to allow children to focus on the counting process. The guided animations kept their attention without the extra work of touch input, suggesting that "less is more." This is consistent with the Goldilocks effect [38], in which determining the "just right" level of engagement is important for maximizing learning. Too little engagement, as observed at baseline, may fail to engage children, but too much involvement, as seen in the interactive condition, could also overwhelm them. The implication of the study result suggests that educational tool designers should consider the developmental stages of their target age-range users, incorporating limited interactivity to ensure tasks are engaging but not overly demanding. For example, animations that guide children through counting tasks without requiring touch inputs and instead respond to verbal utterances might be more

effective for early learners.

5.2 Does Tapping Many Objects Work for Young Children?

We noted that, despite previous research [6] suggesting that 2-year-olds can effectively use touchscreen tablets, many of the 2-year-olds in our study had difficulty with tapping. The experimenter often had to help the child by guiding their hand to tap the cookies or tapping for them after they touched the cookie. According to prior studies, this problem could be caused by a reason such as the cookie size might have been too small [3] or their finger size may have been too small to be accurately recognized by the touchscreen. Also, many of these children may not have had prior experience with tablets 3.7.1. The potentially limited ability for precise tapping requires designers to consider the digital literacy of novices and tailor interaction types to align with children's physical abilities. For instance, children with low motor coordination may benefit more from voice-activated interactions or larger target sizes, reducing the reliance on precise tapping. Furthermore, a tutorial that integrates both content and input gesture accuracy can promote an adaptive user interface.

5.3 Intelligent Interactive Ideas that Might Work

Prior research emphasized the importance of verbal counting in directing children's attention to numerical quantities and improving their understanding of numbers [43]. In the current study, the animated condition counts on its own after asking the child to join with it. However, the system was not capable of detecting if the child is counting along with it or

not. A feature where an intelligent agent listens to what the child utters and recognize it and gives real-time feedback could be valuable. This form of interaction may provide a more personalized learning experience, potentially improving the child's counting abilities through direct feedback.

An interesting behavior we noted during the animated condition was that two children spontaneously used their fingers to count along with the voice assistant, even though the app did not require or encourage this physical counting method. This use of fingers as a counting aid, although limited to a small sample of participants, this behavior reflects young children's natural tendency to rely on bodily gestures to help them learn numbers, which is a type of embodied cognition [25, 52].

In our app, we aimed to promote active learning through tapping on cookies in the touch-based condition. However, this observation has made us consider alternative approaches where we could integrate active learning by allowing children to physically represent numbers. For example, a feature where the voice assistant encourages children to use their hands or fingers to show numbers as they count. For instance, the voice assistant might ask, "Can you show me three cookies using your fingers?" or ask the child to hold up a certain number of fingers, which the system could detect via the touchscreen or inbuilt camera. This type of interaction might improve the learning experience by combining visual and physical engagement, better than tapping in this age group. Because it could address the challenge some children faced with tapping by offering a more intuitive, hands-on way to reinforce counting concepts.

During the interactive condition, the children were particularly enthusiastic about the feature that allowed them to draw a circle around the cookies after counting. Even the children who had a hard time tapping and got tired of the task were interested in drawing the circle. Many children expressed excitement about this interaction, often asking, "Can I draw

the circle?" or saying, "I want to draw the circle," even in the animated condition, where drawing was not part of the test. The act of drawing a circle around the cookies appears to have created a physical interaction that many children enjoyed, suggesting that this kind of hands-on activity improves the learning experience. Incorporating interactive features that align with children's interests such as drawing may improve their level of participation and thereby performance in learning tasks. In the context of the current study, where the goal is to support children's understanding of the large numbers through counting, the circling gesture was intended to support children's learning goals. However, it is possible that such interactions could distract children from their primary learning goals if they are not closely aligned with learning objects. Exploring this balance may be an interesting direction for future research.

5.4 Limitations and Future Work

While this study provides valuable insights into the effects of different levels of interactivity on young children's counting skills, several limitations should be acknowledged.

First, the study focused on children aged two to four years, a developmental range with significant variation in motor and cognitive abilities. Younger children in this group may not have fully developed the fine motor skills required for counting many objects in the interactive condition, potentially impacting their performance. On the other hand, older children might have found the tasks too simple, which could influence their engagement and the overall results.

Second, this was a short-term assessment and thus the results were based on immediate task performance, which may not reflect long-term learning or retention of counting concepts. Future research could assess whether the observed effects persist over time or if certain

types of interactions lead to better retention of counting concepts and understanding of large number words.

Third, the study primarily used touch-based input interactions. Other forms of interactivity, such as voice input were not explored. These might provide different insights into how children engage with digital learning tools. One feature will be to enable the AI agent to listen to the child's spoken responses during activities. By integrating speech recognition technology, the AI can understand what the child says, resulting in more dynamic and responsive interactions, thereby personalizing the experience and removing touch limitations. Another interesting feature would be where the AI agent provides instant, constructive feedback, such as praising correct answers, gently correcting errors, and offering hints to help the child complete counting tasks. Another future aspect would be we thought the cognitive load might have affected the performance what would it be if this was a activity done with collaboration with parents.

These findings show the importance of finding the right level of interactivity when designing educational tools for children. There seems to be a Goldilocks effect when it comes to the perfect level of engagement that promotes learning, where interactions are neither too minimal nor too complex. Future research could concentrate on finding this balance more precisely, investigating how varying amounts of interactivity affect learning across age groups and tasks. Understanding this balance will be key in developing educational apps that promote engagement while supporting cognitive development in early childhood.

Chapter 6

Conclusions

This study explored the impact of different levels of interactive demonstrations on young children's counting skills through the two experimental conditions: animated and interactive, and compare each condition to baseline. The primary innovation of this trans-disciplinary collaborative project is that it is the first to test the impact of integrating interactive demonstration in voice-assisted apps, with a focus on early counting experience. Our findings revealed that the animated condition led to higher verbal engagement and math performance than the touch-based interactive condition, suggesting that the combination of visual and auditory stimuli can significantly enhance engagement and learning outcomes. The results indicated that while touch-based interactions can physically engage children through tapping, they may also introduce cognitive load that can detract from learning. This observation highlighted the importance of selecting appropriate interaction types that balance engagement with cognitive demands. These findings underscore the need for careful consideration of interactivity when designing educational tools using voice assistants for young children. Striking the right balance between engagement and cognitive load would be critical for developers in creating more effective learning experiences that support young children's cognitive development, particularly in foundational skills such as counting.

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Appendices

Appendix A

Parent Survey

Interactive Counting Study (IRB 23-914) - Parent Survey

Dear Parent(s)/Guardian(s),

Thank you for completing this questionnaire as part of a Virginia Tech research study (IRB #23-914) on interactive counting. Please answer these questions to the best of your ability. Whenever a question asks about "**your child,**" it is referring to the child who participated in this project.

To begin the questionnaire, please enter your **participant code** in the space below. Participant codes are used to ensure the confidentiality of your responses. You can find your code in the email message that we sent you with the link to this questionnaire.

For additional questions about this research, please contact our research team at koeun@vt.edu.

Sincerely,

Koeun Choi, Assistant Professor
Human Development and Family Science, Virginia Tech
The CoDeS Team

* Please enter your **participant code.**

You can find your code in the email message that we sent you with the link to this questionnaire.

Household demographics

* What is your age (in years)?

Your age (in years)

* What is your relationship to your child who is participating in this research study?

- ◯ Child's mother or mother figure
- ◯ Child's father or father figure
- ◯ Other

* What is your gender?

- ◯ Prefer not to say
- ◯ Gender expansive/gender nonconforming
- ◯ Transwoman
- ◯ Transman
- ◯ Woman
- ◯ Man

- ◯ Other (Please specify)

* Are you of Hispanic, Latino, or Spanish origin?

- ◯ Hispanic or Latino
- ◯ Not Hispanic or Latino
- ◯ Don't know
- ◯ Prefer not to answer

* How do you describe your race? Check all that apply.

- ☐ American Indian/Alaska Native
- ☐ Asian or Pacific Islander
- ☐ Black or African American
- ☐ White
- ☐ Prefer not to answer
- ☐ Don't know
- ☐ Other (Please specify)

* What is the highest level of school that you have completed?

- ◯ No Formal School
- ◯ Elementary/Primary
- ◯ Middle School
- ◯ High School or Equivalent (e.g., GED)
- ◯ Some College or Vocational Degree (e.g., AA)

- Bachelor's Degree (e.g., BA/BS)
- Master's Degree (e.g., MA, MFA)
- Doctoral or Professional Degree (e.g., MD, JD, EdD, DDS, PhD, VMD)
- Prefer not to answer

* Are you currently employed?

- Not currently employed
- Employed part-time
- Employed full-time
- Employed more than full-time
- On temporary leave (e.g., short-term disability, parental leave, etc.)
- Other (Please specify)

* Which of these ranges best describes your family's yearly income before taxes for last year?

- Less than $10,000
- $10,000 to $19,999
- $20,000 to $29,999
- $30,000 to $39,999
- $40,000 to $49,999
- $50,000 to $59,999
- $60,000 to $69,999
- $70,000 to $79,999
- $80,000 to $89,999

- ◯ $90,000 to $99,999
- ◯ $100,000 to $149,999
- ◯ More than $150,000
- ◯ Prefer not to answer

* Do you receive public assistance (WIC, SNAP, etc.), or have you received public assistance in the last year?

- ◯ I receive public assistance currently.
- ◯ I have received public assistance in the last year, but I do not currently receive public assistance.
- ◯ I have received public assistance in the past (more than one year ago), but I have not received public assistance within the last year.
- ◯ I have never received public assistance.

Child Demographics and Child Care

Most of the questions in this survey will ask about the **child that participated in the study.**

* In what month and year was **your child** born?

Month ⌄ Year ⌄

* What is **your child's** sex assigned at birth?

- ◯ Male
- ◯ Female
- ◯ Prefer not to answer
- ◯ Neutral / Other

* Is **your child** of Hispanic, Latino, or Spanish origin?

- ○ Hispanic or Latino
- ○ Not Hispanic or Latino
- ○ Don't know
- ○ Prefer not to answer

* How would you describe **your child**'s race?

- ☐ American Indian/Alaska Native
- ☐ Asian or Pacific Islander
- ☐ Black or African American
- ☐ White
- ☐ Prefer not to answer
- ☐ Don't know
- ☐ Other (Please specify)

* Is a language other than English spoken to **your child** in your home?

- ○ No
- ○ Yes, some of the time
- ○ Yes, most of the time

* Which languages and what proportion of time does **your child** typically hear these languages in the home?

For instance, if a child hears English about half of the time and Spanish about half of the time, you can write "English 50%, Spanish 50%"

* Where does **your child** live?

- ◯ My child lives in my household only
- ◯ My child lives in another household only
- ◯ My child lives in lives in two or more households

* How much time does **your child** spend in your household rather than another household?

- ◯ More than half the time
- ◯ About half the time
- ◯ Less than half the time

* **Besides you and your child,** are there any other adults or children living in your home?

- ◯ No, **my child and I are the only people** living in my home.
- ◯ Yes, there are **other people** living in my home

How many adults (age 18 years or older) and children (age under 18 years) reside in your household, including you and **your child**?

Please indicate the number of adult(s) or child(ren) living in your household for each item.

You (the person completing this survey)	
Number of adults **other than you**	
The child who participated in this study	
Other children **older** than your child	
Other children **the same age as** your child	
Other children **younger** than your child	
	0

* How would you describe your current parenting situation?

- ◯ Raising **my child** with a spouse or live-in partner
- ◯ Raising **my child** with someone who lives in a different household
- ◯ Raising **my child** on my own

* Has your child started **Kindergarten**?

Please answer yes only if your child has already been attending a kindergarten program.

- ◯ Yes, my child **has completed** kindergarten.
- ◯ Yes, my child is **currently attending** kindergarten.

- ◯ No, my child has **not started** kindergarten.

* Does **your child** attend an early learning/child care center or preschool (not Kindergarten)?

- ◯ Yes
- ◯ No

* What type of childcare do you use for **your child**?

- ◯ In-home care with nanny or relative other than you (in your home or a nanny/relative's home)
- ◯ Family-based home childcare (outside your home and with other children)
- ◯ Childcare center, nursery school, preschool or other group program
- ◯ I do not use regular childcare for my child
- ◯ Other (Please specify)

* On average, how much time does your child spend in childcare each week?

- ◯ Less than 20 hours per week
- ◯ 20 or more hours per week

Child Vocabulary

* This questionnaire is designed to assess your **child's current vocabulary**.

