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The Relation Between Math Anxiety and Play Behaviors in 4- to 6-Year-Old Children

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Supplementary Materials: Materials [see Index of Supplementary Materials]

Abstract

From a young age, children's math achievement is influenced by individual factors, such as math anxiety. While math anxiety has been linked to math avoidance, few studies have explored this link in young children, particularly in the context of play. Because play-based instruction is commonly used for math in early childhood classrooms, understanding the impact of math anxiety on children's engagement in math-related play may have important implications for children's early math learning. The current study examined the role of children's math anxiety in their persistence and exploration during a math toy play task. We observed wide variability in children's play behaviors, finding that children's actions during play did not relate to their math anxiety, but their talk related to math while playing with the toy did. There are also age and gender differences in math anxiety, school experience, and reasoning about the toy play task. These results suggest that math anxiety may influence certain aspects of children's engagement in math-related play, and that more research is needed to consider links between math anxiety and math avoidance in young children.

Keywords

math anxiety, math avoidance, play, exploration, persistence

Math knowledge in early childhood is predictive of academic and math achievement through adolescence (Watts et al., 2014). However, from a young age, children's math achievement is influenced by a number of factors. Math anxiety (an anxiety specific to math performance; Ashcraft, 2002) is an individual factor, which can be particularly detrimental to math learning and performance (Ramirez et al., 2013). However, little is known about math anxiety in early childhood. The present study considers the influence of math anxiety on young children's persistence and exploration during math play.

Math Anxiety

Math anxiety is defined as a domain-specific anxiety—such that it is anxiety specific to math performance, including anxiety about problems on math tests and about using math in everyday life, such as calculating a tip (Ashcraft, 2002). Math anxiety is a separate construct from generalized anxiety, and people with math anxiety may or may not experience other forms of anxiety (Ashcraft & Krause, 2007). Several recent meta-analyses have shown that math anxiety has negative impacts on academic performance both in math and in related areas (Barroso et al., 2021; Zhang et al., 2019). Children and adults with high math anxiety tend to perform worse on math tests, have lower math self-competence, and are more likely to exhibit math avoidance (i.e., be less likely to voluntarily engage in math-related activities and classes; Ashcraft, 2002; Ashcraft & Krause, 2007; Choe et al., 2019; Jameson, 2014). For example, high math anxious adults tend to take fewer math courses in high school and college, and are less likely than low math anxious adults to pursue careers in STEM (Chipman et al., 1992; Hembree, 1990).

Understanding the impact of math anxiety on specific areas of children's math development has important implications for children's learning and achievement. Individual differences in math anxiety have been found in young elementary-age children, including children as young as first grade (Ganley & McGraw, 2016; Harari et al., 2013; Jameson, 2013; Maloney et al., 2015; Nurhayati et al., 2019; Primi et al., 2020; Szczygieł, 2019; Szczygieł & Pieronkiewicz, 2022). For young elementary-age children, math anxiety can negatively impact arithmetic performance as well as overall math achievement. Specifically, studies have shown negative impacts of math anxiety for first through third graders on arithmetic problem solving (Haase et al., 2012), arithmetic strategy use (Ramirez et al., 2016), and understanding of arithmetic properties (Tomasetto et al., 2021), as well as general math achievement (Gunderson et al., 2018; Pantoja et al., 2020).

Further, longitudinal studies with children in second and third grades have shown that math anxiety relates to lower performance on math tasks, such as calculation, story problems, and number sentence completion, (Vukovic et al., 2013) and that the negative influence of math anxiety increases over time from second to third grade (Cargnelutti et al., 2017). Studies examining children's math anxiety in relation to standardized measures of math achievement have found similar patterns in the relations of math anxiety and math achievement. These studies have shown that higher math anxiety relates to lower scores on standardized achievement tests for children ages 6 to 12 years old (Lauer et al., 2018), and that the negative impact of math anxiety on achievement is separate from the impact of general anxiety for children in first through sixth grade (Haase et al., 2012; Wu et al., 2012).

Fewer studies have examined math anxiety in preschool- and kindergarten-aged children. In one such study, Lu and colleagues (2021) developed a measure of math anxiety for children in kindergarten. Kindergarten students showed variability in their math anxiety, both on items about worry about math (e.g., "Do you ever feel nervous when you get out your math worksheets?") and items about somatic responses to math (e.g., "Does math give you a stomachache?"). In addition, children's responses to open-ended questions about math tests, demonstrated that kindergarteners have a wide range of math anxiety as well, such as concerns about completing math tasks in a timely manner and getting answers incorrect (Lu et al., 2021).

In another study, Short and colleagues (2019) examined the relations of math anxiety, mindset, and math ability in 5-year-old children. Children were administered a math anxiety measure in a whole class setting in their school. Questions were displayed one at a time, and children were asked to circle one of three smiley faces to indicate how they would feel about that question (e.g., "How would you feel if you had to count the ducks?"). Children also completed measures of forwards and backwards counting, numerical mapping (selecting which of two sets of dots depicts a certain quantity), and a growth mindset task. Results indicated that children with growth mindsets were less likely to have math anxiety than those with a fixed mindset, however relations between children's performance on the counting and numerical mapping tasks and their math anxiety and mindset were not reported. Thus, even in preschool-age children there is variability in math anxiety, but more work is needed to understand how this variability impacts early math development.

Together these studies highlight the negative impact that math anxiety has on children's math abilities and achievement from a young age. Although, as these studies demonstrate, the majority of studies on children's math anxiety primarily focus on the impact of children's math anxiety on elements of their formal math performance, such as test-taking and solving arithmetic problems. However, math in early childhood is not limited to these formal settings or tasks. In addition to formal math instruction, early childhood math learning often involves math concepts taught through play and games, or with math toys, materials, or manipulatives (Sarama & Clements, 2009; Taylor-Cox, 2009).

