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When We Were Young: Memories of Early Mathematics Experiences

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Supplementary Materials: Materials [see Index of Supplementary Materials]

Abstract

Early math experiences predict children's later math abilities and beliefs. However, less is known about longer-term associations between early childhood math experiences and adult math outcomes. The present study examined emerging adults' earliest memories of mathematics and reading experiences, asking whether characteristics of their early learning memories differ across domains of learning and relate to their adulthood math achievement and beliefs. Undergraduate students (n = 161, M_{Age} = 19.6 years) described their earliest memories of math and reading, then completed measures of their math anxiety, math task value, and math achievement. Our results reveal significant domain differences in participants' age during their earliest memories, the level of social interaction, and their overall rating of the experience. Emerging adults with more positive memories of their earliest math experiences had lower math anxiety, higher math task value, and higher math achievement. Our results provide additional evidence of the long-term associations between early math experiences and later math outcomes and underscore the need to promote early math experiences that are positive and engaging for young children.

Keywords

early mathematics, math anxiety, math task value, math achievement, memory

Non-Technical Summary

Background

Many of our adulthood math abilities and beliefs about math are formed during childhood. Given the challenges in conducting research that follows people across childhood into adulthood, there are many open questions about how our earliest experiences of learning can continue to affect our adulthood outcomes.

Why was this study done?

Our goal was to determine whether there were differences in adults' memories of their earliest math and reading experiences, and whether differences in their earliest memories (such as how much they enjoyed the experience and whether they were with someone else during the experience) related to their current, adulthood math ability and beliefs.

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What did the researchers do and find?
In this study, we asked undergraduate students to describe their earliest memories of math and reading. We found that students were younger during their earliest reading experience compared to their earliest math experience, liked their earliest reading experiences more than their earliest math experiences, and were more likely to describe an experience of reading together with someone else and describe an experience of doing math independently. Our major finding was that students who reported more positive memories of their earliest math experiences had lower math anxiety, stronger beliefs in the importance and value of math, and higher math achievement as undergraduates.

What do these findings mean?
These results show more evidence that early learning experiences are related to later math abilities and beliefs and highlight the importance of providing positive and engaging early math experiences for young children.

Highlights

- Emerging adults had more positive early memories of reading compared to math.
- Participants had more socially interactive early memories of reading compared to math.
- Participants with more positive memories of early math had lower math anxiety, higher math task value, and higher math achievement as adults.
- Associations between more positive memories of early math and adulthood math-related outcomes were maintained when controlling for prior math achievement.

Many adults dislike or experience anxiety about math. People who experience math anxiety as children and adults tend to have lower mathematics achievement and subsequently less access to much-needed, highly compensated careers in science, technology, engineering, and mathematics (STEM; Barroso et al., 2021; Foley et al., 2017). Adults with lower mathematics achievement are less likely to enter and graduate from college, have lower rates of full-time employment, and earn lower annual incomes (Geary, 2011; Ritchie & Bates, 2013). These adulthood math-related outcomes are likely set in motion much earlier in development (Carkoglu et al., 2023; Duncan et al., 2007). Prior research has shown that mathematical experiences in early childhood predict children's math achievement concurrently and up to several years later (Daucourt et al., 2021; Dunst et al., 2017). However, less is known about longer-term associations between early childhood math experiences and adult math outcomes. The present study examined emerging adults' earliest memories of mathematics and reading experiences, asking whether characteristics of their early learning memories differ across domains of learning and relate to their current math anxiety, task value, and achievement. The goal was to determine whether early math experiences predict adult outcomes over a decade later, and in turn, identify which aspects of early math experiences were the most strongly associated with long-term outcomes and may serve as targets for future early mathematics interventions.

Early Mathematics Experiences and Later Outcomes

Early experiences with math in childcare and school settings or at home with family members lay the foundation for children's developing math abilities and beliefs (e.g., Eason et al., 2022; Klibanoff et al., 2006; Zhang et al., 2020). Children's early mathematical abilities, such as counting, recognizing numerals, comparing numbers to say which is more and which is less, and repeating and extending patterns predict their math achievement later in primary and secondary school (Duncan et al., 2007; Rittle-Johnson et al., 2017). Longitudinal studies of math achievement show relative rank-order stability over time, such that children who have lower performance in math in early elementary school tend to show lower performance in math throughout high school (Davis-Kean et al., 2022; Ribner et al., 2023). Children's math abilities similarly predict their affective beliefs and attitudes towards math. Young children with higher math skills tend to report liking math more 5 months later (Fisher et al., 2012) and are less likely to experience later math anxiety relative to children with lower math skills (Gunderson et al., 2018; Ramirez et al., 2018). Moreover, after

a period of relative stability during elementary school (Wigfield et al., 1997), longitudinal research suggests that older children and adolescents' interest in math tends to decline over time (Frenzel et al., 2012; Jacobs et al., 2002), while roughly 40 percent of adolescents show patterns of consistently high or increasing math anxiety during secondary school (Ahmed, 2018). There is also some evidence to suggest that these patterns in attitudes are domain-specific rather than domain general and representative across subjects of early learning. For example, some prior research suggests that young children report greater interest in reading compared to math (Nurmi & Aunola, 2005; Wigfield et al., 1997).