- In general, children understand many more words than they say. Please mark each word in the list below that **you have heard your child SAY**.
- If your child uses a different pronunciation of a word (e.g. "duckie" instead of "duck") or a different part of speech (e.g. "walked" instead of "walking"), mark it anyway.

- **Please do not ask your child** whether he/she knows the word as we are interested in your assessment. This list includes words that children tend to learn at some point between 2 and 18 years of age.
- If you have not heard your child say any of the words listed, please check "NA."

To mark a word, please click the corresponding box. Click the box a second time to unmark the word.

- [ ] boy
- [ ] chair
- [ ] puppy
- [ ] bike
- [ ] laughing
- [ ] sleeping
- [ ] hugging
- [ ] walking
- [ ] ball
- [ ] dog
- [ ] spoon
- [ ] foot
- [ ] duck
- [ ] banana
- [ ] show
- [ ] cup
- [ ] eating

- [ ] picking
- [ ] bus
- [ ] flower
- [ ] mouth
- [ ] pencil
- [ ] cookie
- [ ] drum
- [ ] turtle
- [ ] red
- [ ] jumping
- [ ] carrot
- [ ] reading
- [ ] toe
- [ ] belt
- [ ] fly
- [ ] painting
- [ ] dancing
- [ ] whistle
- [ ] pigeon
- [ ] kicking
- [ ] lamp
- [ ] square

- [ ] fence
- [ ] empty
- [ ] happy
- [ ] fire
- [ ] castle
- [ ] squirrel
- [ ] throwing
- [ ] farm
- [ ] penguin
- [ ] gift
- [ ] feather
- [ ] cobweb
- [ ] elbow
- [ ] juggling
- [ ] inhaling
- [ ] fountain
- [ ] net
- [ ] shoulder
- [ ] dressing
- [ ] roof
- [ ] peeking
- [ ] ruler
- [ ] tunnel

- [ ] branch
- [ ] envelope
- [ ] diamond
- [ ] calendar
- [ ] buckle
- [ ] sawing
- [ ] panda
- [ ] vest
- [ ] arrow
- [ ] hazardous
- [ ] target
- [ ] dripping
- [ ] knight
- [ ] delivering
- [ ] cactus
- [ ] dentist
- [ ] floating
- [ ] claw
- [ ] uniform
- [ ] gigantic
- [ ] furry
- [ ] violin

- [ ] group
- [ ] globe
- [ ] vehicle
- [ ] chef
- [ ] squash
- [ ] ax
- [ ] flamingo
- [ ] chimney
- [ ] sorting
- [ ] waist
- [ ] vegetable
- [ ] hyena
- [ ] plumber
- [ ] river
- [ ] timer
- [ ] catching
- [ ] trunk
- [ ] vase
- [ ] harp
- [ ] bloom
- [ ] horrified
- [ ] swamp
- [ ] heart

- [ ] ankle
- [ ] flaming
- [ ] wrench
- [ ] aquarium
- [ ] refueling
- [ ] safe
- [ ] boulder
- [ ] reptile
- [ ] canoe
- [ ] athlete
- [ ] towing
- [ ] luggage
- [ ] directing
- [ ] vine
- [ ] digital
- [ ] dissecting
- [ ] predatory
- [ ] hydrant
- [ ] surprised
- [ ] palm
- [ ] clarinet
- [ ] valley

- [ ] kiwi
- [ ] interviewing
- [ ] pastry
- [ ] assisting
- [ ] fragile
- [ ] solo
- [ ] snarling
- [ ] puzzled
- [ ] beverage
- [ ] inflated
- [ ] tusk
- [ ] trumpet
- [ ] rodent
- [ ] links
- [ ] polluting
- [ ] archeologist
- [ ] coast
- [ ] injecting
- [ ] fern
- [ ] mammal
- [ ] demolishing
- [ ] isolation
- [ ] clamp

- [ ] dilapidated
- [ ] pedestrian
- [ ] interior
- [ ] garment
- [ ] departing
- [ ] feline
- [ ] hedge
- [ ] citrus
- [ ] florist
- [ ] hovering
- [ ] aquatic
- [ ] reprimanding
- [ ] carpenter
- [ ] primate
- [ ] glider
- [ ] weary
- [ ] hatchet
- [ ] transparent
- [ ] sedan
- [ ] constrained
- [ ] valve
- [ ] parallelogram

- [ ] pillar
- [ ] consuming
- [ ] currency
- [ ] pentagon
- [ ] appliance
- [ ] poultry
- [ ] cornea
- [ ] peninsula
- [ ] porcelain
- [ ] detonation
- [ ] cerebral
- [ ] perpendicular
- [ ] submerging
- [ ] syringe
- [ ] lever
- [ ] apparel
- [ ] talon
- [ ] cultivating
- [ ] wedge
- [ ] ascending
- [ ] depleted
- [ ] sternun
- [ ] maritime

- [ ] incarcerating
- [ ] dejected
- [ ] quintet
- [ ] incandescent
- [ ] confiding
- [ ] mercantile
- [ ] upholstery
- [ ] filtration
- [ ] replenishing
- [ ] trajectory
- [ ] perusing
- [ ] barb
- [ ] converging
- [ ] honing
- [ ] angler
- [ ] NA

Child Activities

* The next several questions ask about different activities children often do.

How often does **your child** do each of the following activities in the **last month**?

	Has never done this	Less than once a month	Less than once a week	Once a week	Several times a week	Once a day	Several times a day
Watch videos, including movies, series, TV shows, home-videos, or video clips. This includes watching videos on any device, for instance YouTube, TV, smartphones, tablets, and computers.	○	○	○	○	○	○	○
Play digital games on any device, including computers, tablets, smartphones, or consoles (XBox, PlayStation, Switch, etc). This could be any kind of game that is controlled directly on a screen or remote control. For example, puzzle apps, gaming apps, online games, strategy games, or touchscreen drawing.	○	○	○	○	○	○	○
Video chat on any device. This could be any kind of video chat on any device, including smartphones, tablets, and computers.	○	○	○	○	○	○	○

	Has never done this	Less than once a month	Less than once a week	Once a week	Several times a week	Once a day	Several times a day
Read digital books with visuals. This includes e-books, fairy tale story apps, picture book apps, and interactive stories.	○	○	○	○	○	○	○
Listen to audio media without visuals. This includes audiobooks and podcasts.	○	○	○	○	○	○	○
Read or look at print books such as traditional picture books or board books.	○	○	○	○	○	○	○

	Has never done this	Less than once a month	Less than once a week	Once a week	Several times a week	Once a day	Several times a day
Play without digital media or books, such as building with blocks, coloring with markers, or playing on a playground.	○	○	○	○	○	○	○
Ask questions or give commands to the voice-activated assistant on a phone (e.g., Siri) or a smart speaker (e.g., Alexa, Google Assistant). Smart speakers include Amazon Echo Dot, Google Home, and AppleHomePod.	○	○	○	○	○	○	○
Use a virtual reality headset (e.g., Oculus Rift, Google Cardboard, or PlayStation VR)	○	○	○	○	○	○	○

	Has never done this	Less than once a month	Less than once a week	Once a week	Several times a week	Once a day	Several times a day
Interact with a programmable robot (e.g., Nao, Aibo)	○	○	○	○	○	○	○

* In the **last month**, how often did **you and your child** do the following things at **home** (not at daycare or elsewhere) **without digital media**?

*(**not using** TVs, smartphones, tablets, or computers)*

	Did not occur	A few times a month	About once a week	A few times a week	Almost daily	My child is still too young for that
Counting objects	○	○	○	○	○	○
Sorting things by size, color, or shape	○	○	○	○	○	○
Coloring, painting, writing	○	○	○	○	○	○

	Did not occur	A few times a month	About once a week	A few times a week	Almost daily	My child is still too young for that
Identifying names of written alphabet letters	○	○	○	○	○	○
Identifying names of written numbers	○	○	○	○	○	○
Making music	○	○	○	○	○	○

	Did not occur	A few times a month	About once a week	A few times a week	Almost daily	My child is still too young for that
Identifying sounds of alphabet letters	○	○	○	○	○	○
Playing with puzzles	○	○	○	○	○	○

* In the **last month**, how often did **you and your child** do the following things at **home** (not at daycare

or elsewhere) **using digital media**?

*(**using** TVs, smartphones, tablets, or computers)*

	Did not occur	A few times a month	About once a week	A few times a week	Almost daily	My child is still too young for that
Counting objects	○	○	○	○	○	○
Sorting things by size, color, or shape	○	○	○	○	○	○
Coloring, painting, writing	○	○	○	○	○	○

	Did not occur	A few times a month	About once a week	A few times a week	Almost daily	My child is still too young for that
Identifying names of written alphabet letters	○	○	○	○	○	○
Identifying names of written numbers	○	○	○	○	○	○
Making music	○	○	○	○	○	○

	Did not occur	A few times a month	About once a week	A few times a week	Almost daily	My child is still too young for that
Identifying sounds of alphabet letters	○	○	○	○	○	○
Playing with puzzles	○	○	○	○	○	○

Watching Videos

The following questions are about **WATCHING VIDEOS**, including movies, series, TV shows, home-videos, or video clips. This includes watching videos on any device, for instance, TVs, cellphones, tablets, or computers.

Thinking about a typical **weekday** (Monday-Friday) and a typical **weekend day** (Saturday-Sunday) during the **last month**, how much time does your

child spend watching videos at home?

Please move the slider below to indicate time.

* On a typical **weekday** (Monday - Friday), **my child** spent about _____ **hour(s)** _____ **minute(s)** **per day** watching video content.

Hour(s)

Minute(s)

* On a typical **weekend** day (Saturday - Sunday), **my child** spent about _____ **hour(s)** _____ **minute(s)** **per day** watching video content.

Hour(s)

Minute(s)

List the **three most common TV shows or videos** that **your child** watches.

If you don't know the exact titles, you can give a description, such as "YouTube videos of other kids opening toys".

* When **your child** watches videos (movies, series, TV shows, home-videos or video clips), how often do **you watch together** with the child?

- ◯ Never or almost never
- ◯ Less than half the time
- ◯ About half the time
- ◯ More than half the time
- ◯ Always or almost always

* Why does your child watch **TV programs or videos**?

	Never	Rarely	Sometimes	Often	Always
to educate my child	◯	◯	◯	◯	◯
to calm my child down when they are upset	◯	◯	◯	◯	◯
to keep my child busy while I get things done or take a break	◯	◯	◯	◯	◯
because my child enjoys doing it	◯	◯	◯	◯	◯
to spend time together or connect with other people	◯	◯	◯	◯	◯

* When your child watches **TV programs or videos**, do they mostly watch it on a TV set that doesn't move or on a mobile device they can carry around with them?

- ◯ Mostly TV set
- ◯ Mostly mobile device (e.g., laptop, tablet, smartphone)
- ◯ Both

Playing Digital Games

This and the following questions are about **PLAYING DIGITAL GAMES** on any device, including computers, tablets, smartphones, or consoles (XBox, PlayStation, Switch, etc). This could be any kind of game that is controlled directly on a screen or remote control. For example, puzzles, gaming apps, online-games, strategy games, or touchscreen drawing.

Thinking about a typical **weekday** (Monday-Friday) and a typical **weekend day** (Saturday-Sunday) during the **last month**, how much time does **your child** spend playing digital games at home?

Please move the slider below to indicate time.

* On a typical **weekday** (Monday - Friday), **my child** spent about _____ **hour(s)** _____ **minute(s)** **per day** playing **digital games** at home.

Hour(s)

Minute(s)

* On a typical **weekend** day (Saturday - Sunday), my child spent about _____ **hour(s)** _____ **minute(s)** **per day** playing **digital games** at home.

Hour(s)

Minute(s)

List the **three most common digital games** that your child plays.

If you don't know the exact titles, you can give a description, such as "Smartphone app game that shoots birds".

* When **your child** plays **digital games** on any device, how often **do you play together** with the child?

- Never or almost never
- Less than half the time
- About half the time
- More than half the time
- Always or almost always

* Why does your child play **digital games**?

	Never	Rarely	Sometimes	Often	Always
to educate my child	○	○	○	○	○
to calm my child down when they are upset	○	○	○	○	○
to keep my child busy while I get things done or take a break	○	○	○	○	○
because my child enjoys doing it	○	○	○	○	○
to spend time together or connect with other people	○	○	○	○	○

* When **your child** plays **digital games**, do they mostly play on a TV set or gaming console that doesn't move or on a mobile device they can carry around with them?

- ○ Mostly TV set and gaming console (e.g., XBox, PlayStation)
- ○ Mostly mobile device (e.g., laptop, tablet, smartphone)
- ○ Both

Voice Assistants

This and the following questions are about **VOICE ASSISTANTS** on a phone (such as Siri) or a smart speaker (such as Alexa, Google Assistant). Smart speakers include Amazon Echo, Google Home, and Apple HomePod.