Math-Related Play and Exploration

Learning math through play provides students with contextual practice of math concepts in an engaging and motivating way (Clements & Sarama, 2014; Fisher, Hirsh-Pasek, et al., 2012; Sarama & Clements, 2012), making play and exploration

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important components of children’s math learning during early childhood. Prior research has shown that children naturally explore early math topics in their free play, engaging in activities such as counting, sorting, and making categories, patterns, and comparisons (Ginsburg, 2006; Sarama & Clements, 2009). Studies also indicate that there is variation in children’s math-related play and exploration, including the amount of time they play, their enjoyment while playing, and the goal-directedness of their play (Fisher, Dobbs-Oates, et al., 2012), as well as the mathematical content of their verbal and nonverbal play and exploration (Zippert et al., 2019), and this variation relates to children’s math learning and achievement.

Many early childhood education classrooms have center time or free time when children can select learning activities. Because this time involves an opportunity to choose between math- and non-math-related play, it is important to consider what factors may influence children’s choice of, exploration of, and persistence with math play activities. Edens and Potter (2013) examined factors related to children’s choice of activities during free play in their preschool classrooms. They observed 4-year-old children during their preschool’s center time, a time during which children were free to select which activities they engage in, and coded activities by type. Types of activities included: activities involving math, books or writing, small motor, large motor, block construction, art, computer, social or dramatic play, or transition time. They also measured children’s counting skills, spatial skills, spontaneous focus on numerosity (SFON), as well as children’s ratings of their math ability and persistence. Results indicated that children overall did not frequently choose to engage in math play, and the most common forms of math play chosen were block construction and computer games. Choosing to play with math activities was not related to children’s math abilities or SFON. Children with lower math abilities were more likely than children with higher math abilities to choose small motor activities, which are seen as less challenging activities than others.

The variation in children’s choice of activities indicates that children differ in their self-initiated engagement and persistence in math activities. While math ability relates to the choice of certain activities but not of math activities, it is possible that other factors may influence children’s engagement and persistence in math activities. Because math anxiety relates to math avoidance (Ashcraft, 2002), it is possible that math anxiety could influence children’s choice of activities or their choice to persist in a math activity they have chosen. As play provides a child-directed context for learning, it is possible that children’s math anxiety would influence the type of play they engage in and therefore the way they engage in their own learning experiences. The current study examines this by exploring how children’s math anxiety influences their persistence and exploration during math-related play.

Current Study

The current study examined the relations of math anxiety and play behaviors for children ages 4- to 6-years-old. This age range was selected based on previous research on children’s math anxiety, as children in this age range have been shown to experience different levels of math anxiety (Harari et al., 2013; Krinzinger et al., 2009; Short et al., 2019). The study addresses a gap in the literature by examining the relations between math anxiety and math avoidance in young children, and by exploring these relations in the context of children’s behaviors during play. Because play-based instruction for math is commonly used in preschool and early elementary school classrooms, understanding the impact of math anxiety on children’s persistence and engagement in math-related play is important.

In the present study, children were given a toy that required engaging in a simple math-related activity in order to make it work. Specifically, activating the toy required the child to count the number of dots on a card and press a button on the toy the corresponding number of times to hear a sound. After a demonstration, children were given an opportunity to play with the toy, but it did not work (Gweon & Schulz, 2011), providing the opportunity to observe children’s persistence in the face of what could plausibly be seen as a challenging math situation. Children were also given measures of math anxiety as well as their counting and cardinality skills.

There were four overall aims of this study. The first was to examine the relation between children’s math anxiety and their play behaviors, specifically persistence and exploration. We predicted that children with higher math anxiety would be more likely to exhibit math avoidance and therefore be less persistent in trying to activate the math-related toy when it failed to work.

The second aim was to examine if children's math anxiety predicted the type of explanations they offered for why they were not able to activate the math toy. Because children with higher math anxiety are more likely to have lower math self-concept and math self-efficacy (Jameson, 2014), it is possible that math anxiety could influence children's reasoning about why they were unable to activate the math toy. Accordingly, we predicted that higher math anxiety might lead children to use more internal explanations (such as "I counted wrong") for why the math toy didn't work, as they may be less sure of their math abilities. In contrast, children with lower math anxiety may be more confident in their abilities and thus more likely to adopt an external explanation (such as, "the toy is broken") for why the toy didn't work.

The third aim was to examine the relation of math anxiety and gender. Based on previous research (Gunderson et al., 2018; Lauer et al., 2018), we predicted that girls would have higher levels of math anxiety than boys.

Finally, the fourth aim was to examine the relations between math anxiety and the role of school experience, specifically whether children had or had not started kindergarten. This aim was exploratory. Understanding the relations of math anxiety and school experience is important because schooling may influence children's math anxiety, possibly through the introduction of formal math instruction or the influence of teacher or peer math anxiety.

In addition to the four pre-registered aims, we also conducted additional analyses to further examine variability in children's toy play behaviors and relations with math anxiety. These analyses included examining each aim in terms of age and gender differences, as well as further examining children's responses on the math anxiety questions. We also further examined children's toy play behaviors by considering additional behaviors and coding the talk children used during the test trial. The following sections describe both the pre-registered and additional methods and analyses.

Method

Procedures and planned analyses were pre-registered on Open Science Framework (see Supplementary Materials). Assuming a medium effect size, power analyses indicated that 128 participants were required to reach power of 0.8. Due to inability to complete data collection because of COVID-19, results presented are from a slightly smaller sample than originally planned.

Participants

Participants were 106 4- to 6-year-old children (mean age 63.4 months, range 48 to 82 months, 47% female). Participants were recruited from children's museum and preschool settings in the mid-Atlantic region of the United States. Parents provided informed consent, and children provided verbal assent prior to participation in the study. An additional 16 children were tested and excluded from analyses due to parent or sibling interference during the tasks ($n = 11$), voluntary withdrawal by the parent or child ($n = 3$), experimenter error ($n = 1$), and the child not completing the tasks ($n = 1$).

Parents completed a demographic survey, including parent and child race/ethnicity, languages spoken at home, highest level of education completed by each of the child's parents, and annual household income. Table 1 shows descriptive statistics for these demographic variables.

Procedure

All study procedures were approved by the University of Maryland, College Park Institutional Review Board prior to the start of the study. Children first completed a math anxiety questionnaire, then a toy play task, followed by a measure of cardinality. All tasks were completed in a small room at their preschool or in a children's museum. All sessions were videotaped. Parents also completed a short demographic survey at the time of providing consent.