These predictive relations suggest that children's early math learning experiences may play a crucial role in explaining individual differences in their math achievement and anxiety across childhood into adolescence and emerging adulthood. For example, prior theoretical work suggests that early experiences that focus on visual-only presentations of number (rather than combining with additional auditory information) will increase children's selective attention to and learning of mathematics over time (Bahrick et al., 2020). However, we are unaware of longitudinal research examining the relations between characteristics of math experiences in early childhood and math outcomes in adulthood. This is likely due to the substantial methodological barriers in conducting a longitudinal study spanning over a decade of childhood. In the present study, we instead use a retrospective method to assess the characteristics of adults' earliest math experiences, taking a first step towards addressing this gap. Our approach is inspired by previous research on adults' memories of prior math experiences, which has demonstrated associations between math experiences in adolescence and adulthood outcomes (Towers et al., 2017). We build on and extend previous research in adults' math memories by drawing from research in STEM identity development, which demonstrates consistent, positive associations between characteristics of science experiences during early childhood and having a STEM identity in adulthood (i.e., seeing oneself as a "STEM" or "science person"; Dou et al., 2019).

Memories of Mathematics Experiences

Little is known about adults' memories of math experiences in early childhood. Although many adults are unable to remember experiences that occurred before they were 3 to 4 years old (Tustin & Hayne, 2010), people can recall specific past events in detail when they are emotionally salient experiences (McAdams & Bowman, 2001). Similar experiences that prompt similar emotional reactions that are repeated over time may ultimately become self-defining memories, which organize significant experiences around a central emotional theme (John et al., 2022; Singer, 1995). According to the control-value theory of achievement emotions (Pekrun, 2006), students' emotional states during domain-specific academic tasks form feedback loops that predict both their performance on the task itself as well as their perceptions of personal control and value during future tasks within that domain. For example, a student who experiences positive emotions during a math task is more likely to experience positive outcomes on that task, and in turn, feel more positively and experience more positive outcomes on future math tasks (John et al., 2022; Pekrun, 2006).

Prior research has examined children and adults' open-ended, narrative descriptions of math experiences, demonstrating associations between the emotional valence of participants' math narratives and their current math attitudes and beliefs (John et al., 2020; Towers et al., 2017). For example, John and colleagues (2020) asked undergraduate students to describe a turning point in their mathematics learning and found that participants with more negative memories reported higher math anxiety and lower math self-expectancy and task value relative to participants whose narratives were more positive. Moreover, participants with more negative memories were more likely to report that they planned to avoid math in the future (John et al., 2020). These findings provide further evidence that prior experiences of math may relate to long-term attitudes and beliefs, although past work has focused on math experiences that occurred during adolescence or early adulthood (Towers et al., 2017). However, by the time someone enters adolescence and emerging adulthood they have already had many prior years of math experiences, and in turn, likely hold a set of personal affective beliefs about math (e.g., math anxiety, math interest, STEM identity).

To our knowledge, no prior research has examined adults' earliest memories of math, leaving open questions as to the context and content of these experiences, patterns in their emotional valence, and whether and how they are associated with long-term math attitudes. In addition, although previous work has demonstrated associations between memories of math and participants' perceived competence in math (Towers et al., 2017), no prior research has examined associations with participants' math achievement. Identifying characteristics of early learning experiences that are

associated with long-term math outcomes may provide an opportunity to support mathematical development early in the lifespan before attitudes and abilities solidify.

The Present Study

The present study extends prior research on math memories to include adults' earliest memories of learning and their association with math attitudes and achievement. Guided by prior research, we focus on participants in emerging adulthood (aged 18 to 29 years old), as they can use higher-level cognitive skills to reflect on and describe their prior experiences and are more likely than adolescents or older adults to be currently making academic and career choices to seek or avoid math (John et al., 2020). The first aim is to describe the characteristics of emerging adults' earliest memories of math and reading experiences. Specifically, we examined the nature of the early math and reading experiences (e.g., socially interactive, independent); the type of math or reading activity described; the emotional valence of the experience; and the participant's approximate age at the time of the memory.