Thinking about a typical **weekday** (Monday-Friday) and a typical **weekend day** (Saturday-Sunday) during the **last month**, how much time does **your child** spend asking questions or giving commands to the voice assistants on a phone or smart speaker?

Please move the slider below to indicate time.

* On a typical **weekday** (Monday - Friday), **my child** spent about _____ **hour(s)** _____ **minute(s)** **per day** using a **voice assistant** at home.

Hour(s)

Minute(s)

* On a typical **weekend** day (Saturday - Sunday), **my child** spent about _____ **hour(s)** _____ **minute(s)** **per day** using a **voice assistant** at home.

Hour(s)

Minute(s)

* When **your child** uses a voice assistant on a phone (such as Siri) or a smart speaker (such as Alexa, Google Assistant), how often do **you do that together** with the child?

- ◯ Never or almost never
- ◯ Less than half the time
- ◯ About half the time
- ◯ More than half the time

- ◯ Always or almost always

* Why does **your child** use a voice assistant on a phone (such as Siri) or a smart speaker (such as Alexa, Google Assistant)?

	Never	Rarely	Sometimes	Often	Always
to educate my child	◯	◯	◯	◯	◯
to calm my child down when they are upset	◯	◯	◯	◯	◯
to keep my child busy while I get things done or take a break	◯	◯	◯	◯	◯
because my child enjoys doing it	◯	◯	◯	◯	◯
to spend time together or connect with other people	◯	◯	◯	◯	◯

Playing Digital Counting Games

This and the following questions are about **PLAYING DIGITAL COUNTING GAMES** on any device, including computers, tablets, smartphones, or consoles.

Counting games involve finding out how many things there are.

* Have your child played any **digital counting game**?

- *Counting games* involve finding out how many things there are.
- *Digital counting games* could be on on any device, including computers, tablets, smartphones, or consoles.

- ◯ Yes
- ◯ No

* When your child plays **digital counting games** on any device, how often do you play together with

the child?

- ◯ Never or almost never
- ◯ Less than half the time
- ◯ About half the time
- ◯ More than half the time
- ◯ Always or almost always

---

* Why does your child play **digital counting games**?

	Never	Rarely	Sometimes	Often	Always
to educate my child on counting	◯	◯	◯	◯	◯
to help my child learn to use technology	◯	◯	◯	◯	◯
to keep my child busy while I get things done or take a break	◯	◯	◯	◯	◯
because my child enjoys doing it	◯	◯	◯	◯	◯
because my child can use it anytime and anywhere.	◯	◯	◯	◯	◯
because it gives rewards to my child during learning	◯	◯	◯	◯	◯
because it makes learning interactive.	◯	◯	◯	◯	◯

---

* Do you think each of the following activities would help, hurt, or make no difference to **your child's counting skills**?

	Hurts a lot	Huts a little	Make no difference	Helps a little	Helps a lot
Watching counting videos	◯	◯	◯	◯	◯
Playing digital counting games using any device (TV, smartphone, tablet, computer)	◯	◯	◯	◯	◯
Playing physical counting games using real objects	◯	◯	◯	◯	◯
Reading counting books	◯	◯	◯	◯	◯

Appendix B

IRB Documentation

INSTRUCTIONS:

- *Use this "TEMPLATE PROTOCOL (HRP-503)" to prepare a study protocol outlining your research plan.*
- *Depending on the nature of your study, some major sections might not be applicable to your research. If so, simply mark as "N/A." For example, a simple survey might have many sections with "N/A." For subsections (e.g., 1.x or 8.x) you can mark as "N/A"if you are certain that the subsection is not applicable.*
- *Once the IRB/HRPP approves your submission, your latest approved version of the protocol will be stored in the IRB Protocol Management online system.*
- *If your research plan changes and you need to modify the protocol, please submit an amendment to Protocol Management with the requested modifications. Download your current protocol from Protocol Management and indicate the changes/revisions using the track changes feature in order to make review of the modifications easier to follow. If you are unable to use track changes, please create a new paragraph wherever you need to make a change, and indicate "Amendment: Date" before making a change to any section. Protocol management will store the older versions of your protocol if the IRB or HRPP staff need to compare them during the review.*

PROTOCOL TITLE:

Include the full protocol title.

Interactive Counting

PROTOCOL NUMBER:

Include the number assigned in Protocol Management (verify this has been added before submitting protocol to HRPP).

23-914

PRINCIPAL INVESTIGATOR:

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FUNDING:

Sponsor(s): Institute for Society, Culture and Environment (ISCE)
Funded already or in the proposal phase?: Funded Already
Is Virginia Tech the primary awardee or the coordinating center of this grant or contract? If not, list the primary institution: Yes

VERSION NUMBER/DATE:

Include the version number and date of this protocol. Versions should start at 1.0.

1.0 2/24/2024

2.0 3/28/2024

REVISION HISTORY:

Use this table to keep track of changes. Add more rows as needed.

Revision #	Version Date	Brief Summary of Changes (i.e., the different sections)	Consent Change?
2.0	3/28/2024	**General Comments:** 1) When the study is over and the PI is ready to share the data with Databrary, we will make sure to work with OSP/Summit if there is any kind of agreement that needs to be signed when handing the data over to Databrary. We have confirmed with IRB that we do not need to have this in place before our IRB application can be approved. 2) "Databrary staff release form" is added to "Other/Misc. (optional)" category 3) Updated CVs are uploaded to the protocol management system. **<u>Research Protocol:</u>** 1) 8.2: We have updated this section to describe the entire research procedure in detail from recruitment and to completion. Additionally, the study design information (i.e., within-subject) is added to 1.0 and 5.1. 2) 8.4: We have added the data obtained from the parents. 3) 8.4: We have clarified that the app is designed by the research team in house, and only the research team will have access to the data. 4) 9.4: We have clarified that we will have the electronic key including name, ID, and	Yes

		documentation of a Databrary signed release form and then the key will be destroyed except for ID and indication of a signed release. 5) 9.5: We have selected IP address. 6) 15.4: We have added our rationale for having a difference in compensation for school vs home/lab visits. 7) 19.3: We have clarified that "no other identifiable information except for IP address and location" will be collected from the parent survey. 8) 20.1: We have added that paticipants can decline to share the video data with databrary and still participate in the study. 9) 24.1: We have added the processes that we will follow to ask parents if they are willing to share the video data with Databrary. Also, we have clarified that those that are willing will be asked to sign the Databrary Release form. The requested Databrary Release form has already been included in the permission form in the previous submission, so we have not made any changes there. **Consent documents:** 1) In the "What happens to the information collected for the research?" we have added the following: The games are designed by our research team and data will be stored and accessed only by the research team. 2) We have added the following explanation regarding the option to share the video recordings with Databrary: "You will have the option to share the video recordings with Databrary. By signing the Databrary release form, the videos will be shared according to the terms of the release you sign. Alternatively, you may choose not to share the video recordings with Databrary and still participate in the study." **Recruitment Materials:** Thank you for catching this error. We have removed "$20 gift card compensation" for the school options in the social media post document.	

Table of Contents

1.0 Study Summary

Study Title	Interactive Counting
Study Design	- This is a 2-site study to be conducted at VT and Rutgers. - Participants will be 2- to 4-year-old children (n = 120; 60 VT, 60 Rutgers) and their parents (n = 120, 60 VT, 60 Rutgers). Each child will complete counting tasks on a touchscreen device either at their school, at their home, or in our lab located at Virginia Tech or Rutgers. This study uses a within-subject experimental design in which children will complete two conditions (with different levels of interactivity), the order of which will be randomized across participants. Children's performance will be recorded on the touchscreen devices as well as a separate camcorder. Parents will complete a 10-minute online survey to report demographic information and child media use.
Primary Objective	The primary goal of this study is to develop an interactive math game to help young children learn math through multimodal interaction (auditory, visual, tactile) with technology and to evaluate the extent to which the math game could facilitate young children's engagement in learning from interactive counting.
Secondary Objective(s)	The secondary goal of this study is to understand the extent to which the impact of interactive counting would vary as a function of child characteristics (e.g., vocabulary and math skills, media use).
Study Population	Children aged between 2 and 4 years and their parents
Sample Size	240 participants (120 children – 60 at VT, 60 at Rutgers, 120 parents, 60 at VT, 60 at Rutgers)
Research Intervention(s)/ Investigational Agent(s)	Children will participate in two 30-min sessions completing behavioral tasks. Parents will complete an online survey to report demographic information and child media use.
Study Duration for Individual Participants	Children will participate in two 30-min sessions. Parents will complete an online survey which will last about 10 minutes.
Acronyms and Definitions	Rutgers = Rutgers University-New Brunswick AI Voice Assistant = Conversational Voice Assistant System powered by Artificial Intelligence (AI)

2.0 Objectives

2.1 Describe the purpose, specific aims, or objectives of this study:

The primary goal of this study is to develop an interactive math game to help young children learn math through multimodal interaction (auditory, visual, tactile) with technology. We intentionally choose to integrate two increasingly affordable or ubiquitous technologies (touchscreens, AI voice assistants) in children's environments across various socioeconomic backgrounds with a goal to reduce the disparity in parental math engagement and screen time among young children.

The secondary goal of this study is to systematically evaluate the extent to which the application could facilitate young children's engagement in learning from interactive counting.

2.2 State the hypotheses to be tested:

The hypothesis to be tested is that interactivity provided by technology has the potential to improve children's engagement and learning as children participate in counting activities.

3.0 Background

3.1 Summarize the relevant prior research on this topic and gaps in current knowledge within the field of study:

Despite the profound impact of numeracy on academics, financial, and health outcomes, there is a gap in basic math concepts that roots in early home learning environments. Specifically, in-person counting experience available early in life (Goldstein et al., 2016) significantly contributes to children's later math knowledge (Gibson et al.,2020; Levine et at.,2010). However, factors such as socioeconomic status (SES) significantly constrain the quality and quantity of children's in person counting experience through less parental engagement (Levine et at.,2010), putting children from underprivileged backgrounds at risk of later achievement gaps (Hanushek et al., 2019). At the same time, lower SES is also associated with higher exposure to screen media in early childhood, with lower-income homes using 116 minutes more each day compared to higher-income households in 2020 (Rideout & Robb, 2022). Therefore, there is an urgent need to understand how screen media can be harnessed to help reduce the gap in children's interactive counting experience at early ages.

Although learning from traditional, non-interactive media (e.g., television) is attenuated compared to in-person learning among very young children, referred to as "video deficit" (Anderson & Pempek, 2025), technology that

affords socially contingent interactions can ameliorate this deficit and facilitate children's engagement and learning (Troseth et al., 2007; Roseberry et al., 2014). However, most children's screen time is limited to non-interactive video viewing (73%), which remains largely a solo activity rather than involving interaction with human social partners, such as parents (Rideout & Robb, 2022). We intentionally choose to integrate two increasingly affordable or ubiquitous technologies (touchscreens, AI voice assistants) in children's environments across various socioeconomic backgrounds with a goal to reduce the disparity in parental math engagement and screen time among young children.

3.2 Describe any relevant preliminary data:

N/A

3.3 Based on the existing literature, provide the scientific or scholarly rationale for and significance of your research and how will it add to existing knowledge:

The primary innovation of this transdisciplinary collaborative project is that it is the first to test the impact of integrating interactive touchscreens with Artificial Intelligence (AI) voice assistant technology on child development, with a focus on early counting experience that has long-term academic, financial, and health impacts. Results from this project will provide new and critically needed data for advances in both fields of children's cognitive development and human-computer interaction.

Next, this work is innovative in the development of the application that integrates interactive touchscreens with AI voice assistant technology. The method and research materials developed from this project will provide the information and tools needed for further work examining how such technological integration can promote children's learning in different developmental domains, encourage parent-child interaction, and facilitate data collection using touchscreen devices in longitudinal and naturalistic settings (e.g., homes, schools, museums, and libraries).

4.0 Study Endpoints

*4.1 Describe the primary and secondary **study** endpoints. See links below for discussion of study endpoints and how they may differ from study objectives. These are most common in clinical trials but are sometimes*

applicable to other types of biomedical research, as well as social, behavioral, or educational research. See link below for a discussion.

https://docs.google.com/document/d/1Wocz7K7a0hCQJPPO_khh5l1SQQjhGDDGHzcOPRHR5Tw/edit?usp=sharing

N/A

*4.2 Describe any primary or secondary **safety** endpoints. These should be included for all studies that are greater than minimal risk. (Minimal risk: The probability and magnitude of harm or discomfort anticipated in the research that are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.)*:

N/A

5.0 Study Design and Statistical Analysis Plan

5.1 Describe the basic study design/approach (e.g., qualitative study using five focus groups of first year students to describe assimilation into the university community; randomized controlled trial of a behavioral change intervention to increase dietary intake of whole grains; pre- post-test evaluation of new pedagogical techniques to improve adult literacy):

The study will use a pretest-posttest randomized within-subject experimental design. Children will play math games with different interactive methods, such as touch inputs and AI Voice Assistant.