Table 1

Descriptive Statistics of Demographic Survey Variables

Variable	*N* = 106
Child Race, *n* (%)	
African American or Black	7 (6)
Asian or Pacific Islander	7 (6)
Biracial/Mixed Race	20 (20)
White	60 (57)
Missing	12 (11)
Child Ethnicity, *n* (%)	
Hispanic or Latino	88 (83)
Not Hispanic or Latino	14 (13)
Missing	4 (4)
Highest Level of Education, Mothers, *n* (%)	
Postgraduate or professional degree	58 (55)
4-year college degree	21 (20)
2-year college degree	3 (3)
Some college coursework or vocational training	10 (9)
High school diploma or GED	3 (3)
Missing	11 (10)
Highest Level of Education, Fathers, *n* (%)	
Postgraduate or professional degree	51 (48)
4-year college degree	22 (21)
2-year college degree	6 (6)
Some college coursework or vocational training	9 (8)
High school diploma or GED	7 (7)
Some high school	1 (<1)
Missing	10 (9)
Annual Household Income, *n* (%)	
$151,000 or more	46 (43)
$101,000 - $150,000	15 (14)
$76,000 - $100,000	13 (12)
$60,000 - $75,000	6 (6)
$60,000 or less	8 (8)
Missing	18 (17)
Child School Experience, *n* (%)	
Home-based Care	4 (4)
Daycare or Preschool	45 (43)
Kindergarten	27 (25)
Other[a]	9 (8)
Daycare or Preschool and Other	11 (10)
Kindergarten and Other	1 (1)
Missing	9 (8)

[a]"Other" school experiences included first grade, Montessori primary, homeschool, elementary, after school care, and grandmother.

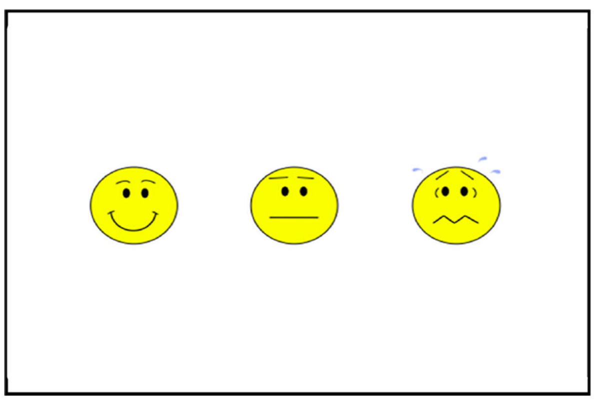
Materials and Measures

Math Anxiety

Schaeffer and colleagues' (in preparation) Child Math Anxiety Measure was used as a measure of children's math anxiety. This questionnaire is intended for use with pre-kindergarten and kindergarten children, and has been shown to be reliable (α = .788) for pre-kindergarten and kindergarten children (Schaeffer et al., in preparation). The experimenter introduces the definition of being nervous or worried, then shows children a three-point smiley face scale with faces indicating feelings of "not nervous at all," "a little nervous," and "very nervous" (see Figure 1). The faces are printed on a laminated 8.5 x 11-in paper. Each smiley face has a 2-in diameter, and the faces are 2.375 in apart on the page. Overall, the use of smiley face scales for collecting measurements of children's math anxiety is well-documented in prior work on math anxiety, and measures using similar response scales have also been shown to be valid and reliable (Jameson, 2013; Krinzinger et al., 2009; Ramirez et al., 2013; Ramirez et al., 2016; Thomas & Dowker, 2000; Wu et al., 2012).

Figure 1

Smiley Face Scale for Math Anxiety Measure



For the current measure, children answered a practice question with feedback on the use of the scale, then were asked seven questions targeting math anxiety, such as "How do you feel when you have to count to 30?" No specific feedback was given during the task. Children's responses for each question were scored from one to three, with a one representing a choice of the "not nervous at all" face, a two representing a choice of the "a little nervous" face, and a three representing a choice of the "very nervous" face. The pre-registered outcome was a math anxiety score calculated as the average of their scores on the items. Therefore, scores closer to one indicate lower overall math anxiety, and scores closer to three indicate higher levels of math anxiety.

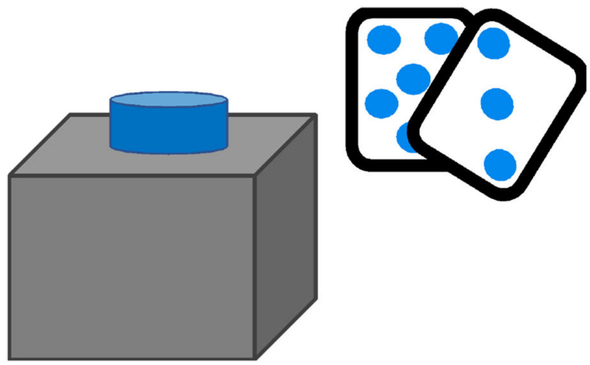
To further examine the relations of children's math anxiety with their toy play behaviors, we also created a composite score of the math anxiety questions related to counting (i.e., "How do you feel when you have to count to 30?", "How do you feel when your teacher asks you to count backwards from 20?," and "How do you feel when your teacher asks you to count as high as you can?"), as the toy play task centered on children's counting skills. Children's average score on the three counting items was used (α = .54).

Toy Play Task

The toy play task involved counting dots on a card and pressing a button to activate the toy. The cards consisted of 5.0 x 3.75 in laminated cards with blue dots (.875-in diameter) on them. The toy was a 6.25 x 7.0 x 4.5 in foam cube covered in black tape with a remote-controlled doorbell hidden inside and a circular (3-in diameter) plastic blue button attached to the top (see Figure 2). The experimenter manually activated the toy throughout the task in accordance with children's behaviors. When activated the toy made a doorbell chirping sound.

Figure 2

Toy and Cards Used for Toy Play Task



Note. During the task, children only use one card at a time.