The second aim is to compare features of earliest math and reading experiences to determine whether emerging adults' memories differed as a function of domain of early learning. Some evidence suggests that young children report greater interest in reading compared to math (Nurmi & Aunola, 2005; Wigfield et al., 1997), thus we hypothesized that participants' memories of early reading experiences would be appraised more positively than memories of early math experiences.

Our third and final aim was to examine whether characteristics of emerging adults' early math memories would relate to their current math anxiety, task value, and achievement. In keeping with the control-value theory of achievement emotions (Pekrun, 2006), children's emotions during math experiences predict both the outcome of their individual experiences (i.e., more or less successful) as well as their future emotional states and math-related outcomes. Specifically, we hypothesized that more positive memories of early math (but not reading) would relate to lower math anxiety and higher task value and achievement, extending prior research that found associations between memories of math from adolescence and early adulthood related to math attitudes and beliefs (John et al., 2020; Towers et al., 2017). This aim allowed us to answer whether the emotional valence of early learning memories are broadly associated with adult attitudes and achievement, or whether the associations are unique within the domain of math.

Method

Participants

Participants were recruited from the research subject pool of the Department of Human Development from a large, public university in the northwestern United States in exchange for course credit. We recruited 164 undergraduate students. Three participants were excluded for not completing the focal questionnaire measure in sufficient detail (n = 1) and for describing recent math and reading experiences instead of their earliest memories of math and reading (n = 2). This left an analytic sample of 161 students (M_{Age} = 19.57, SD_{Age} = 2.08; 76.9% women, 20.6% men, and 2.5% nonbinary or other; 79.3% White, 9.7% Asian, 5.2% Black or African American, 1.9% American Indian or Alaskan Native, 1.9% Native Hawaiian or other Pacific Islander, and 1.9% biracial or multiracial; 18.6% Hispanic or Latinx; 44.1% freshman or first year, 27.3% sophomore or second year, 20.5% junior or third year, and 8.1% senior or final year of undergraduate enrollment). Participants' highest level of math coursework completed in high school was 1.2% basic math or pre-algebra, 1.9% algebra 1, 1.9% geometry, 28.6% algebra 2, 39.1% trigonometry or precalculus, 19.9% calculus, 5.6% statistics, 1.2% college preparatory math, and 0.6% linear algebra.

Procedure

Participants completed all measures as part of a Qualtrics survey administered in an on-campus lab setting with a trained research assistant present. First, participants answered a series of demographic questions. Next, they were asked about their early learning experiences related to math and reading, their math task value, and their math anxiety. The

order of presentation for the early learning experiences, math task value, and math anxiety measures was randomized to prevent confounding from order effects. Finally, all participants completed a 10-item math assessment.

Measures

Early Learning Experiences

Participants were asked to spend 3 minutes describing their earliest memory of math in a free-response text box. They were asked to include what they did, where they were, who was there, and any thoughts or emotions they experienced during each memory. Participants were given the same instructions to describe their earliest memory of reading.

After describing each memory, participants were asked a set of follow-up questions, including a multiple choice item rating their emotions during their described early learning experience on a 7-point Likert-type scale (i.e., very negative, negative, somewhat negative, neutral, somewhat positive, positive, and very positive); a multiple choice item describing the approximate age they were during their learning experience (i.e., 0-3 years, 4-6 years, 7-10 years, 11-13 years, and 14 years and older); and a checkbox item asking whether anyone else was present during their learning experience (i.e., they were alone; with a parent or family member; with a teacher or tutor; with other children or classmates).

Math Task Value

Participants' math task value was measured using a 6-item Likert-type scale adapted from the Motivated Strategies for Learning Questionnaire (MSLQ; Jiang et al., 2018; Pintrich et al., 1991). Items assessed participants' utility, attainment, and interest value (e.g., "I think math is useful for me to learn"). Participants were asked to rate how true each statement was to them with a 7-point scale (i.e., not true at all; not true; somewhat not true; neutral; somewhat true; true; very true). Internal consistency for this sample was $\alpha = .90$.

Math Anxiety

Participants' math anxiety was assessed using the 24-item Mathematics Anxiety Rating Scale – Revised (MARS-R; Plake & Parker, 1982). Participants were asked to rate how anxious specific situations would make them feel, such as "walking into a math class", on a 5-point Likert-type scale (i.e., not at all anxious; slightly anxious; moderately anxious; very anxious; extremely anxious). Math anxiety overall scores were calculated for all participants using the average of the items with a response from each participant. Previous research has reported reliability of the MARS-R as $\alpha = .98$ (Plake & Parker, 1982); internal consistency for this sample was $\alpha = .95$.