This research will be conducted in 1) quiet rooms at children's preschools and child care centers (School Visit), 2) at their home (Home Visit), or in our lab located at Virginia Tech or Rutgers University (Lab Visit). There will be two 30-minute sessions (60 minutes total) per child. During the session, firstly children's verbal consent will be collected, and they will then be asked to complete counting games that consist of practice trials and test trials with different types of interactivity. Following this, children will complete cognitive tasks (numerical comparison and working memory).

Throughout the session, children's behaviors will be video recorded for accuracy check (during the two sessions) and for measuring children's behavioral engagement.

Parents will complete a survey including questionnaires on the child's background, media use, and development, which will take about 10 minutes. Parents will have an option to complete the survey either electronically or by returning a paper copy to their child's school (School Visit), home (Home Visit), or a researcher in our lab (Lab Visit).

5.2 Describe corresponding data analysis plan/approach (e.g., content analysis of focus group transcripts; descriptive analysis followed by linear regression modeling; nonparametric analysis of pre- and post-test measures):

As preliminary analyses, we will use correlation to test whether child background, media use, vocabulary, and cognitive skills are related to engagement and learning outcomes. As our main analysis, we will conduct two separate linear mixed-effects models to examine the impact of integrating interactive technology on children's engagement and math learning respectively. In each model, we will compare participants' performance on the two versions of the counting task (e.g., Touchscreen Only, Touchscreen + AI Voice Assistant). Each model will predict children's task performance as a function of condition as a within-subject factor and Child Age, Vocabulary, Numerical Comparison, and Working Memory as between-subject factors, and Participant as a random effect. Additional exploratory models will be run, including counterbalancing order, the demographic and home environment measures, and any interaction terms between factors, and then select models based on Bayesian Information Criterion (BIC) values.

6.0 Setting

6.1 Describe the sites or locations where your research team will conduct the research. Consider each of the items listed below:

- *Identify where your research team will identify and recruit potential subjects.*
- *Identify where the team will perform the research procedures.*
- *Describe the composition and involvement of any community advisory board(s).*
- *For research conducted in other locations, describe:*
  - *Site-specific regulations or customs affecting the research at those locations.*
  - *Local scientific and ethical review structure at those locations. Examples include work in other cultures or ethnic groups (within or outside of the U.S.) and work with churches. The HRPP will provide additional guidance for international research.*

For the VT site: Parents and infants from the New River Valley and surrounding areas will be recruited for participation in this study through multiple methods (University email announcements, working parents' listserv, lab Facebook page, word of mouth, flyers distributed at local day care centers and on campus). The research lab activities (e.g., video and paper data storage and coding) will occur on the VT campus, Wallace Hall, specifically in 400 Wallace.

For the Rutgers site: This is a 2-site study with Rutgers University-New Brunswick as the other site. The PI at Rutgers is Dr. Jenny Jinjing Wang. The Rutgers site will rely on the VT IRB for oversight. Recruitment will be done in a similar manner at the Rutgers site. Rutgers research lab activities will occur at Room 147 of Psychology Building in the Busch campus of Rutgers University-New Brunswick.

Rutgers has completed the local context document associated with this IRB application.

For both VT and Rutgers, data collection involves following:

For **school visits**, participants will be children (2-4 years) enrolled in preschools and child care centers that support this project and their parents/guardians. We will work with preschools and centers that are run independently, as well as other local districts with preschool programs (e.g., Virginia Preschool Initiative, Head Start) that do not require additional approvals. We will refrain from directly recruiting from MCPS, as they require additional approvals. Preschool/center directors will provide a signed support letter. After receiving approval from the director of each new site, research personnel will provide packets, one for each child, containing a parent letter (description of study, contact information for PI), brochure (information about the current study, general information about children's media use, resources for parents related to children's media use), parent permission form, child date of birth form, and parent consent form. The packet will be placed in parent mail boxes. Parents are asked to fill in the parent permission form, child date of birth form, and parent consent form and return them back to school. We will also offer the online version of the forms so that parents have the option to sign the forms electronically. The link to the online forms will be provided via a QR code embedded in the flyer and the brochure. The QR code will be directed to the online forms. Once the forms are received by researchers, researchers will start data collection with children and send parents a link to the parent survey. For children, the proposed study will be conducted in quiet rooms at children's preschools or child care centers. For parents, they will be asked to complete a survey online. A hard copy of the parent survey will be provided if needed.

For **home or lab visits**, participants will be recruited by word-of-mouth recruitment and posting in physical and digital community spaces, such as local

child museums, libraries, community events, Facebook groups, and pages for parents and research participants, email listservs, etc. Participants who are interested in participating will be able to find a link to an interest form. We will check their eligibility based on their responses to their interest forms. For eligible families, we will send an email including a link to Calendly website to schedule a visit. After the scheduling is done, they will be contacted by a researcher with more information. Using Calendly, we will send reminder emails the day before and day of the lab/home visit. For Calendly, the low-risk low-cost approval is attached. At the beginning of the visit (lab or home), the parent will complete permission form, consent form, and child date of birth form using physically or electronically, depending on the parent's preference.

7.0 Study Intervention(s)/Investigational Agent(s)

7.1 Describe the study interventions (including behavioral interventions) and/or investigational agents (e.g., drugs or devices) to be used in this study. Consider each of the items listed below:

- *Drug/Device Handling: If the research involves drugs or devices, describe your plans to store, handle, and administer the drugs or devices so that they will be used only on subjects, and only by authorized investigators.*
- *Describe whether any of the following will be used: microwaves, X-rays, DEXA scans, general anesthesia, or sedation*
- *If control of the drugs or devices used in this protocol will be accomplished by following an established, approved organizational SOP (e.g., Research Pharmacy SOP for the Control of Investigational Drugs, etc.), please reference the SOP in this section.*

N/A

7.2 List the name of all drugs (including any vitamins, supplements, herbs, or nicotine) to be used in the study. Indicate whether they have FDA approval, and list any limitations for their use:

N/A

7.3 List all devices, how they will be used, their purpose in the study, and if they will be used in a manner consistent with their approved uses. If they will be used in ways that are not yet FDA approved, indicate whether they

need an IDE or a determination that they are exempt from the IDE Determination. If a determination of significant risk or non-significant risk is needed for any of the devices, include the researcher's recommendation for each of those devices:

N/A

7.4 If the drug is investigational (has an IND) or the device has an IDE or a claim of abbreviated IDE (non-significant risk device), include the following information:

- *Identify the holder of the IND/IDE/abbreviated IDE.*
- *Explain procedures followed to comply with sponsor requirements for FDA regulated research for the following:*

	Applicable to:		
FDA Regulation	***IND Studies***	***IDE studies***	***Abbreviated IDE studies***
21 CFR 11	***X***	***X***	
21 CFR 54	***X***	***X***	
21 CFR 210	***X***		
21 CFR 211	***X***		
21 CFR 312	***X***		
21 CFR 812		***X***	***X***
21 CFR 820		***X***	

N/A

8.0 Procedures Involved

8.1 Describe and explain the study design:

This is a 2-site study conducted at VT and Rutgers. We will recruit 120 children (60 VT, 60 Rutgers) and their parents (n = 120, 60 VT, 60 Rutgers).

Children will complete math games on a touchscreen tablet device. They first do some practice trials followed by test trials. Next, children will complete two cognitive tasks (numerical comparison and working memory) on a touchscreen tablet or laptop device.

Parents will complete the parent survey either electronically or by sending back the physical copy of the survey to the child's school (School Visit) or to the experimenter (Lab or Home Visit). The parent survey will take approximately 10 minutes to complete. Reminder emails regarding the parent survey will be sent to the parents up to two times at an approximately one-week interval.

8.2 Provide a description of:

- *All research procedures being performed*
- *If the study has more than one procedure, session, and/or subject population, describe each procedure, session, and/or study population separately. For complex studies, you are encouraged to include a figure or chart.*

For **school visits**, participants will be children (2-4 years) enrolled in preschools and child care centers that support this project and their parents/guardians. We will work with preschools and centers that are run independently, as well as other local districts with preschool programs (e.g., Virginia Preschool Initiative, Head Start) that do not require additional approvals. We will refrain from directly recruiting from MCPS, as they require additional approvals. Preschool/center directors will provide a signed support letter. After receiving approval from the director of each new site, research personnel will provide packets, one for each child, containing a parent letter (description of study, contact information for PI), brochure (information about the current study, general information about children's media use, resources for parents related to children's media use), parent permission form, child date of birth form, and parent consent form. The packet will be placed in parent mailboxes. Parents are asked to fill in the parent permission form, child date of birth form, and parent consent form and return them back to school. We will also offer the online version of the forms so that parents have the option to sign the forms electronically. The link to the online forms will be provided via a QR code embedded in the flyer and the brochure. The QR code will be directed to the online forms. Once the forms are received by researchers, researchers will start data collection with children and send parents a link to the parent survey. For children, the proposed study will be conducted in quiet rooms at children's preschools or child care centers.

For **home or lab visits**, participants will be recruited by word-of-mouth recruitment and posting in physical and digital community spaces, such as local child museums, libraries, community events, Facebook groups, and pages for parents and research participants, email listservs, etc. Participants who are interested in participating will be able to find a link to an interest form. We will check their eligibility based on their responses to their interest forms. For eligible families, we will send an email including a link to Calendly website to schedule a

visit. After the scheduling is done, they will be contacted by a researcher with more information. Using Calendly, we will send reminder emails the day before and day of the lab/home visit. For Calendly, the low-risk low-cost approval is attached. At the beginning of the visit (lab or home), the parent will complete permission form, consent form, and child date of birth form using physically or electronically, depending on the parent's preference.

Parents will be asked to complete a parent survey, which will take about 10 minutes to report demographics, child media use, and child development (see "IRB-23-914_Parent Survey.pdf") For **school visit** parents, a link to a parent survey will be emailed to parents. For **home or lab visit** parents, we will provide a Virginia Tech or Rutgers tablet device with a link to the survey. A hard copy of the parent survey will be provided if needed.

For **school visit** children, children will complete two 30-minute sessions (20 minutes of research activities and 10 minutes of transition, set-up, and warm-up), scheduled approximately within a week period. For home or **lab visit** children, children will complete two 25-minute sessions (20 minutes of research activities and 5 minutes of set-up and warm-up) with a 10-minute break in between.

As this study uses a within-subject design, children will complete both experimental conditions. The order of the conditions will be randomized across children. In each condition, children will complete the same counting math game except that the level of interactivity will differ based on the condition. In each of the two conditions, children will complete an interactive math game that consists of practice trials, baseline trials, and test trials (approximately 10 minutes). In another condition, In one condition, children will be asked to take some action on the screen like touching and tracing In another condition, children will either watch a video recording of cookie counting events or count the cookies while saying number words aloud in response to an AI voice assistant. The counting game, developed by our research team, will be presented on a Virginia Tech or Rutgers tablet device. Children's touch data will be recorded on the tablet device and will be backed up to a password-protected Virginia Tech server.

After children complete two conditions, children will complete two tasks to access children's cognitive skills including working memory and numerical cognition skills. Each lasting approximately 3-5 minutes. The details of each task are provided below:

1. **Working Memory Task (3-5 minutes)**. Children's working memory will be measured by a Hide and Seek Task adapted from Applin & Kibbe (2022), where children will watch identical objects being hidden in six different possible locations and then be asked to find each object. The task will be presented on a Virginia Tech or Rutgers tablet device, but no data will be stored on the device.

2. Numerical Comparison Task (3-5 minutes). Children's numerical acuity will be measured by the Panamath Task (the psychophysical assessment of number sense acuity (Ly & Halberda, 2013), where children see different numbers of blue and yellow dots flash on the screen briefly and decide which array has more dots. The task will be presented on a password-protected Virginia Tech or Rutgers tablet device, but no data will be stored on the device.

Throughout the child sessions, children's behaviors will be video recorded for accuracy check and for measuring children's behavioral engagement using a camcorder. In addition, researchers will record children's responses using a physical coding sheet during the child sessions.

After completing the counting game two times (once for each within-subject condition) and the working memory and numerical comparison tasks, we will end the experiment and stop the video recording.