The task included three trials: an example, a practice trial, and an exploration test trial. During the example trial, the experimenter introduced the toy to the child and explained that the toy had cards that made it work, and that the toy would work when the button was pressed the same number of times as the dots on the card. The experimenter showed the child a card with two dots, labeled the quantity two, demonstrated pointing and counting the dots, and then pressed the button twice. The experimenter asked the child to acknowledge hearing the sound the toy made. The experimenter then demonstrated that pressing the button one time would not make the toy make a sound and repeated that the button needed to be pressed the same number of times as the number of dots on the card in order for the toy to work. Next, children were given a card with three dots and told it was their turn to count the dots and press the button. The experimenter had children practice until they could successfully press the button three times and activate the toy.

In the test trial, the experimenter told the child that she had to write something down but she had another card for the child to play with, and gave the child a card with eight dots. Children were given 90 seconds to play with the toy as they chose. During the 90 second period the toy did not activate for any responses. The extent to which children persisted in trying to activate the toy provided an implicit measure of children's expectations that the toy ought to work given the actions they had performed (consistent with prior work on children's persistence and exploration; e.g., Butler & Markman, 2012; Bridgers et al., 2019; Gweon & Schulz, 2011; Leonard et al., 2017). Following the 90 seconds, the experimenter asked children if the toy worked and why they thought the toy didn't work. Children's responses were coded as either internal (e.g., "because I probably counted too many"), external (e.g., "because [the toy] is broken"), or other (e.g., "I don't know") explanations of why the toy didn't work. Two coders coded responses with 93% agreement. Disagreements were resolved by a third coder. After children gave their explanation, the experimenter gave the child a final card with four dots and prompted the child to count the dots and press the button. When the child pressed the button four times (on their own, or with feedback from the experimenter), the toy activated and made sound.

Toy Play Behaviors — Videos from the 90 second interval of play were coded using Datavyu software (Datavyu Team, 2014). Three types of behaviors were coded: counting attempts, pressing button attempts, and time spent exploring the toy numerically. These behaviors were identified at the time of pre-registration to be coded, as they are math-related ways of engaging with the toy, and they have the potential to vary with children's level of math anxiety. We also added two additional measures to further understand observed variability in children's toy play behaviors. First, we examined additional information from the play behavior coding specifically the amount of time children spent on counting attempts and button attempts. Second, we coded children's talk during the test trial. The following sections describe both the pre-registered and additional measures.

Counting Attempts — Counting attempts were defined as the number of times children counted the dots on the card (counting either correctly or incorrectly). To be coded as a counting attempt, children had to count out loud. Looking at the card without saying anything (with or without pointing) was not considered as a counting attempt. Starting to count and then restarting was coded as one attempt, and counting only some of the dots was also coded as one counting attempt.

Button Pressing Attempts — Button pressing attempts were defined as the number of sets of times children pressed the button on the toy (e.g., if the child pressed the button seven times, then recounted and pressed the button eight times, this would count as two button pressing attempts, not 15 button pressing attempts). To differentiate between attempts, pauses were defined as a period two seconds or greater between button presses. This rule was also used to distinguish button pressing attempts when children started pressing the button while counting then started over; when they started recounting out loud but continued to press the button in one string of presses; and when children changed the rate at which they were pressing the button during a string of presses.

Button pressing attempts were coded as long as the child was pressing the button purposefully. Button pressing attempts were not coded when children's hand was resting on the button but they were not actively pressing it.

Time Exploring the Toy — Time spent exploring the toy was divided into two categories: (1) exploring the toy in a number-related way and (2) exploring the toy non-numerically or not exploring the toy. Together these variables accounted for the full 90 seconds of the play interval. Time spent exploring the toy numerically included behaviors, such as counting the dots on the card, pressing the button, and listening for the toy to make sound after a string of button presses (up to five seconds after they stop pressing the button). In addition, time spent talking about math (e.g., "I counted eight") to themselves, to the experimenter, or to their parent was coded as numerical time.

All other observed behaviors were defined as time not exploring the toy or exploring the toy non-numerically. Typical examples of non-numerical exploration included shaking the toy, moving the card around, turning the button but not pressing it, or not engaging with the toy materials in any way. In addition, any time children spent talking not related to math or number (e.g., "it's not working,") or talking to get the attention of a parent or experimenter (e.g., "excuse me?") was also considered non-numerical time. Similarly, time spent looking at the experimenter or a parent without saying anything was considered non-numerical time, as was time spent moving around the testing room or engaging with other materials in the testing room.

Time Spent on Counting and Button Attempts — We examined the amount of time children spent on counting attempts and button attempts during the test trial to include an additional measure of persistence that would capture the differences in the rate at which children were counting the dots on the card and pressing the button on the toy.

Children's Talk During Test Trial — To further understand relations between children's toy play behaviors and math anxiety, we examined the talk children used during the test trial, beyond their counting attempts, because we observed that children were using talk during their exploration more than we had anticipated. Videos of children completing the test trial were coded for talk. The coding scheme included four categories of talk: math knowledge/procedure statements, math questions/uncertainty statements, non-math statements, and attention-getting statements (see Table 2 for code definitions and examples).

To differentiate the talk measure from measures of counting and button attempts, counting out loud was not coded. Each statement was coded into only one category, as the definitions of math and non-math statements are mutually exclusive. If a statement included elements of both attention-getting and one of the other three categories (e.g., "Excuse me I counted to eight and it's not working"), it was coded as the other category (e.g., math knowledge/procedure statements). Statements that described procedures of interacting with the toy but did not include specific math content (e.g., "I did it the right amount of times but it's not working") were coded as non-math statements. Non-word sounds and statements cutoff at the end of the test trial time were not coded. The number of statements in each category was used as a measure of children's talk.

Table 2

Talk Coding Definitions

Category	Definition	Examples
Math knowledge/procedure statements	Statements of math knowledge, quantity, or math-related task procedures.	• "That was 8." • "I counted to 8." • "I'm pressing it 8 times but it's not working." • "It's 4+4."
Math questions or uncertainty statements	Questions about math, quantity, or counting, or statements indicating uncertainty about math knowledge/procedures, quantity, or counting.	• "Is it 8?" • "How many is that?" • "I don't know how to count this card." • "Can you help me count this card?"
Non-math statements	Statements not related to math. May include statements about the functionality of the toy or interactions with the toy, or other non-task-specific statements.	• "Why isn't it working?" • "I don't know." • "I broke it." • "Maybe the battery is dead."
Attention-getting statements	Statements to get attention of experimenter or other adult(s) in testing room.	• "Excuse me?" • "See?"