Math Achievement

Participants' math achievement was assessed using 10 multiple choice items drawn from two publicly available preliminary SAT (PSAT) practice exams (The College Board, 2015). The items ranged in mathematics content (e.g., geometry, algebra). All participants were provided with scratch paper and a pen to solve the problems if they chose, but none of the items required a calculator to solve. To calculate the overall math achievement score, items that were incorrect or missing were scored as a 0 and correct items were scored as 1, then summed across the ten items to reflect the total number of correct items. Prior research has demonstrated high reliability among items in the PSAT mathematics section ($\alpha = .87$; The College Board, 2006). The 10 items selected were pilot tested with three undergraduate students prior to the beginning of the study and demonstrated sufficient variability ($M = 7.3$ correct, range = 6 – 8).

Analytic Plan

Qualitative Analysis

Participants' open-ended responses describing their earliest math and reading memories were qualitatively coded by two trained researchers. Codes were determined in a blend of deductive and inductive approaches across two phases. During the first phase, we identified the major themes of interest, including participants' emotions; participants' level of engagement (i.e., active vs. more passive); whether the experience was socially interactive; and the type of learning activity described. These themes were identified from the literature on supporting children's math learning and

achievement broadly (e.g., Daucourt et al., 2021; Dunst et al., 2017; Pekrun, 2006; Zippert & Rittle-Johnson, 2020; Zosh et al., 2018). In the second phase, we refined our initial coding scheme based on a subset of participants' responses. During this phase, we made several key data-driven adaptations to our initial codes, including to our definition of active engagement (e.g., completing a math activity themselves versus listening to a teacher describe a math concept) and to our subcodes related to social interaction (e.g., whether other people were participating in the activity; whether other people were present but not participating; whether other people were referenced as a point of comparison; and whether participants described a male parent/caregiver, female parent/caregiver, a teacher, sibling, or friend/peer as present during the experience). Our final coding scheme with example responses is available in Appendix A (Scalise et al., 2025S).

Following our second phase of coding development, we completed interrater reliability. Codes were not mutually exclusive. Two trained research assistants coded 20% of the total open-ended responses for the characteristics listed above with Cohen's kappa ranging from .74 to 1 across codes, meeting benchmark criteria for moderate to strong agreement; 14 coding categories out of the 19 total categories had Cohen's kappas between .90 and 1, representing near perfect agreement (McHugh, 2012). Discrepancies during the reliability coding phase were resolved by the first author. After achieving acceptable coding reliability, the trained research assistants independently coded the remaining responses.

Quantitative Analysis

Descriptive statistics (i.e., mean, standard deviation) were used to address the first aim of describing the characteristics of emerging adults' earliest memories of math and reading experiences. Welch's *t*-tests were used to test for potential differences in responses between groups of participants (e.g., female vs. male participants; participants who described someone else engaging in the activity with them vs. participants who did not describe someone else engaging in the activity with them). Welch's *t*-tests are appropriate for comparative analyses where groups do not show homogeneity of variance, common in psychological research (Delacre et al., 2017). In addition, a Pearson's correlation was used to test for a potential bivariate association between participant age and participants' rating of the emotional valence of their earliest math memory, using responses to the 7-point Likert scale item administered after their free-response description of their experience.

Paired samples *t*-tests were used to address the second aim of comparing characteristics of participants' earliest math and reading memories. Finally, to address our third aim, simple linear regression models were used to determine whether characteristics of participants' earliest learning memories predicted their math-related outcomes in emerging adulthood. Specifically, participants' responses to the multiple-choice items following their descriptions of earliest math and reading experiences (i.e., rating of emotional valence, approximate age at time of experience) were tested as potential predictors of adulthood math anxiety, task value, and achievement.

Results

Preliminary Analyses and Missing Data

To test for potential order effects, we conducted three one-way ANOVAs with task order as the independent variable and math value, anxiety, and achievement as the dependent variables, respectively. There were no significant effects of task presentation order on participants' math outcomes (anxiety, task value, and achievement). Demographic information on participants' age and gender identities are presented from available data (n = 150 − 160). Analyses that include measures with missing data used pairwise deletion for missing responses, with maximum ns ranging from 129 to 161.