8.3 Describe:

- *Procedures or safeguards intended to reduce the probability and magnitude of risks. (For example: Reducing the risk of injury in a virtual reality study either by having the subjects sit during the study or by providing an obstacle-free space for walking.)*
- *Be sure to describe all drugs and devices used in the research, when they will be administered or used, and their purpose.*
- *Methods used to collect data about subjects. Please upload all data collection forms to Protocol Management. Some common examples are:*
  - *Screening questionnaires*
  - *Survey(s), including online surveys*
  - *Demographic questionnaire(s)*
  - *Interview guide(s), e.g., questions or pool of questions for semi-structured interviews*
  - *Focus group guide(s)*
  - *Other documents used to collect data*

The risk of participating in the current research is minimal to none. Still, participants will be informed that they can stop the tasks or survey at any time without repercussions. They will be informed that study participation is completely voluntary. Researchers will monitor children during the assessments

for any signs of undue stress or anxiety in completing tasks, or any signs that the child may want to discontinue the session.

To minimize all the risks of the study, all materials (e.g., data sheets, survey results) will be marked with a participant ID and be stored separately from identifiers (e.g., consent forms, videos).

To identify and address unanticipated problems or complications, all materials will be stored on password-protected Virginia Tech computers in locked Virginia Tech offices accessible only to lab personnel, and they will be stored within locked cabinets in locked offices when not in use. For the Rutgers site, all materials will be stored on password-protected Rutgers computers in locked Rutgers offices accessible only to lab personnel, and they will be stored within locked cabinets in locked offices when not in use. In the unlikely event of a security breach (e.g., office break in), we would contact the IRB office immediately.

No drugs will be used in the research.

8.4 What data will you collect during the study and how you will obtain them? Please include descriptions of electronic data collection, database matching, and app-based data collection:

Cognitive tasks: The two cognitive tasks will be administered (numerical comparison and working memory) on a Virginia Tech or Rutgers touchscreen tablet or laptop device. No data will be stored on the device. Researchers will record children's responses using a physical coding sheet during the child sessions.

Counting app touch data: During each session, children will play the counting game using the app on a Virginia Tech or Rutgers tablet device. The counting app is developed by our research team in house and only our research team will have access to data. During the game play, children's touch data will be automatically saved to a password-protected Virginia Tech server for both VT and Rutgers sites. The app does not ask for any identifiable information related to participants. Each child will have a participant ID and these IDs will be entered to the app. The data will be marked with a participant ID (not child name) and be stored separately from identifiers (e.g., consent forms, videos).

Video recordings: Upon the completion of child assent, the researcher will record the session using camcorders and video recordings will be stored on a password-protected Virginia Tech (or Rutgers for the Rutgers site) computer in a locked office accessible only to lab personnel. Recordings will be marked with a participant ID.

Parent survey data: Parents will complete a survey to report child demographics, child media use, and child development. The data will be collected by either electronically using QuestionPro (VT) or Qualtrics (Rutgers) or on paper using the paper survey form. This QuestionPro and Qualtrics online survey will track location and IP address to exclude duplication and ensure validity. No other identifiable information, except for IP address and location, will be collected from the parent survey via QuestionPro and Qualtrics. Also, data manually entered from paper will be reviewed by trained lab personnel, who have all been added to the protocol, to ensure accuracy.

8.5 Who will transcribe or code audio and/or video recordings?:

Only IRB-approved research personnel (undergraduate and graduate students, PIs) transcribe and code video recordings.

8.6 Include a description of any deception to be used in the study. Include justification for the use of deception (why the deception is necessary), describe the debriefing process, and describe how the study meets <u>all</u> the following criteria for alteration of consent (deception is considered an alteration of informed consent):

- *The research involves no more than minimal risk to the subjects*
- *The alteration will not adversely affect the rights and welfare of the subjects*
- *The research could not practicably be carried out without the alteration/deception*
- *(Optional but encouraged in most cases) Subjects will be provided with additional pertinent information after participation (i.e., debriefing for studies involving deception)*

N/A. This study does not include any deception.

8.7 If the study involves long-term follow-up (once all research related procedures are complete), describe what data will be collected during the follow up period and when it will occur:

N/A

9.0 Data and Specimen Long Term Storage and Use

9.1 If you will store data or specimens for future use, describe where you will store the data or specimens, how long they will be stored, and how and by whom the data or specimens will be accessed:

Data will be stored in locked VT or Rutgers research offices accessible only to lab personnel. All electronic materials (e.g., survey results, video recordings, audio recording, coding sheets, data files) will be stored on password-protected VT or Rutgers computers in locked offices and will be stored within locked cabinets in locked offices when not in use. Paper copies of study materials (coding sheets, scoring sheets of pre- and post-tests) will be stored within locked cabinets in locked offices.

All materials are marked with a subject ID# (i.e., the unique ID assigned by the investigator to code the data) and do not contain identifying information, although the video recordings themselves may contain identifiable images of a child. Video recordings will be marked with a subject code to be name anonymized and be kept in locked VT or Rutgers research offices accessible only to lab personnel. Child date of birth forms will be marked with a subject code be name anonymized and be stored separately from the rest of the materials, which will be locked in Virginia Tech research offices accessible only to lab personnel. Only authorized research personnel will view these recordings using password protected computers. Recordings will not be shown, either publicly or as part of the presentation of data, unless parents give their permission on the consent form.

Only non-identifying data will be stored in a data file (e.g., records with a subject number but not identifying information). During data analysis, only coded copies of the data files will be used.

All non-identifying data (data files, survey results) will be stored separately from identifiers (e.g., consent forms, video recordings, date of birth forms). A separate document that links participants' numbers to participants' identifying information will be stored as an encrypted file on a password-protected VT or Rutgers computer. Only research team members who need this information will be granted access to it.

Some brief video clips will be used for educational purposes (e.g., presentation of research findings at conferences). Parents will indicate whether they agree to share the video clips for educational purposes during their consent process.

Behavioral data (video recordings; identified only with ID # only) will be temporarily stored on a project dedicated SharePoint site so that the VT

and Rutgers research teams can view each other's lab visits and perform reliability coding for each other's behavioral coding work.

Databrary is a NSF- and NIH-funded repository for data and videos used by many developmental scientists across the United States and Canada. Databrary satisfies the data sharing requirements by allowing other researchers access to data and videos (with parent permission) of research lab visits for secondary data analysis and secondary behavioral coding.

Five years after all publications from this project are published, data will be posted on Databrary, Below is copy/paste information from the Databrary website for use in IRB protocol documents for local IRB review: https://databrary.org/support/irb/irb-application.html

Primary data collection

Data will be handled by the team of researchers approved on the IRB protocols of all Principal Investigators and Co-Investigators. Data are linked to participants by subject ID. However, video data are potentially identifiable because participants' faces are visible and their names may be heard. With participant consent, study data will be stored on Databrary, a secure web-based video library housed at NYU, allowing permission-based access to coders from all labs comprising the project team. At the end of each lab visit, caregivers will be asked whether they are comfortable: 1) storing their videos and children's birthdates and other metadata on Databrary, and 2) sharing their data with authorized researchers outside of this protocol who are members of the academic research and clinical communities authorized to access Databrary. If caregivers agree to video sharing, the videos will be made available to authorized researchers as outlined below. If caregivers do not agree, their videos will be accessible only by researchers on the project protocol and not shared with the larger community. The policies for sharing videos and other potentially identifiable data on Databrary have been carefully developed and monitored with the advice of the legal counsel, grants/contracts office, and IRBs of both New York University and The Pennsylvania State University. Currently, more than 360 institutions in the U.S. and around the world have formally approved the Databrary Access Agreement to enable video sharing and reuse. Parents also will be told that they can share portions of data or ask for particular sessions not to be shared while sharing other sessions.

Policies for Databrary access and data sharing.

Sensitive or identifiable data shared with Databrary will only be viewable to and downloadable by authorized users who have been granted secure access by Databrary's administrators. Select data may be made available to the public, but only as determined by the researcher and on the basis of participant permission. Only researchers with Principal Investigator status

from institutions with Institutional Review Boards or similar review entities, and researchers affiliated with Principal Investigators and under their supervision, are authorized for access.

Authorized users are required to sign a user access agreement that specifies that they will: (1) be responsible for maintaining the confidentiality of the data; (2) abide by ethical principles for treatment of human subjects as mandated by their local Institutional Review Boards; (3) agree not use the data for commercial purposes; and (4) treat data in Databrary with the same high standards of care that they would treat data collected in their own laboratories.

Only videos and other identifiable data that have been permissioned for sharing by all the depicted individuals in each recording are made available to the community of authorized Databrary users. In consultation with ethics board officials at New York University and the Pennsylvania State University, Databrary has developed template Sharing Release forms that contributors can add to their IRB protocol. These forms allow researchers to ask participants for permission to share their data.

Federal policies do not require re-consenting of minor participants when they reach the age of majority, if re-consenting is impractical or otherwise increases risks to participants (e.g., by requiring researchers to maintain links between identifiable information and collected data for extended time periods).

Policies and provisions for reuse and redistribution.

Access to videos and metadata will be available for educational and research purposes, subject to participant consent. Such access will be provided using the Databrary web-based application. Materials generated under the project will be disseminated in accordance with the policies of [GRANT-GIVING ORGANIZATION] and participating institutions. Publication of data shall occur during the project, if appropriate, or at the end of the project, consistent with normal scientific practices.

Archiving and preservation of research data.

Data in Databrary will be preserved indefinitely in a secure data storage facility at New York University (NYU); the facility is managed by the university's Information Technology Services department. Central IT staff handle storage, network, and backup systems. NYU does routine tape backups that are stored off site and performs regular file fixity checks to monitor the integrity of stored assets. Federal regulations do not require that data be destroyed after a particular time period if they are stored indefinitely in a recognized repository.

Data Security.

Data and metadata stored in Databrary are subject to the security policies and best practices implemented by NYU. For more information about

these policies and services, please visit NYU ITS Computer & Network Security at http://www.nyu.edu/its/security/.

9.2 For specimens, list the data to be stored or associated with each specimen:

N/A

9.3 Describe the procedures to release data or specimens outside of the research team, including the process to request a release, approvals required for release, who can obtain data or specimens, and what data will be provided with specimens:

This is a 2-site research study. The other research site is Rutgers and the PI is Jenny Jinjing Wang. We will combine data from the VT site and the Rutgers site in conference presentations and publications.

9.4 Describe the identifiers to be included with stored data or specimens, as well as any key or code that could be used to make them identifiable. Describe where the code will be stored, who will have access to it, and when it will be destroyed:

Each participant will be given an ID number and all data will be associated with that ID number rather than the participant's name. This number will be used instead of a name on all questionnaires and in all data sets.

The key to the ID numbers is stored as an electronic key in the form of an Excel spreadsheet that is password protected on the VT computer for VT participants; and on the Rutgers computer for the Rutgers participants. The VT site will not have access to the electronic key and vice versa. Only the investigators approved for each site have access to the site key. The key will include participant IDs, participants' identifying information (e.g., name), as well as documentation of a signed released form. The electronic key at both sites will be destroyed 5 years after all publications of the data, except for ID and indication of a signed release, which will be retained until data are shared with Databrary.

9.5 Please select the identifiers you will obtain (whether directly from participants or from another source), including but not limited to:

☒	*Name*
☒	*Geographical subdivisions smaller than a state, including street address, city, county, precinct, zip code, and equivalent geocodes (note, the initial three digits of a zip code are not considered identifiable)*
☒	*Elements of dates (except year) for dates directly related to an individual, including birth date, admission date, discharge date, date of death, and single year of age over 89 and all elements of dates (including year) indicative of such age (note, such ages and elements may be aggregated into a single category of age 90+)*
☒	*Phone numbers*
☐	*Fax numbers*
☒	*Electronic mail addresses (e-mail)*
☐	*Social Security numbers*
☐	*Medical record numbers*
☐	*Health plan beneficiary numbers*
☐	*Account numbers*
☐	*Certificate/license numbers*
☐	*Vehicle identifiers and serial numbers, including license plate numbers*
☐	*Device identifiers and serial numbers*
☐	*Web Universal Resource Locators (URLs)*
☒	*Internet protocol (IP) address numbers*
☒	*Biometric identifiers, including finger and voice prints (audio recording)*
☒	*Full face photographic images and any comparable images (including video recording)*
☐	*Student record number or identification number*
☐	*User name for online or computer accounts*
☐	*Any other unique identifying number, characteristic, or code (note this does not mean the unique code assigned by the investigator to code the data)**:*** Click here to explain.