Reliability — Coding reliability was evaluated separately for the counting and button press attempt variables, the time variables, and children's talk during the test trial. For counting and button pressing attempts, two coders coded 20% of the videos at or above 80% agreement. Any disagreements were resolved by discussion. For the time variable, coding was considered reliable when total amount of math time coded by the coders was within plus or minus two seconds on either side of the coded interval. Two coders coded 20% of the videos at or above 80% agreement. For any disagreements, the master coder's coding was used for analyses. For children's talk, coding was completed by two coders. The first coder coded all of the videos, and the second coder coded 20% of the videos. Percent agreement was used as a measure of reliability. Average percent agreement was 95.8% for math knowledge/procedure statements, 100% for math questions/uncertainty statements, 80.3% for non-math statements, and 95.5% for attention-getting statements. For any disagreements, the first coder's coding was used in all analyses.

Cardinality

A "How Many" task (adapted from Wynn, 1992) was used as a measure of children's counting and cardinality. This measure was included as a descriptive measure and potential covariate, because the toy play task involved counting and cardinality. Accordingly, it was expected that children would perform well on the task. Children were shown a sheet of paper with a quantity of stars ranging from three to eight. Children were asked to count the stars on the page. After children provided an answer, the experimenter flipped the page over so that the stars were no longer visible and asked the child to report how many stars they had seen. Children completed 5 trials (quantities of 5, 3, 8, 4, and 6 stars), and order was stable across all participants. No feedback was given during the task.

Children received separate scores for counting and cardinality. Counting was scored as correct if children stated the correct number of stars when viewing the stars (regardless of if they counted out loud or not). Cardinality was scored as correct if children stated the correct number of stars or stated the correct number of stars after a count sequence (e.g., 1, 2, 3…3) after the experimenter flipped the page over. Children did not receive credit for cardinality if they counted without restating the final number of the count sequence (e.g., 1, 2, 3). For both counting and cardinality, final scores were the total number of trials correct (ranging from 0 to 5).

Children's School Experience

Children's school experience was classified from the demographic questionnaire that parents completed at the time of consent. Parents indicated the number of hours per week children attended home-based care, daycare, preschool, kindergarten, or other care/school experiences. Overall, 92% of parents provided a response to this question (see

Table 1). Responses were classified as children who had started kindergarten (e.g., kindergarten, first grade) and children who had not started kindergarten (e.g., home-based care, daycare, preschool).

Results

In this section, we first present descriptive statistics for all measures. Then we present results of preliminary analyses. In the following sections, results are reported by aim, including both pre-registered analyses and additional exploratory analyses.

Descriptive Statistics

Math Anxiety

There was variability in children's math anxiety scores. The average score across questions was 1.74 (*SD* = 0.44), with average scores ranging from 1 to 2.71. For all questions, children's responses included all three choice options (not nervous at all, a little nervous, very nervous). Table 3 shows descriptive statistics for the math anxiety scores for individual items and average scores on all items and on items related to counting.

Table 3

Descriptive Statistics for Math Anxiety Questionnaire

Item	*M*	*SD*	Min	Max	Skew
1. How do you feel when you have to count to 30?	1.75	0.83	1	3	0.47
2. How do you feel when your teacher asks you to count backwards from 20?	2.02	0.84	1	3	-0.03
3. How do you feel when you are sitting in circle time and you learn something new about numbers?	1.3	0.60	1	3	1.81
4. How do you feel when you get called on by the teacher to show what day it is on the calendar?	1.52	0.78	1	3	1.06
5. How do you feel when you have to solve a problem like 4-1 (read: 4 take away 1)?	1.87	0.81	1	3	0.24
6. How do you feel when you see a book with a lot of numbers in it?	1.97	0.82	1	3	0.05
7. How do you feel when your teacher asks you to count as high as you can?	1.73	0.86	1	3	0.55
Average Math Anxiety Score	1.74	0.44	1	2.71	0.05
Average Math Anxiety Score on Counting Items	1.83	0.61	1	3	0.39

Toy Play Task

Children's play behaviors with the toy varied widely (Table 4). Descriptive statistics for children's use of each category of talk are also shown in Table 4.

Table 4

Descriptive Statistics and Correlations of Toy Play Behaviors and Math Anxiety

Variable	*M*	*SD*	Min	Max	1	2	3	4	5	6	7	8	9	10	11
1. Math Anxiety	1.74	0.44	1	2.71	–										
2. Math Anxiety (Counting)	1.83	0.61	1	3	.883**	–									
3. Counting Attempts	2.53	1.66	0	9	-0.019	-0.095	–								
4. Button Attempts	3.32	2.24	0	10	-0.105	-0.173	.504**	–							
5. Time Exploring Toy Numerically	41.11	22.52	0	88.64	-0.022	-0.109	.691**	.828**	–						
6. Time on Counting Attempts	11.94	9.48	0	56.59	0.163	0.091	0.064	0.026	0.105	–					
7. Time on Button Attempts	20.54	13.71	0	51.87	0.133	0.079	-0.031	0.054	0.074	.529**	–				
8. Math Knowledge/Procedure Statements	1.17	1.93	0	11	-.221*	-0.155	0.15	0.06	0.039	0.086	-0.037	–			
9. Math Questions/Uncertainty Statements	0.25	1.26	0	11	0.061	0.017	-0.035	-0.099	-0.119	-0.069	-0.061	0.002	–		
10. Non-Math Statements	1.70	2.23	0	14	-0.05	-0.007	0.015	0.044	-0.006	0.115	.301**	.207*	-0.061	–	
11. Attention-getting Statements	0.21	0.70	0	5	-0.051	-0.06	-0.095	-0.025	-0.013	0.119	0.106	0.122	0.007	0.089	–

*$p < .05$. **$p < .01$.

For justifications for why the toy did not work, 30% of children provided an internal explanation, 33% of children provided an external explanation, and 37% of children provided an explanation that was neither internal or external (e.g., "I don't know").