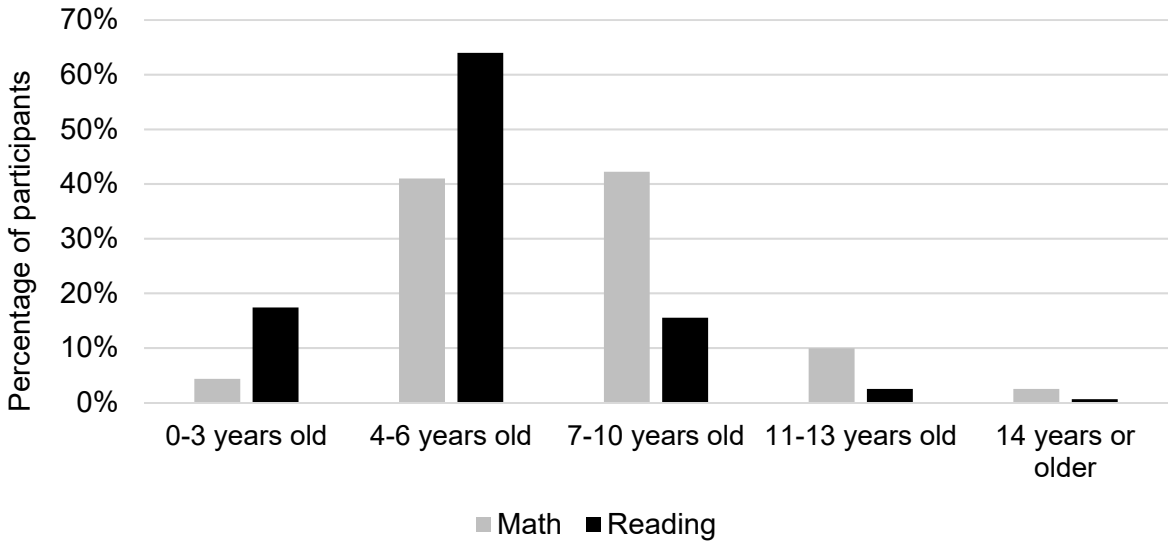
Characteristics of Earliest Mathematics Experiences

Participants' earliest memories of mathematics varied. Most participants were between 4 and 10 years old during their earliest math memory (Figure 1). Nearly all participants (n = 159; 99 percent) were coded as being actively engaged in their earliest math experience. Most participants described an experience that involved numbers (88 percent); only 3

participants described an experience that involved shapes (2 percent). A quarter of participants described an experience involving being timed or having a time limit (25 percent) or practicing math with a worksheet or flashcards (25 percent). Fifteen percent of participants described a math quiz or test.

Figure 1

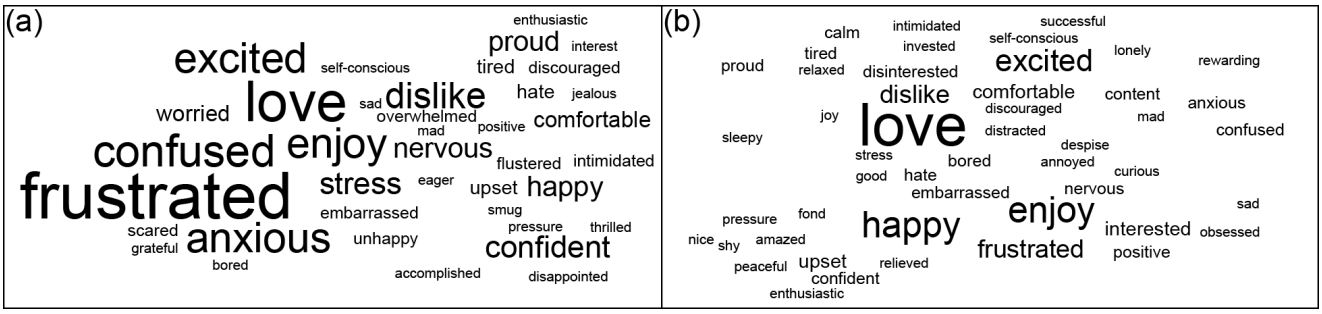
Age of Participants During Earliest Memories of Math and Reading (n = 161)



Most participants (73 percent) included emotion words in their descriptions of their earliest math memory. Figure 2 displays a word cloud summarizing participants' use of emotion words in their open-ended descriptions of their math and reading experiences. When asked to rate how they felt during their earliest math experience, participants ranged from 1 (very negative) to 7 (very positive), with an average of 4.5 (between neutral and somewhat positive; *SD* = 1.75). Participants who were younger during their earliest math memories did not have significantly more positive experiences, $r(127) = -.14$, $p = .11$. Participants identifying as male did not have significantly more positive early math experiences than participants identifying as female ($M_{male} = 4.62$, $M_{female} = 4.52$, Welch's *t*-test $t(45.44) = 0.27$, $p = .79$), nor did participants identifying as female have significantly more positive early reading experiences than participants identifying as male ($M_{male} = 5.83$, $M_{female} = 5.40$, Welch's *t*-test $t(69.69) = 1.46$, $p = .15$).

Figure 2

Word Cloud of Emotion Words During Descriptions of Math Experience (a) and Reading Experience (b)



Note. The size of the font of each word indicates the relative frequency.