10.0 Sharing of Results with Subjects

10.1 Describe whether you will share results (study results or individual subject results, such as results of investigational diagnostic tests, genetic tests, or incidental findings) with subjects or others (e.g., the subject's primary care physician). If so, describe how you will share the results and include this

information as part of the consent document. Upload materials you will use to explain the results to subjects:

In publications resulting from this study, only group characteristics will be published, and individuals will not be identifiable. No individual study results will be shared with participants. The generalized study results will be shared on the PIs' lab websites to disseminate research findings at the conclusion of the study. We also offer to share publications upon request.

11.0 Study Timelines

11.1 Describe:

- *The duration of an individual subject's participation in the study (for example, 1 hour, 2-4 weeks, 3-5 years).*
- *The amount of time expected to enroll all study subjects (weeks, months, years, etc.)*
- *The amount of time expected for the investigators to complete this study including primary data analyses.*

The duration of an individual child subject's participation in the study is approximately 60 minutes in total. For school visit children, children will complete two 30-minute sessions (20 minutes of research activities and 10 minutes of transition, set-up, and warm-up), scheduled approximately within a week period. For home or lab visit children, children will complete two 25-minute sessions (20 minutes of research activities and 5 minutes of set-up and warm-up) with a 10-minute break in between. Parents of participating children will participate in a 10-minute survey. The amount of time expected to enroll all study subjects is 2 years. The amount of time expected for the investigators to complete this study including primary data analyses and publications is 5 years.

12.0 Inclusion and Exclusion Criteria

12.1 Describe how you will screen individuals for eligibility. When will screening occur and what procedures will you use? Upload any screening scripts or surveys to Protocol Management:

For the first level screening for school and lab visit children, we will communicate with parents or directors at preschools and child care centers to identify children in the right age range (2-4 years) and who speak English. In the rare case that we happen to have a consent form for children who do not meet the first level screening criteria, we will check their consent forms and their date of birth form to calculate their age. Children who do not meet this age range will be excluded from the

enrollment. The screening criteria are stated in the permission and consent forms and recruitment materials.

For home-visit children, we had an additional criterion related to the location of the participants' homes due to the geographical constraints. For the VT site, we restrict it to the New River Valley and surrounding areas in Virginia, USA. For the Rutgers site, we restrict it to New Brunswick and surrounding areas, New Jersey, USA. This additional criterion is also stated in the permission and consent forms and recruitment materials.

12.2 Describe the eligibility criteria that define who will be included and who will be excluded from enrollment for each procedure of your study. Include any geographic criteria (e.g., Virginia Tech undergraduate students, a national sample of adults with engineering degrees, minors aged 8-12 in the New River Valley, university faculty in Virginia and Paris, France):

Children should be between the ages of 2 and 4. In addition, we will only recruit children who speak English. In the rare case that a parent's responses in the child date of birth form do not meet the first level screening criteria for this study (mentioned above), we will inform parents that they are not eligible for this study by sending an email. For home visit parents, we will check the geographical proximity and inform them if they are not eligible for this study by sending an email. For the VT site, we restrict it to the New River Valley and surrounding areas in Virginia, USA. For the Rutgers site, we restrict it to New Brunswick and surrounding areas, New Jersey, USA.

12.3 Indicate specifically whether you will include or exclude each of the following special populations: (You may not include members of these populations as subjects in your research unless you indicate them in the description of your subject population.)

- *Minors, as defined by state law where the study is performed (infants, children, teenagers)*
- *Pregnant women (can be included in minimal risk studies by mentioning in section 13.1)*
- *Prisoners (including all incarcerated individuals)*
- *Adults not capable to consent on their own behalf*

This study includes children aged between 2 and 4 years and their parents who consent their child to participate in the research. The proposed study will not include prisoners and adults not capable to consent on their own

behalf. As this is a study involving no more than minimal risk, we are not excluding pregnant women.

13.0 Vulnerable Populations

13.1 If the research involves individuals who are vulnerable to coercion or undue influence, please describe additional safeguards you will include to protect their rights and welfare. Consider the applicable items listed below:

- *If the research involves Virginia Tech students, indicate whether these are students of any of the investigators. If so, describe whether the activities will take place during class time as part of the curriculum and the steps you will take to reduce the possibility that students feel obliged to participate in order to improve their course grade. The HRPP can provide further guidance as needed. Describe whether you will request access to student records (e.g., SAT, GPA, GRE scores).*
- *If the research involves employees of Virginia Tech or the research sponsor, describe steps you will take to ensure that the employees are freely participating and describe how their data will be protected from inspection by their supervisors.*
- *If the research involves Virginia Tech NCAA athletes, you must obtain approval from the athletic department.*
- *For research involving Montgomery County Public Schools, you must obtain county approval (after obtaining contingent Virginia Tech approval). Other locales have different requirements; please check on these and describe here. Approval is typically granted by the superintendent, principal, and classroom teacher (in that order). Approval by an individual teacher is insufficient. School approval, in the form of a letter or a memorandum should be uploaded as a supporting document.*
- *If the research involves pregnant women, review "CHECKLIST: Pregnant Women (HRP-412)" to ensure that you have provided sufficient information in this protocol.*
- *If the research involves prisoners, review "CHECKLIST: Prisoners (HRP-415)" to ensure that you have provided sufficient information in this protocol.*
- *If the research involves persons who have not attained the legal age for consent to treatments or procedures involved in the research (minors), review the "CHECKLIST: Minors (HRP-416)" to ensure that you have provided sufficient information in this protocol.*

- *If the research involves cognitively impaired adults, review "CHECKLIST: Cognitively Impaired Adults (HRP-417)" to ensure that you have provided sufficient information in this protocol.*

Children of Virginia Tech students or employees may be recruited to participate as part of the general population in the area. However, these students would not be specifically any of the investigators' students, and their child's participation would not be as part of a class activity. Also, Virginia Tech employee's employment would not be recorded. Virginia Tech NCAA athletes would not be recruited specifically for this study but may be recruited to participate as part of the general population in the area. The research will not involve the public school system that require additional approvals, prisoners, or cognitively impaired adults.

The results of the study will be always reported in the form of group averages and individuals will not be identifiable. The data will be confidential, and results will not be disclosed from any individual participant to parents, subjects, or the university. The research records will include some information about participants (including age, gender), and this information will be stored in such a manner that some linkage between participants' identity and responses in the research exists. This information will be kept confidential by limiting individuals' access to the research data and keeping it in a secure location. The research team and the Institutional Review Board are the only parties that will be allowed to see the data, except as may be required by law.

14.0 Number of Subjects

14.1 Indicate the total number of subjects to be enrolled and how this number was determined (e.g., sample size calculation [show], number of available subjects in a finite pool, number of tests funding award would allow):

The total number of subjects to be enrolled in this study is 240 (120 children, 120 parents) across the two data collection sites. Based on prior research this is an acceptable number to adequately examine the research questions.

14.2 If this is a multi-site study, indicate the number of subjects to be enrolled at this site and the total to be enrolled from all sites:

This is a 2-site study conducted at VT and Rutgers.

14.3 If applicable, indicate the number of potential subjects you expect to screen for enrollment, and the number of subjects you will need to complete the research procedures:

The first level screening will be conducted by the PIs and research personnel. Based on other experiments on similar age ranges, we expect 15% dropout rates. As such, we would expect to screen 120 subjects for enrollment and have about 100 subjects for final samples.

14.4 If the study has more than one procedure, indicate the total number of subjects to undergo each procedure separately:

N/A

15.0 Recruitment Methods

15.1 Describe when, where, and how you will recruit potential subjects:

1) School visit participants

Child recruitment will occur through a parent letter distributed to preschools and child care centers after we get a support letter from directors. First, a letter to directors, and a support letter (attached to this protocol) will be shared with directors of preschools across the New River Valley and surrounding areas (e.g., Blacksburg, Christiansburg, Radford, Giles County) for the VT site and New Brunswick and surrounding areas for the Rutgers site. A parent letter and a recruitment brochure will be also shared with directors for their reference. Directors will provide a signed support letter. After receiving approval from directors for each new site, research personnel will provide packets, one for each child, containing a parent letter (description of study, contact information for PI), the brochure (information about the current study, general information about children's media use, some resources), parent permission form, child date of birth form, and parent consent form. The packet will be placed in parent mail boxes. Parents can fill in the parent permission form, child date of birth form, and parent consent form and return them back to school. We will also offer the online version of the forms so that parents have the option to sign the forms electronically. The link to the online forms will be provided via a QR code embedded in the flyers (small, large) as well as the brochure. The QR code will be directed to our lab website, where parents can find the online forms and complete them. The recruitment will occur between March 2024 and March 2026.

2) Home visit participants & Lab visit participants

We will distribute our flyers electronically through email listservs and social media sites (e.g., Facebook, Twitter) and distribute physical flyers in public spaces (e.g., libraries, children's museums, stores, child care centers). When distributing flyers in public spaces, we will follow necessary procedure as described in the venue.

15.2 Describe the source of subjects (for example, clinic patients with specific conditions, students in the library, community members at a gathering, or members of a local gym):

We will be recruiting parents and their children aged between 2 and 4 who speak English. For school visits, child recruitment will occur through a parent letter distributed to preschools and child care centers from the New River Valley and surrounding areas for the VT site and New Brunswick and surrounding areas for the Rutgers site after we get a support letter from directors or through electronic and physical flyers. For home- and lab visits, we will distribute our flyers electronically through email listservs and social media sites (e.g., Facebook, Twitter) and distribute physical flyers in public spaces (e.g., libraries, children's museums, stores, child care centers), targeting the New River Valley and surrounding areas for the VT site and New Brunswick and surrounding areas for the Rutgers site.

15.3 Describe the methods that you will use to identify potential subjects:

For school visits, we will communicate with directors of preschools and childcare centers or parents to identify children between 2-4 years of age who speak English. For home and lab visits, we will distribute our flyers electronically through email listservs and social media sites (e.g., Facebook, Twitter) and distribute physical flyers in public spaces (e.g., libraries, children's museums, stores, child care centers), targeting the New River Valley and surrounding areas for the VT site and New Brunswick and surrounding areas for the Rutgers site.

15.4 Describe materials that you will be use to recruit subjects. Attach copies of these documents with this protocol in Protocol Management and be sure to include the IRB protocol number on each document.

- *For flyers, attach the final copy of printed flyers.*

- *For Virginia Tech News, Facebook postings and ads, newspaper ads, websites, MTurk/SONA/online survey systems, etc., attach the final wording and graphics to be used.*
- *For email recruitments, please include the subject line.*
- *For advertisements meant for audio broadcast, please submit the wording of the advertisement prior to taping (to avoid having to re-record with approved language) and submit the final recorded version for IRB review before use.*
- *Describe any compensation to subjects. Separate compensation into appropriate categories, such as: reimbursement for expenses, time and effort, and additional incentives for study participation. For each category, specify the amount (including any pro-rated amount), schedule, and method of payment.*

For school visits:

School-visit children will receive small prizes (i.e., stickers) after the session upon approval of their school. As we are meeting with children at their schools, parents are not required to be present during children's sessions. Therefore, no compensation will be offered for parents who participated in school visit sessions.

For home or lab visits:

Home or lab visit children will receive small prizes (i.e., stickers) after the session. As parents of home-visit or lab-visit children need to present during the research visits, there may be missed opportunities for work or childcare. Therefore, for home visits and lab visits, a total of $20 USD electronic gift card compensation will be made for their time, contingent upon the completion of the 2 sessions and parent survey.

16.0 Withdrawal of Subjects

16.1 Describe circumstances under which you anticipate subjects could be withdrawn from the research without their consent:

None of the participants will be withdrawn from the research study without their consent/assent. If a child does not want to participate in the activities, they will be asked if they want to take a short break and come back for the session. If they do not want to come back, we will stop that session.

16.2 If applicable, describe any procedures for orderly termination (e.g., discontinuation of a study drug or debriefing after a behavioral intervention):

Parents and children are free to withdraw from this study at any time. If children wish to stop at any time, they can tell the experimenter during the session, and the experimenter will end the session and test immediately. If the parents wish to withdraw their children from the study, they can contact PIs, research personnel, directors, or staff. If parents wish to stop their survey, parents can either discard their paper survey form or exit their browser, and the survey will be discontinued immediately. This procedure will be clearly stated in the consent form.

16.3 Describe procedures that you will follow when subjects withdraw from the research, including partial withdrawal from procedures with continued data collection (e.g., participant declines to continue with regular blood draws, but continues with periodic behavioral questionnaires):

Parents and their children are free to withdraw from this study at any time. The parent survey and the child session will be discontinued immediately. For children, small gifts (i.e., stickers) will be given regardless of the completion of the session upon approval of their child's school (School Visit) or parents (Home Visit).