Counting and Cardinality

The majority of children (82%) answered all five counting questions correctly, and 12% of children did not answer any of the questions correctly. The average score for the counting task was 4.74 (*SD* = 0.69). The majority of children (64%) answered all five cardinality questions correctly, and 12% of children did not answer any of the questions correctly. The average score for the cardinality task was 4.02 (*SD* = 1.70).

Preliminary Analyses

Gender

Preliminary analyses were conducted to examine if there were differences in math anxiety by children's gender, as previous research has indicated that girls are more likely to have higher math anxiety than boys (Gunderson et al., 2018; Lauer et al., 2018). Results indicated that math anxiety was higher for girls (M = 1.85) than boys, M = 1.64; $t(104) = -2.516$, $p = .013$, $d = -.490$. These results are also reported in Aim 3. Because anxiety differed based on children's gender, gender was included as a covariate in the subsequent regression analyses.

Cardinality

Preliminary analyses were conducted to examine if there were relations between math anxiety and children's cardinality scores, as previous research has indicated that higher math anxiety is related to lower math performance (Ashcraft, 2002). Results indicated that children's math anxiety scores were not correlated with their scores on the cardinality task ($r = -.150$, $p = .126$). Because there were no relations between children's math anxiety and their cardinality scores, cardinality was not included as a covariate in analyses.

Primary Analyses

Aim 1: Math Anxiety and Play Behaviors

The first aim was to examine the relations between math anxiety and children's behaviors during play with the toy. These relations were examined in multiple ways. Pre-registered analyses included correlations and regressions. Table 4 presents correlations between math anxiety and play behaviors, including pre-registered and additional outcome variables. As shown in Table 4, math anxiety was not related to any of children's toy play behaviors.

Linear regressions (pre-registered) were conducted to predict toy play behaviors from children's math anxiety. One regression was used to predict a composite of counting attempts and pressing button attempts, and a separate regression was used to predict time spent exploring the toy numerically. Results indicated that math anxiety was not a significant predictor of children's counting and button attempts, $\beta = -0.068$, B = -0.526, $t(103) = -0.676$, $p = .500$, or their time exploring the toy numerically, $\beta = -0.015$, B = -0.761, $t(103) = -0.147$, $p = .883$. Finally, a *t*-test (pre-registered) was used to compare toy play behaviors for high math anxious (HMA) and low math anxious (LMA) children. For this analysis, the HMA and LMA groups were defined as the top and bottom quartiles of math anxiety scores, respectively. Results indicated that children's button attempts, $t(50) = .327$, $p = .745$, $d = .091$, counting attempts, $t(50) = -.553$, $p = .583$, $d = -.154$, and numerical exploration time, $t(50) = -.548$, $p = .586$, $d = -.153$, did not differ based on their math anxiety level.

As an additional analysis, we examined children's use of talk during the test trial in multiple ways. Table 4 shows correlations of talk with math anxiety. Children's use of math knowledge/procedure statements was significantly negatively related to children's math anxiety, such that children with lower math anxiety were more likely to use statements indicating math knowledge or math-related task procedures during the test trial, such as "That was 8". Regressions were also used to predict children's use of each category of talk from children's math anxiety. As shown in Table 5, math anxiety was a significant predictor of children's use of math knowledge/procedure statements, and was not a significant predictor of children's use of other types of talk.

Table 5

Summary of Regression Results Predicting Each Category of Talk

	Statements											
	Math Knowledge/Procedure			Math Questions/Uncertainty			Non-Math			Attention-Getting		
Variable	*B* (*SE*)	*t*	*p*	*B* (*SE*)	*t*	*p*	*B* (*SE*)	*t*	*p*	*B* (*SE*)	*t*	*p*
Math anxiety	-.963 (.417)	-2.309	.023*	.173 (.280)	.619	.537	-.251 (.495)	-.506	.614	-.081 (.155)	-.518	.605
	R^2 = .049, F(1, 104) = 5.332, p = .023			R^2 = .049, F(1, 104) = .383, p = .537			R^2 = .002, F(1, 104) = .256, p = .614			R^2 = .003, F(1, 104) = .269, p = .605		

*$p < .05$.

We also conducted additional analyses to examine whether the relations between children's math anxiety and their play behaviors varied by age and gender, because children's math anxiety differed significantly by both children's age, F(2, 103) = 3.721, p = .028, and gender, t(104) = -2.516, p = .013, d = -.490. Specifically, we examined correlations between math anxiety and play behaviors separately by age (i.e., 4-, 5-, and 6-year-olds) and by gender. There were no differences based on age or gender, with the exception that time spent on button attempts significantly related to math anxiety for boys, r(54) = .312, p = .019, and for 4-year-olds, r(41) = .356, p = .019.

Aim 2: Math Anxiety and Explanations

The second aim was to examine the relations of math anxiety and children's explanations of why the toy did not work. Pre-registered analyses included correlation and logistic regression. The correlation between children's math anxiety score and their type of explanation was not significant (r = 0.171, p = .167). A logistic regression was used to predict explanation type (internal or external) from math anxiety. Table 6 shows a summary of the regression results. Overall, math anxiety was not a significant predictor of children's use of internal or external explanations.

However, additional analyses revealed children's math anxiety on the counting items was significantly related to their explanations of why the toy did not work, r_{pb}(65) = .305, p = .012. Specifically, reporting higher math anxiety on the counting items was related to using an external explanation for why the toy did not work.

Additional analyses also considered age and gender differences in the relations between math anxiety and explanation type. There were no differences in the relation of children's math anxiety and their explanations of why the toy did not work by age. However, we found the relation of math anxiety and children's explanations of why the toy did not work varied based on children's gender. Specifically, the correlation between children's math anxiety score and their type of explanation was significant for boys, r_{pb}(35) = .388, p = .018, but not significant for girls, r_{pb}(28) = -.120, p = .527. In addition, logistic regression results showed that math anxiety was a significant predictor of children's use of internal or external explanations for boys but not for girls (see Table 6). Specifically, boys with higher math anxiety were more likely to use an external explanation than boys with lower math anxiety.