Table 1 summarizes the types of social relationships and interactions that were described in participants' earliest math and reading memories. Participants who described other people in their earliest math memory who were participating in the activity with them rated their memory as more positive than participants who did not describe someone participating in the activity with them (M = 4.85 and 4.09, respectively; Welch's t-test $t(111.25) = 2.46$, $p < .05$). However, participants who described someone else in their memory who was not participating in the activity did not have more positive ratings of their experience (M = 4.41 and 4.62, respectively; Welch's t-test $t(126.57) = 0.67$, $p = .50$).

Table 1

Social Characteristics of Earliest Math and Reading Experiences

Social Characteristic	Math (%)	Reading (%)
Someone else present during experience	98	99
Someone else there but not directly participating	55	30
Someone else actively participating	47	88
Someone referred to as a point of comparison for performance	26	8
Peer or friend present	59	32
Teacher present	44	29
Female parent or caregiver present	13	45
Male parent or caregiver present	11	21
Sibling present	7	12

Comparing Earliest Math and Reading Experiences

On average, participants were younger during their earliest reading experience compared to their earliest math experience, $t(160) = 10.28$, $p < .001$ (see Figure 1). Participants also rated their earliest reading experiences as significantly more positive than their earliest math experiences, $M_{read} = 5.5$, $M_{math} = 4.5$, $t(115) = 4.46$, $p < .001$.

Although nearly all participants described other people in their earliest math and reading memories, participants were more likely to describe another person actively participating in their earliest reading memory compared to their earliest math memory, $t(160) = 5.45$, $p < .001$. In contrast, participants were more likely to describe another person who was present but not participating in the same activity in their earliest math memories compared to their earliest reading memories, $t(160) = 3.41$, $p < .001$. Participants were more likely to describe someone else as a point of comparison or reference for their performance in their earliest math memories compared to their earliest reading memories, $t(160) = 4.58$, $p < .001$. In addition, participants' earliest math memories were more likely to reference a teacher or tutor ($t(160) = 2.89$, $p < .01$) or a friend or peer ($t(160) = 5.65$, $p < .001$) compared to earliest reading memories, whereas participants' earliest reading memories were more likely to reference a female caregiver ($t(160) = 7.27$, $p < .001$) or male caregiver ($t(160) = 2.72$, $p < .01$) compared to earliest math memories.

Relations Between Early Math Experiences and Current Math Attitudes and Ability

Table 2 presents descriptive statistics on participants' current mathematics interest, anxiety, and achievement. There were no significant differences in the current mathematics interest, anxiety, and achievement scores for participants identifying as male compared to participants identifying as female (Welch's t-test ps > .05).

Participants' self-reported emotional valence of their early math memories significantly predicted their math task value, anxiety, and achievement as adults. The simple linear regression with math task value regressed on the emotional valence of their earliest math experience was statistically significant, $R^2 = 0.083$, $F(1, 126) = 11.38$, $p < .001$. Participants with more positive early math memories reported higher math value and interest beliefs ($B = 0.210$, $t(126) = 3.37$, $p < .001$). The simple linear regression with math anxiety regressed on emotional valence was also statistically significant ($R^2 = 0.053$, $F(1, 127) = 7.13$, $p < .01$), such that participants with more positive early math memories had lower math anxiety ($B = -0.094$, $t(127) = -2.67$, $p < .01$). Furthermore, the simple linear regression with math achievement regressed on emotional valence was statistically significant ($R^2 = 0.051$, $F(1, 127) = 6.90$, $p < .01$), such that participants with more

positive early math memories had higher math achievement (B = 0.256, t(127) = 2.63, p < .01). The emotional valence of participants' earliest math experiences remained a significant predictor of adulthood math task value, math anxiety, and math achievement in multiple linear regression models controlling for participants' highest level of high school math coursework (see Appendix B; Scalise et al., 2025S).

Table 2

Descriptive Statistics of Current Math Interest, Anxiety, and Achievement

				Range	
Math-Related Outcome	***n***	***M***	***SD***	**Potential**	**Actual**
Math interest	160	4.59	1.27	1 – 7	1.7 – 7.0
Math anxiety	161	2.45	0.72	1 – 5	1.1 – 4.9
Math achievement	161	6.06	1.99	1 – 10	1 – 10

In contrast, none of the simple linear regressions of math value and interest beliefs, math anxiety, and math achievement regressed on the emotional valence of participants' earliest reading experiences were statistically significant, indicating that participants with more positive early reading memories did not have higher math value and interest beliefs, less math anxiety, or higher math achievement as adults (ps > .05). Finally, participants who were older in their earliest math memories had higher current math anxiety (R^2 = 0.072, F(1, 159) = 12.38, p < .001, B = 0.237, t(159) = 3.52, p < .001), whereas participants who were younger during their earliest math memories tended to have higher current math achievement scores (R^2 = 0.038, F(1, 159) = 6.33, p < .05, B = -0.478, t(159) = -2.52, p < .05).