If participants want to discontinue, they can terminate the session at any time. If they wish to withdraw, parent participants will be asked for permission to use data collected up to the point of withdrawal. This procedure will be included in the consent form.

17.0 Risks to Subjects

17.1 List the reasonably foreseeable risks, discomforts, hazards, or inconveniences to the subjects related the subjects' participation in the research. Include for the IRB's consideration a description of the probability, magnitude, duration, and reversibility of the risks. Consider physical, psychological, social, legal, privacy, and economic risks. Do not indicate "No risk" or "N/A." Instead, for studies with very low risk (e.g., anonymous online questionnaire on a mundane topic) indicate "The investigators are not aware of any risks from participation in this study." or "No more than risks than are found in everyday life." The example consent form presents a tabular method for risk information, which you can also use here. Common risk types include:

- *Physical (e.g., potential for pain, discomfort, infection)*
- *Psychological (e.g., potential for stress, discomfort, and/or embarrassment)*
- *Social (e.g., potential for discrimination or stigmatization and disruption of personal and family relationships)*

- *Legal (e.g., potential for disclosure of illegal activity, negligence)*
- *Privacy (e.g., potential for personal information being accessed, used, or disclosed without the subjects' knowledge or consent, breach of confidentiality/security)*
- *Economic (e.g., potential for individuals to lose access to economic services, employment, insurability)*

This study consists of filling in a survey by parents and playing counting games during in-person sessions with children. There are no risks associated with this study beyond those associated with everyday life. Possible risks for participants would be boredom or lack of desire to participate. We will reduce this risk by allowing participants to stop at any time by exiting out of their online survey browser or by telling the experimenter to end the session. The online survey and in-person sessions will be discontinued immediately.

17.2 Indicate the measures you will use to minimize risks and monitor subjects for safety. (e.g., asking a subject at regular intervals to rate how they are feeling from 1 to 10, or to slowly crouch in order to check their balance.)

N/A. This is a low-risk study. In case of boredom or lack of desire to continue, participants can stop at any time by stopping their survey, exiting out of their browser, or by telling the experimenter to end the session. The survey and in-person sessions will be discontinued immediately.

17.3 If applicable, indicate which procedures might have risks to the subjects that are currently unforeseeable. This will be rare, and usually applicable when testing a new drug or device or a new use of an existing drug or device:

N/A

17.4 If applicable, indicate which procedures might have risks to an embryo or fetus should the subject be or become pregnant:

N/A

17.5 If applicable, describe risks to others who are not subjects (e.g., collection of sensitive health data that might affect sexual partners if disclosed,

mandatory reporting of abuse, DNA testing that might affect family members or relationships):

N/A

18.0 Potential Benefits to Subjects

18.1 Describe the potential benefits that individual subjects might experience from participating in the research. Include the probability, magnitude, and duration of the potential benefits, as this will be useful to the IRB's risk:benefit analysis. Do not include benefits to society or others. Do not list monetary or non-monetary compensation for participation, as this is not a benefit These should be included in section 2 or 3 of this document:

The participants are not expected to directly benefit from participation in this study, but the information we gain will increase our knowledge to better understand how to design and use interactive technology to promote early math learning.

Children may gain knowledge (Counting from 1-10) from these counting tasks. The magnitude and duration of the potential benefits related to the specific learning domain have not been examined yet.

18.2 If applicable, specify that there are no anticipated direct benefits for participants:

There are no anticipated direct benefits for participants.

19.0 Data Management and Confidentiality

19.1 Describe procedures that you will use for quality control to ensure validity of collected data:

Standardized and scripted interviews and questionnaires will be presented to ensure validity of collected data. Video and survey data will be reviewed by trained lab personnel, who have all been added to the protocol, for quality control to ensure validity. The data will also be

periodically reviewed and checked for validity by trained lab personnel. In addition, lab personnel will report any adverse conditions observed by devices during study sessions in order to prevent device malfunction from disrupting data validity.

19.2 Describe any existing data or biospecimens you will obtain as part of this study. Include:

- *Variables or samples to be obtained*
- *Source of the data or specimens*
- *Your authorization to access or receive the data or biospecimens*
- *Whether the data or biospecimens are publicly available*
- *Whether the data or specimens you receive will contain identifiers*

N/A

19.3 Describe the steps that you will take to handle and secure study data during data collection, storage, use, and transmission. Include information about training of study staff, authorization of access, password protection, encryption, physical controls, certificates of confidentiality, separation of identifiers and data, etc.:

Parent survey data will be collected by either electronically using QuestionPro (VT) or Qualtrics (Rutgers) or on paper using the paper survey form. This QuestionPro and Qualtrics online survey will track location and IP address to exclude duplication and ensure validity. No other identifiable information, except for IP address and location, will be collected from the parent survey via QuestionPro and Qualtrics. Also, data manually entered from paper will be reviewed by trained lab personnel, who have all been added to the protocol, to ensure accuracy.

For home-visit children, Calendly will be used to schedule each session. For Calendly, the low-risk low-cost approval is attached.

Data collected in the secure facilities will only be transported between secure facilities by trained lab personnel. Data will only be entered and accessed by authorized lab personnel. All materials (e.g., survey results, video recordings, coding sheets) will be stored on password-protected computers in locked Virginia Tech offices and will be stored within locked cabinets in locked offices when not in use. All computers used to collect and store electronic data will be password protected. Identifiers will be kept separate from data, and the identification key will have further limited access.

A separate document that links participants' numbers to participants' identifying information will be stored as an encrypted file on a password-protected Virginia Tech or Rutgers computer. Only research team members who need this information will be granted access to it.

In publications resulting from this study, only group characteristics will be published, and individuals will not be identifiable unless participants give their permission to use identifiable recordings of participation beyond the study completion on the consent form. While there will probably be publications as a result of this study, the participant's name will not be used.

19.4 For multi-site studies, describe how data or specimens will be handled and secured for each site (e.g., central or disseminated data storage, data coordinating center):

N/A

19.5 Describe the plan for data disposition following the conclusion of the study (e.g., long term maintenance of data, data destruction methods).

- *What information will be included in the long term storage of data or specimens?*
- *How long will the data or specimens be stored?*
- *Where and how data or specimens will be stored?*
- *Who will have access to the data or specimens during long term storage?*
- *Who is responsible for receipt or transmission of the data or specimens?*
- *How will data or specimens be shared or transported?*
- *When and how will personal identifiers be destroyed?*

Participant data (completed surveys, video recordings, data coded from the sessions) will be included in long-term data storage for this study. Video data will be downloaded and stored on password-protected computers in PI Choi's locked research offices, and then backed up to identical external hard drives. Once video data is backed up to these hard drives, it will be deleted from the computers. Physical data will be kept in locked filing cabinets in PI Choi's locked research offices. Data that are scanned in electronic form will be kept securely on a password-protected computer in the PI Choi's locked research offices, separate from the password-protected computer on which the name-ID number encrypted file is kept. Any electronic data collected through Virginia Tech QuestionPro surveys will be in the QuestionPro platform and also downloaded as electronic files to be stored on a password-protected computer in

PI Choi's locked research offices. Only lab personnel, including the PI and approved graduate and undergraduate research assistants, will have access to the secured data.

For PI Wang's participant data will be managed in the same fashion at the Rutgers site. A difference would be Rutgers Qualtrics will be used instead of Virgina Tech QuestionPro.

At the conclusion of the study, all identifiers including the identification key linking them to the data will be destroyed after 3 years after study completion, along with the paper copies of data. Identifiable videos will be maintained until 3 years upon completion of the study unless participants give their permission to use identifiable recordings of participation beyond the study completion on the consent form.

20.0 Provisions to Protect the Privacy Interests of Subjects

20.1 Describe the steps that you will take to protect subjects' privacy interests. "Privacy interest" refers to a person's desire to place limits on with whom they interact or to whom they provide personal information (e.g., collecting the minimal amount of private information required to complete the study, protecting the data once it is obtained):

Only minimal identifying information will be collected. Contact information will be kept separate from data. Participants will be assigned non-identifiable participant IDs in order to protect their privacy.

Participants can decline to share the video data with Databrary and still participate in the study.

20.2 Describe steps that you will take to make subjects feel at ease with the research situation in terms of the questions being asked and the procedures being performed. "At ease" does not refer to physical discomfort, but the sense of intrusiveness a subject might experience in response to questions, examinations, and procedures (e.g., use of a same gender investigator to place sensors on the torso, a private changing area if clothing must be changed, sensitivity when discussing pregnancy testing with subjects, making it clear on surveys that participants can discontinue at any time, not asking questions about private or sensitive issues unless necessary for the research):

Consent form, assent script, and survey questionnaires will make clear their confidential nature, as well as the ability of the participant to

discontinue at any time without penalty. The in-person sessions with children will also have the ability to end at any time.

20.3 Describe how you plan to access existing sources of information about the subjects (e.g., medical records, grades) and how you will protect participant privacy through the data security plan:

N/A

20.4 Describe any required reporting that might occur as a result of your research questions, study populations, and data collection methods. Examples for Virginia and Virginia Tech include:

- ***Any*** *suspicions (e.g., circumstantial, disclosed) of child abuse (physical, emotional, sexual) and neglect*
- *Sexual discrimination and/or sexual violence that involves a student*
- *Disclosure or signs of intention to harm oneself (i.e., suicidal ideation and/or plan)*
- *Disclosure or signs of desire to harm others (i.e., homicidal ideation and/or plan)*
- *Suspected abuse, neglect or exploitation of vulnerable adults (e.g., individuals with a disability, elderly persons)*

Any suspicions of child abuse, neglect, or other concerning circumstances will be reported by researchers to the PI, Dr. Choi, who will report to the appropriate channels. Specifically, Dr. Choi, after informing the parent, will be obligated to contact the Department of Social Services, in compliance with the mandatory reporting laws of the state of Virginia. This information is included on the parent consent form.

21.0 Provisions to Monitor the Data to Ensure the Safety of Subjects

Safety monitoring is required when research involves greater than minimal risk and is sometimes appropriate for other studies.

21.1 Describe:

- *The plan to periodically evaluate the data collected regarding both harms and benefits to determine whether subjects remain safe (e.g., periodic reporting to the IRB, establishing a data monitoring committee, reporting data monitoring committee findings to the IRB and the sponsor).*

- *What data you will review, including safety data, unexpected events, and data that show the ability to produce the intended results.*
- *How the safety information will be collected (e.g., with case report forms, at study visits, by telephone calls with subjects).*
- *The frequency of data collection, including when safety data collection starts.*
- *Who will review the safety data and with what frequency.*
- *The statistical tests for analyzing the safety data to determine whether harm is occurring.*
- *Any conditions that will trigger an immediate suspension of the research (e.g., a serious adverse event).*

N/A

22.0 Compensation for Research Related Injury

22.1 If the research involves more than minimal risk to subjects, describe the available compensation in the event of research-related injury, if any:

N/A

22.2 Provide a copy of contract language, if any, relevant to compensation for research-related injury. At Virginia Tech, this is most common for sponsored research:

N/A

23.0 Economic Burden to Subjects

23.1 Describe any costs that subjects might be responsible for because of participation in the research, including any uncompensated costs for items such as transportation, missed work, and childcare:

For school-visit children, there are no costs that subjects might be responsible for because of participation in the research, including any uncompensated costs for items such as transportation, missed work, and childcare. However, for home-visit and lab-visit children, there is the potential for missed work and childcare as parents will need to be present at their homes or in the lab during the session. Accordingly, the

compensation for this study will be a $20 USD electronic gift card for their time.

24.0 Consent Process

24.1 Indicate the process by which you will obtain consent for study participation. Please upload all consent, parental permission, and assent forms, documents, and scripts referenced in this section to Protocol Management.

Describe the following:

- *Where the consent process will take place (e.g., clinic waiting area, classroom, online)*
- *The time interval between sharing the consent information with the prospective subject and obtaining consent. For lab, interview, and focus group studies, the Virginia Tech IRB prefers that subjects have at least 24 hours to review the consent form and study information before the appointment where consent will be obtained. For simple online survey studies, you can typically present the consent information immediately before subjects begin participation.*
- *If applicable, processes to ensure ongoing consent or assent (e.g., for multiple sessions; for research in which a minor will turn 18 during the study; for longitudinal research with minors who will later be asked to provide or affirm their assent).*
- *Please review "SOP: Informed Consent Process for Research (HRP-090)" for recommended procedure. Describe your process, being sure to include:*
  - *The name and role of all study personnel who will be trained and certified by the PI to conduct the consent process*
  - *The time that will be devoted to the consent discussion*
  - *Steps that you will take to minimize the possibility of coercion or undue influence*
  - *Steps that you will take to gauge or ensure the subjects' understanding*

For school-visit children, participants will be children (2-4 years) enrolled in preschools or child care centers that support this project and their parents/guardians. Preschool directors will provide a signed support letter. After receiving approval from directors for each new site, research personnel will provide packets, one for each child, containing a parent letter, parent permission form, child date of birth form, and parent consent form, and a flyer. The packet will be placed in parent mail boxes. We will also offer the online version of the forms so that parents have the option to

sign the forms electronically. The link to the online forms will be provided via a QR code embedded in the flyer and the brochure. The QR code will be directed to the online forms so that interested parents can complete them electronically.