Table 6

Logistic Regression Summary

	Overall				Boys				Girls			
Variable	Estimate	*SE*	*Z*	Pr(>|*z*|)	Estimate	*SE*	*z*	Pr(>|*z*|)	Estimate	*SE*	*z*	Pr(>|*z*|)
Constant	0.521	0.965	0.540	0.589	-3.292	1.526	-2.158	0.031*	1.337	1.879	0.711	0.477
Math Anxiety	0.230	0.498	0.462	0.644	2.025	0.907	2.234	0.026*	-0.626	0.956	-0.654	0.513
Gender	-0.149	0.438	-0.341	0.733								
	Null deviance: 129.84 on 105 degrees of freedom Residual deviance: 129.41 on 103 degrees of freedom				Null deviance: 51.266 on 36 degrees of freedom Residual deviance: 45.363 on 35 degrees of freedom				Null deviance: 41.455 on 29 degrees of freedom Residual deviance: 41.018 on 28 degrees of freedom			

*$p < .05$.

Aim 3: Math Anxiety and Gender

The third aim was to examine the relation of math anxiety and gender (as a replication of previous research). As reported under preliminary analyses, a *t*-test (pre-registered) comparing math anxiety for boys and girls indicated that girls' math anxiety was significantly higher than boys' math anxiety, $t(104) = -2.516$, $p = .013$, $d = -.490$.

Additional analyses were conducted to examine age differences in the relations between children's math anxiety and gender. We found significant differences in the relation of math anxiety and gender. Specifically, there were no significant differences in math anxiety by gender for 4-year-olds, $M_{Girls} = 1.93$, $M_{Boys} = 1.77$; $t(41) = -1.174$, $p = .247$, $d = -.360$, or 5-year-olds, $M_{Girls} = 1.85$, $M_{Boys} = 1.65$; $t(37) = -1.543$, $p = .131$, $d = -.496$. However, for 6-year-olds, girls' math anxiety ($M_{Girls} = 1.73$) was significantly higher than boys' math anxiety, $M_{Boys} = 1.32$; $t(22) = -2.595$, $p = .017$, $d = -1.063$.

Aim 4: Math Anxiety and School Experience

The fourth aim was exploratory, to examine the relations between math anxiety and children's school experience. We examined this because schooling has the potential to influence children's math anxiety, possibly through the introduction of formal math instruction or the influence of teacher or peer math anxiety. School experience was classified as children who had or had not yet attended kindergarten. This classification was distinct from children's age. Parents reported that 59.4% of children had not yet attended kindergarten (e.g., home-based care, daycare, preschool), and 40.6% of children had attended kindergarten or first grade). A *t*-test (pre-registered) was used to compare math anxiety for children who had ($M = 1.718$) and had not yet started kindergarten ($M = 1.796$). Results indicated that math anxiety did not differ based on children's school experience, $t(94) = .864$, $p = .390$, $d = .180$.

Similar to the previous aims, we conducted additional analyses to examine whether the relations between children's math anxiety and school experience varied by gender and age. There were no differences in the relation of children's math anxiety and school experience based on children's gender. For children's age, math anxiety was significantly higher for 5-year-olds who had started kindergarten ($M = 1.90$, $n = 19$) than 5-year-olds who had not yet started kindergarten ($M = 1.60$, $n = 15$; $t(32) = -2.234$, $p = .033$, $d = -.772$).

Discussion

The goal of the current study was to examine the relations of children's math anxiety with their persistence and exploration during a math-related play task. Findings indicate that overall children's math anxiety did not relate to their play behaviors, explanations of why the toy did not work, or school experience, but that there were differences in the pattern of results across age and gender. In addition, children's talk during the toy play task related to their math anxiety, such that children with higher math anxiety made fewer statements about math knowledge or math procedures. This section describes these results in the context of links between children's math anxiety and math avoidance and in relation to the current literature.

Math-Related Play Behaviors and Math Anxiety

Previous research has indicated that children's engagement in math-related play and exploration relates to their math learning and achievement, and that children vary in the amount and type of play and exploration they engage in at school (Edens & Potter, 2013; Fisher, Dobbs-Oates, et al., 2012). In the current study, we observed children's persistence and exploration during a math-play task to examine if children's math anxiety contributes to this variation in children's play behaviors. We considered children's play behaviors in multiple ways, including children's actions and use of talk during play and exploration. Overall, we observed wide variability in each of the play behaviors measured. Contrary to our predictions, children's math anxiety was not a significant predictor of children's counting attempts, button attempts, or time spent engaging with the toy mathematically. However, in the current task it is also possible that children with lower math anxiety might also spend less time exploring the toy, if they are confident that they counted correctly the first time. Examining children's talk during the play task allowed us to examine this possibility further. We found that children's math anxiety was a significant predictor of children's use of talk during the play task, such that children with higher math anxiety were less likely to use math-related statements (e.g., “I counted to eight”) than children with lower math anxiety.

Overall, these findings are consistent with previous research showing variability in children’s engagement in math play (Edens & Potter, 2013). Our findings also suggest that math anxiety may influence children’s engagement in certain aspects of their math-related play. Understanding how math anxiety relates to children’s play behaviors is important for understanding children’s math development, as play is a common method for teaching math concepts in early childhood classrooms. For example, if math anxiety predicts children’s use of talk related to math knowledge, children with higher math anxiety may talk less about math concepts while playing with math-related toys in their classroom, which could have implications for their learning from the toy. Further, because math anxiety is known to be negatively related to academic math performance (Barroso et al., 2021), understanding children’s engagement and persistence in math play tasks has implications for children’s later math learning and engagement in math.

Children’s Reasoning About the Play Task

In addition to examining children’s play behaviors, we were also interested in children’s explanations of why the toy did not work during the test trial. We predicted that children with higher math anxiety would be more likely to use internal explanations (e.g., “I counted wrong”) and that children with lower math anxiety would be more likely to use external explanations (e.g., “because it is broken”). In contrast to our predictions, our primary analyses indicated that children’s overall math anxiety was not a significant predictor of explanation type. However, in our additional analyses we found that children’s explanations were significantly correlated with their math anxiety on questions that specifically asked about nervousness about counting. Because the toy play task specifically involved counting (dots on the card, number of button pushes), this suggests the influence of math anxiety on their reasoning about why they were not able to activate the toy may be specific to nervousness about relevant aspects of the task, rather than math anxiety in general. Future studies could examine this further by comparing toys or play that involve different aspects of children’s math skills (e.g., counting, arithmetic) in relation to children’s reported math anxiety levels on sets of questions related to each of these skills.