Discussion

Prior research has demonstrated concurrent and longitudinal associations between early math experiences and children's math abilities and beliefs across several years (Daucourt et al., 2021; Dunst et al., 2017), yet less is known about adults' memories of their early math experiences. The present study takes a first step at describing emerging adults' memories of their earliest math and reading experiences, revealing differences between the learning domains as well as individual differences in math experiences that predict adulthood math anxiety, task value, and achievement.

Our first aim was to describe the characteristics of emerging adults' earliest memories of math. We found that most people were between 4 and 10 years old during their earliest memory of math, and most described an experience that involved numbers. Number knowledge is a focal area of early mathematics standards (NCTM, 2000), early childhood instruction (Scalise et al., 2025), and home mathematics interactions (Zippert & Rittle-Johnson, 2020). It is therefore less surprising that our prompt to reflect on participants' earliest math experience resulted in descriptions of number-related experiences more frequently that shape, patterning, or measurement experiences. On average, participants rated their earliest math memory as a neutral to slightly positive experience, however, there was significant variability between participants. This finding aligns with previous research on math interest and anxiety in preschool and elementary school: Some children report negative attitudes towards mathematics early on in childhood (Fisher et al., 2012; Frenzel et al., 2012; Gunderson et al., 2018; Ramirez et al., 2018). Although nearly all participants reported that someone else was present during their earliest math memory, only participants who described someone else actively participating in the math activity with them reported a more positive overall experience. This finding is well aligned with traditional cognitive development theories that posit social interactions during learning experiences are key to children's engagement and understanding (e.g., Vygotsky, 1978).

Our second aim was to compare features of participants' earliest math and reading experiences to determine whether characteristics of memories differed as a function of domain of early learning. We found that participants were younger on average during their earliest memories of reading relative to their earliest memories of math. As with participants' focus on number-related activities, this may reflect common beliefs about the domain of early math. Unlike reading in

early childhood, adults may be more likely to conceptualize early math as formal, explicit learning experiences (e.g., completing a worksheet or using flash cards) relative to more informal learning experiences (e.g., singing counting songs, playing board or card games, measuring quantities while cooking together). There is also a range in caregivers' unprompted tendencies to talk about mathematical concepts during interactions with young children, with some adults noticing and talking more and others less about math while engaging with the same open-ended materials (DePascale et al., 2021; Ramani et al., 2015). In contrast, informal early reading experiences may be more readily recognizable to adults (e.g., bedtime stories or other experiences reading to a preliterate child).

In addition to being older during their earliest memories of math compared to reading, participants were also less likely to describe themselves as participating in the math activity together with someone else than in their earliest reading experiences. Put another way, adults' memories of their earliest math experiences were more independent and less socially interactive than their earliest reading experiences. Again, this discrepancy may reflect the need to share examples of informal, socially interactive early math activities with caregivers of young children more broadly (Daucourt et al., 2021; Dunst et al., 2017). Informal learning experiences where children are exposed to math concepts in passive, open-ended, or playful ways parallel the rich preliteracy concepts that children are exposed to during shared book reading experiences (e.g., how to hold a book and turn pages in the correct orientation, text and letter exposure). Critically, early math learning experiences that were socially interactive were rated more positively by participants, underscoring the significance of promoting more interactive early math experiences.

As hypothesized, we found that adults rated their earliest math memories less positively than their earliest reading memories. Adults were also more likely to describe someone else as a point of comparison for their math performance (e.g., completing an activity slower or less accurately than a classmate) than in their reading experiences. As described above, this may reflect a bias for adults to recall more formal, independent math learning experiences relative to less formal, more socially interactive reading experiences. It is possible that the observed difference in how positively adults rated their earliest math and reading experiences would be attenuated if we had instead asked about their earliest memories of learning how to read or reading independently. Regardless, this observed domain difference suggests an opportunity to improve upon math experiences in early and mid-childhood. Theories of playful learning suggest that engaging, socially interactive, and joyful experiences with math, such as playing board or card games, can promote children's learning and interest (Zosh et al., 2018). Incorporating more home and family-based math experiences in early childhood may also increase positive associations with math, as adults were more likely to describe participating in math experiences with a teacher or peer versus participating in reading experiences with a parent or caregiver.