For home-visit and lab-visit children, the brochure and flyer will be delivered to parents either physically or electronically. Parents will have time to ask questions about the research before filling in the forms for in-person recruitments. For online recruitments such as flyers and emails, parents can email the researchers to ask questions.

Parents will be asked to fill in the parent permission form, child date of birth form, and parent consent form using either physical or eletronic forms. In the parent permission form, parents will be asked to enter their name, child name, today's date, and contact information (i.e., email address). In the parent consent form, they will be asked to enter their name, today's date, and contact information (i.e., email address). Once the forms are received by researchers, researchers will send parents a link to the online parent survey. A hard copy of the parent survey will be provided if needed.

Alternative is not to allow their child to take part in the research. If they disagree to participate in the study, they can choose not to return the forms (parent permission form, child date of birth form, and parent consent form). Participation is completely voluntary, and subjects can choose not to agree or agree to participate and later change their mind.

In the child date of birth form, we ask parents to provide the child's full date of birth (MM/DD/YYYY) for research purposes. Child's date of birth is necessary to calculate the exact age of child, which is required to compute their standardized language scores from the receptive Vocabulary Test.

At the very beginning of the first session, children's verbal assent will be collected. Children will be informed that they are free to withdraw from this study at any time. If children or parents wish to stop at any time, they can tell the experimenter, and the experimenter will end the session immediately.

Parents will be asked if they are willing to share the video data with Databrary following the processed described on the Databrary website as follows:

The data that researchers collect from babies and families are incredibly valuable for helping scientists to understand how children develop.

So we wanted to ask if you are comfortable with allowing us to share the data we collected from this session with other researchers just like the professor who runs this lab/project. The data would be shared in a secure, online library, it's not available to the public-- only researchers that are authorized by their University would be able to access the information in the library.

This permission form also asks whether you would allow other professors/ researchers like Dr. [PI's Name] to show short bits of the videos to students or researchers for educational and scientific purposes. These data will not be used or shown for commercial purposes.

If parents are willing, they will be asked to sign the Databrary Release form, which is included at the end of the permission forms.

- *Indicate what language(s) other than English are understood by prospective subjects or representatives.*
- *If non-English speakers will be recruited, describe the process you will use to ensure that the oral and/or written consent information provided will be in a language that they understand.*
- *If you translate consent forms and study materials, please provide a certified translation of the form as well as the certification document.*
- *Indicate the spoken language that study personnel obtaining consent will use. Describe how you will assess fluency of personnel obtaining consent to ensure that the translation is accurate.*

Non-English-speaking subjects will not be recruited.

Waiver or Alteration of Consent Process (consent will not be obtained, required information will not be disclosed, or the research involves deception)

- *Review the "CHECKLIST: Waiver or Alteration of Consent Process (HRP-410)" to ensure you have provided sufficient information for the IRB to make these determinations (i.e., that it meets the criteria for a waiver or alteration of the consent process).*

N/A

Subjects who are not yet adults (minors: infants, children, teenagers)

- *Describe the criteria that you will use to determine legal age for consent to treatments or procedures involved in the research under the applicable law of the jurisdiction in which the research will be conducted (e.g., in Virginia, individuals under the age of 18 years).*

  - *For research conducted in Virginia, review "SOP: Legally Authorized Representatives, Minors, and Guardians (HRP-013)" to determine which individuals in the state meet the definition of "minor."*
  - *For research conducted outside of the state, please describe the legal requirements for the definition of "minor."*
- *Describe the process for obtaining parental permission.*
  - *Permission from one parent is acceptable for studies that involve no greater than minimal risk OR involve greater than minimal risk but present the prospect of direct benefit to the minor subject.*
  - *Permission from both parents is required in all other cases (unless one parent is deceased, unknown, incompetent, or not reasonably available, or when only one parent has legal responsibility for the care and custody of the minor).*
- *Describe whether you will obtain permission from individuals other than parents or Legally Authorized Representatives, and if so, who will be allowed to provide permission. Describe the process you will use to determine these individuals' authority to consent to the minor's general medical care.*
- *Indicate whether you will obtain assent from all, some, or none of the minors. If you will obtain assent from some minors, indicate which minors will be required to assent. Consider chronological age and intellectual capacity when determining who will be required to provide assent (e.g., infants are unable to assent. However, teenagers are likely able to read and sign an assent form).*
- *When assent of minors is obtained, describe whether and how you will document it. Will minors sign an assent form or give verbal assent?*
- *Attach parental permission and minor assent forms or scripts in Protocol Management.*

This study includes children aged between 2 and 4 years. After getting a permission form from the parents, we will ask the children's verbal assent at the very beginning of the session. We will obtain parental permission only from parents or legally authorized representatives.

Adults Unable to Consent

- *Describe the process you will use to determine whether an individual adult is capable of consent.*
- *List the individuals from whom you will obtain permission in order of priority (e.g., durable power of attorney for health care, court*

appointed guardian for health care decisions, spouse, and non-minor child).
    - *For research conducted in the Virginia, review "SOP: Legally Authorized Representatives, Minors, and Guardians (HRP-013)" to determine which individuals in the state meet the definition of "legally authorized representative."*
    - *For research conducted outside of Virginia, please describe the legal requirements for obtaining permission from a legally authorized representative in the state where the research will occur.*
- *Describe the process for assent of the subjects.*
    - *Indicate whether you will require assent from all, some, or none of the subjects. If some, indicate which subjects will be required to assent and which will not.*
    - *If you will not obtain assent from some or all subjects, please provide justification for not obtaining assent.*
    - *Describe whether and how you will document assent.*

N/A

25.0 Process to Document Consent in Writing

25.1 Consult "SOP: Written Documentation of Consent (HRP-091)" for recommended procedures, and describe whether and how consent of the subject will be documented in writing:

For school-visit children, parent permission form will be collected by asking parents to complete and return their forms to their child's school or filling out the form electronically. Parental consent forms for their own participation will be collected in the same way, asking parents to complete and return their forms to their child's school or filling out the form electronically.

For home-visit and lab-visit children, parent permission forms will be collected by asking parents to complete and return their forms to researchers or filling out the form electronically. Parental consent forms for their own participation will be collected in the same way, asking parents to complete and return their forms to researchers or filling out the form electronically.

Children's verbal assent will be obtained and recorded on assent forms by the experimenter at the very beginning of the first session.

25.2 If the research presents no more than minimal risk of harm to subjects and involves no procedures for which written documentation of consent is normally required outside of the research context, you can request that the IRB waive the requirement to obtain written documentation of consent (e.g., consent to participate is indicated by pressing a button for an online questionnaire – after the consent information is presented and before the questionnaire begins):

N/A

25.3 If you will document consent in writing, attach a consent document with places for signatures. If you will obtain consent, but not document consent in writing, please attach the consent script or text. Review "CHECKLIST: Waiver of Written Documentation of Consent (HRP-411)" to ensure that you have provided sufficient information. You should use "TEMPLATE CONSENT DOCUMENT (HRP-502)"to create the consent document or script:

The parent permission form, parent consent form, and the child assent form are attached.

26.0 Resources Available

26.1 Describe the resources available to conduct the research. For example, as appropriate:

- *Describe the PI's availability to supervise the research.*
- *Justify the feasibility of recruiting the required number of suitable subjects within the agreed recruitment period. For example, how many potential subjects do you have access to? What percentage of those potential subjects do you need to recruit?*
- *Describe the time that you will devote to conducting and completing the research.*
- *Describe your facilities.*
- *Describe the availability of medical or psychological resources that subjects might need as a result of an anticipated or unanticipated consequence of participation in the research.*
- *Describe your process to ensure that all persons assisting with the research are adequately informed about the protocol, the research procedures, and their duties and functions (e.g., training plans, detailed study notebooks).*

The VT PIs and the Rutgers PI will supervise the research at their respective institutions. They each have faculty offices in the same building as their research labs. All PIs (Choi, Lee, & Wang) typically spend 3-4 days a week on campus; and are regularly available for virtual meetings when working off-campus.

Koeun Choi, PI: Cognitive Developmental Science (CoDeS) Laboratory

Laboratory Space: A locked laboratory space and a locked office are provided for PI Choi. The laboratory is close to her office. The locked laboratory and office have password-protected desktop and laptop computers. All data are stored in locked file cabinets.

The recruitment numbers are feasible based on the resources as well as the planned compensation available. Data collection will be conducted via undergraduate and graduate researchers, which allow time for PIs to supervise the rest of the research processes such as analyzing data and publishing findings.

All persons assisting with the research will be properly trained prior to conducting any work on the study. This training consists of any mandatory training or certifications otherwise required through the department or University, a reading through of the protocol and observation of the study sessions, and practiced operation of the study sessions with trained lab personnel/willing confederate. All research personnel will have consistent access to study protocol/manual to refer to during study sessions and otherwise to refresh on procedures as necessary.

PI: Koeun Choi, Assistant Professor, Department of Human Development and Family Science at Virginia Tech. PI Choi has examined the impact of digital media on cognitive development focusing on early childhood by employing experiments, individual difference measures, and eye-tracking methodologies. She has published work on young children's attention to and learning from media in highly impactful journals including Psychological Science and Child Development. She is responsible for managing data collection, analyzing data, and presenting and publishing the findings from the project.

Dr. Sang Won Lee, Assistant Professor, Department of Computer Science at Virginia Tech. Dr. Lee has worked to create interactive systems that facilitate empathy among users. His research vision of computer-mediated empathy comes from his background in computer music, thriving to bring the expressive, collaborative, and empathic nature of music to computational systems. He has published work on HCI and User Interface design in highly impactful conferences and journal of the Association for Computing Machinery. Dr. Lee will be responsible for designing the application and the experiment as well as presenting and publishing the findings from the project.

Dr. Jenny Jining Wang, Assistant Professor, Department of Psychology at Rutgers University-New Brunswick. Dr. Wang's research explores how experiences impact children's number sense and how these impacts extend to children's school math performance. She is an expert in assessing and experimentally intervening on numerical abilities in infants and young children. She has extensive experience conducting cognitive development research with young children in the laboratory, at preschools, and museums, as well as online via Zoom or on unmoderated platforms such as Lookit

(Scott & Schultz, 2017) expertise in children's counting concepts and its development. She is responsible for managing data collection at the Rutgers site, analyzing data, and presenting and publishing the findings from the project.

Sulakna Karunaratna, a graduate student, will be working on this study. Sulakna has been developing the platform and will support the research process.

Daniel Vargas-Diaz, a graduate student, will be working on this study. Daniel has been developing the platform and will support the research process.

Jisun Kim, a graduate research assistant, will be working on this study along with various undergraduate research assistants.

27.0 Multi-Site Research

Contact the HRPP for multi-site research (involving multiple institutions) and the details required for this section will be provided. Otherwise, indicate N/A.

VT IRB will serve as the IRB of record for this study. We have uploaded "local context" document for Rutgers University-New Brunswick (data collection). We have uploaded Rutgers recruitment documents and permission and consent forms for review.

Appendix C

IRB Approval

Division of Scholarly Integrity and Research Compliance
Institutional Review Board
North End Center, Suite 4120 (MC 0497)
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE: June 10, 2024

TO: Koeun Choi, Sang Won Lee, Hailey Annibell, Monika Khadka, Shuqi Yu, Mahmut Sami Gurdal, Ilan Litvak, Junwoo Seo, Sulakna Binoka Kumarihamy Karunaratna, Daniel Alfredo Vargas Diaz, et. al.

FROM: Virginia Tech Institutional Review Board (FWA00000572)

PROTOCOL TITLE: Interactive Counting

IRB NUMBER: **23-914**

Effective June 10, 2024, the Virginia Tech Institution Review Board (IRB) approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 6,7**
Protocol Approval Date:	**April 4, 2024**
Progress Review Date:	**April 4, 2025**

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol.

SPECIAL INSTRUCTIONS:

This is an amendment, approved on June 10, 2024, to added two new versions of the interest forms (e.g. home visits and lab visits).

Date*	OSP Number	Sponsor

* Date this proposal number was added.

If this protocol is to cover any other grant proposals, please contact the HRPP office (irb@vt.edu).