In our additional analyses, we found that there were gender differences, such that overall math anxiety was a significant predictor of explanation type for boys, but not for girls. Specifically, boys with higher math anxiety were more likely to use an external explanation than boys with lower math anxiety. This result was unexpected. It is possible that explanation type may be influenced by additional variables not examined here, such as math ability and math competence. Future studies could further examine relations of children’s reasoning and their math anxiety, including examinations of relations with these other variables. It is also important to consider that not all children provided an explanation that could be categorized as internal or external. To further understand children’s reasoning about their abilities to activate the toy, future studies could include additional questions to specifically target children’s perceptions of their ability to complete the math-related aspects of a toy play task.

Gender and Age Differences in Math Anxiety

Based on previous research, we examined relations of math anxiety and gender. Our findings replicated previous research, showing that even in younger children, girls reported significantly higher math anxiety than boys (Gunderson et al., 2018; Lauer et al., 2018). When examining these relations separately by age, we found that the difference was significant for 6-year-olds, but not for 4-year-olds or 5-year-olds. This suggests the possibility that while math anxiety emerges at a young age, gender differences in math anxiety may emerge later. However, as there are few studies examining math anxiety in preschool and kindergarten-aged children, additional research is needed to further examine gender differences at these young ages. Further, as many previous studies examining children’s math anxiety focus on elementary school-age children, studies that have reported gender differences for different groups often focus on children’s grade level rather than age. For example, Lauer and colleagues (2018) examined math anxiety in children in grades 1 through 5 (ages 6 through 12) and found that math anxiety was higher for girls than boys, and that this remained consistent at each grade level examined. Future studies could similarly examine changes in the relations of math anxiety and gender for children of preschool and kindergarten ages as well.

We examined children's school experience in relation to their math anxiety. For the current study, we classified children's school experience as children who had or had not started kindergarten, as we were interested in the role of formal school experience. While we did not find overall differences, there were significant differences based on children's age. Math anxiety was significantly higher for 5-year-olds who had started kindergarten than 5-year-olds who had not. This suggests that children's experiences in kindergarten have the potential to influence their math anxiety, as kindergarten may be their first experience with formal math instruction. In addition, it is also possible that interactions with math anxious teachers and/or peers at school could influence children's own math anxiety.

The difference in children's math anxiety being significant for 5-year-olds but not 4- or 6-year-olds may reflect the characteristics of our sample. In our sample, 56% (n = 19) of 5-year-olds had started kindergarten, and 44% (n = 15) had not. In contrast, 100% of the 4-year-olds in the study had not started kindergarten, and 91% (n = 20) of the 6-year-olds in the study had started kindergarten. Because of this, comparisons by school experience were not possible for the 4-year-old and 6-year-old groups. It is possible that the influence of school experience on children's math anxiety may be more salient as they are starting kindergarten, as children adjust to formal math instruction. Future studies could further examine these possibilities by specifically examining changes in children's math anxiety before and after starting kindergarten.

Limitations and Future Directions

The current study has multiple limitations, but opens up several promising lines for future research. First, it is important to consider how math anxiety is measured, particularly in relation to children's age and ability level. Given the range in our sample of children's ages and experiences with school, it is possible that children may have differed in their perceived difficulty of the problems included in the math anxiety questions (e.g., counting to 30, counting backwards from 20, solving 4 − 1). This could impact children's reported math anxiety, as the perceived difficulty level of the specific problems in the math anxiety questions can change the pattern of responses children provide (Lu et al., 2021). For example, if younger children perceive the problems as more difficult, they may be more likely to report higher math anxiety. In this sense, reported relations of math anxiety with children's age and school experience could differ based on the specific math anxiety questionnaire used.

In addition, the toy play task we used to examine children's play behaviors was specifically designed for the current study. The task involved play with a novel toy that had one function—counting dots on a card and pressing a button the same number of times to hear a sound. While this toy allowed us to examine variation in children's play behaviors during a math-related task, the characteristics of the toy are limiting in terms of understanding children's engagement with more conventional math toys. Future studies could further examine the relations of children's math anxiety and play behaviors with different types of math-related toys, such as blocks, puzzles, and shapes, or toys with multiple functions. This would allow for a more nuanced understanding of the relations between children's math anxiety and their play behaviors. Similarly, future studies could also consider math avoidance in the context of play by examining children's engagement with math toys when they have a choice of different non-math related toys or activities (e.g., math toys, literacy toys, other games, books, etc.). This could approximate the types of choices children have during classroom center time, and allow for further understanding of children's self-initiated engagement and persistence in their math learning.

Finally, the sample included in the current study had predominantly high household income and high levels of parent education. It is possible that these demographic factors may relate to children's experiences with math at home as well as parents' own math anxiety levels, which could in turn impact children's math anxiety levels. Future studies should aim to recruit a more diverse sample of participants and could also include additional measures to examine parent math anxiety and families' experiences with math at home.

Conclusions

The current study examined relations of children's math anxiety and play behaviors. The study addressed a gap in the literature by examining the relations of math anxiety and math avoidance in young children, and in the context of play. Findings indicated that children's actions during play did not relate to their math anxiety, but their talk about math knowledge while playing did relate to their math anxiety. Overall, these findings suggest that children's math anxiety may relate to certain aspects of engagement in math-related play and exploration. Results also indicate that more research is needed to further examine links between math anxiety and math avoidance in early childhood. Understanding the connections between children's math anxiety, math avoidance, and their engagement and performance in math could have important implications for children's overall math development and later math and academic achievement.

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Ethics Statement: Our research was conducted in accordance with ethical standards. All study procedures were approved by the University of Maryland, College Park Institutional Review Board prior to the start of the study.

Supplementary Materials

The Supplementary Materials contain the pre-registration information for this study (for access see Index of Supplementary Materials below).

Index of Supplementary Materials

DePascale, M., Butler, L. P., & Ramani, G. B. (2019). *Supplementary materials to "The relation between math anxiety and play behaviors in 4- to 6-year-old children"* [Pre-registration information]. OSF. https://osf.io/b7qrz

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