Our final aim was to examine whether characteristics of emerging adults' early math memories would relate to their current math anxiety, task value, and achievement. Theories of achievement emotions suggest that emotions that occur during domain-specific academic tasks may continue to influence later performance and attitudes towards future tasks in the same domain (Pekrun, 2006). As hypothesized, we found that participants with more positive early math memories reported lower adulthood math anxiety and higher math task value and achievement. These associations were domain-specific – participants with more positive early reading memories did not have lower math anxiety or higher math task value and achievement as adults. Though most participants described math experiences that occurred 10 to 15 years prior, there are significant associations between learning experiences in early childhood and vital math outcomes in emerging adulthood. Although our study design does not allow for causal inference or the testing of specific mechanisms connecting emotions during domain-specific tasks to adulthood outcomes (see Limitations and Future Directions below), our findings add to the growing literature on the importance of early learning experiences for promoting children's long-term STEM outcomes (Daucourt et al., 2021; Dou et al., 2019).

Limitations and Future Directions

The present study has several limitations. First, the study design does not allow for causal inference. Retrospective accounts of learning experiences during childhood are predictive of outcomes in adulthood (e.g., John et al., 2022; Dou et al., 2019), but longitudinal or experimental studies with multi-year follow up measures would provide stronger evidence of a causal relationship between early math experiences and adult math outcomes. It is possible, if not likely, that the association between memories of math experiences and current math attitudes and ability levels is bidirectional. An

adult who has low math anxiety, high math task value, and strong math achievement may feel more positively towards math in general and be more primed to remember a positive early math experience than a negative early math experience. Indeed, studies of memory show strong evidence for mood congruence, such that people are significantly more likely to recall memories that match the emotional state of their current experience (Kensinger & Ford, 2020). Future research could examine this with the use of state-based emotion reports (e.g., what emotions do you feel currently, as you are remembering this experience?) and state-based measures of anxiety and math self-efficacy, versus the more generalized trait measures in the present study. People are also more likely to retrieve memories that corroborate their current sense of self and identity, to maintain self-continuity between their past and present experiences (Kensinger & Ford, 2020; Wood & Conway, 2006). Theories of math interest similarly suggest repeating bidirectional associations with math achievement, such that more positive math attitudes promote greater achievement and vice versa over time (Ma, 1997). Moreover, future research should investigate the interaction effects of early math attitudes, including anxiety and task value, and their longitudinal effects on achievement and memories of math experiences (e.g., Ramirez, 2017). In addition, future research could further examine the relations between the emotional valence of participants' earliest math memories and their math task value, anxiety, or mathematics achievement with a within-person analysis asking participants to describe both a positive and a negative early experience.

Second, the generalizability of our results is limited due to the nature of our sample. Our sample of emerging adults is not representative of national adult demographics nor of emerging adults enrolled in postsecondary education. The majority of our sample identified as female, and all participants were recruited from an introductory social sciences course. In particular, our sample may reflect fewer gender differences in early math and reading experiences, as well as higher rates of math anxiety and lower rates of math task value and achievement than would be expected had we recruited a sample of undergraduate students majoring in STEM fields explicitly, although participants did vary in their highest levels of prior math coursework. Future research should assess the associations between memories of early math experiences and current math outcomes in a more representative sample of adults.

Finally, as noted above, some of the observed differences between participants' earliest memories of math and reading may be driven in part by the open-ended prompt we used. Future research should examine domain differences in memories of early learning experiences when specific phases of learning are prompted, such as early memories for learning to do math or read independently.

Conclusion

In sum, our results provide additional evidence for the associations between early math learning experiences and later math abilities and affective beliefs. Although a singular experience with math in early childhood may be unlikely to relate to math outcomes in adulthood, similar and repeated early experiences with math may build over time to form the foundation math skills and attitudes. Researchers, educators, and caregivers should continue to promote early math experiences that are positive and engaging for young children, such as informal, playful math activities.

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Ethics Statement: The research we report was conducted in accordance with APA ethical principles and standards. The study protocol was certified as Exempt Research by Institutional Review Board of Washington State University (IRB# 19665-001).

Data Availability: The data collected in this study are not publicly available in keeping with the consent form participants signed at the onset of the study, however, additional information including summary statistics, analysis methods, and study materials are available upon request from the corresponding author.

Supplementary Materials

The Supplementary Materials contain the following items (for access, see Scalise et al., 2025S):

- Appendix A: Coding scheme definitions and examples
- Appendix B: Supplemental analyses controlling for highest level of prior math coursework

Index of Supplementary Materials

Scalise, N. R., Santiago, I. M., & Canning, E. A. (2025S). *Supplementary materials to "When we were young: Memories of early mathematics experiences"* [Online appendices]. PsychOpen GOLD. https://doi.org/10.23668/psycharchives.16455

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