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The Role of Gender on the Associations Among Children's Attitudes, Mathematics Knowledge, Digital Game Use, Perceptions of Affordances, and Achievement

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Abstract:
The purpose of this study was to explore associations among children's prior attitudes, prior mathematics knowledge, and frequency of digital game use, with children's perceptions of game affordances, and transfer to out-of-game performance when interacting with digital math games, with respect to gender. A total of 187 children (ages 8-12) participated in this study involving 12 digital math games. An SEM mediation path analysis using MPLUS software showed significant direct effects for all pathways for all children, and significant indirect effects on five of six pathways for male children and four pathways for female children. More favorable attitudes, prior math knowledge, and perception of the helping affordances was associated with increased posttest performance, while increased frequency of digital game use and stronger perception of the hindering affordances was associated with decreased posttest performance. Results specific to male children showed that prior mathematics knowledge, perception of affordances, and frequency of digital math game use were important factors relating to mathematics performance. Results specific to female children showed that prior attitudes about mathematics, prior mathematics knowledge, and perception of helping affordances were important factors relating to mathematics performance. These results suggest important relationships among positive mathematics attitudes, prior mathematics knowledge, frequency of digital game use, perceptions of in-game affordances, and out-of-game performance.

Keywords: *gender, affordance, attitude, digital games, mathematics*

The use of digital games in K-12 classrooms is becoming increasingly popular. In a survey of teachers in the USA, more than half reported using digital games in their classrooms at least once a week, with 10% using digital games every day (Jhee, 2014). Over 500,000 educational apps and games for touch-screen devices are available for download on Apple and Android devices (Larkin, 2015). Most of these apps are primarily "edutainment" and do not promote mathematical learning. However, games with affordances such as interactive properties, scaffolding supports for users, and a conceptual mathematics focus, have the potential to promote deep mathematics learning (Larkin, 2015).

Although there are a variety of research studies regarding design features in digital math games that promote learning (e.g., Hays, 2005; Vogel et al., 2006), many research studies are limited because they exclude an examination of children's attention to, and perception of these design features. Recent studies, involving digital games with virtual manipulatives, report positive effects on learning when users attend to game features and the learning opportunities the features afford (e.g., Authors 2013/2019; Kermani & Aldemir, 2016). However, these studies lack consideration of pre-existing factors that may affect this awareness, such as children's attitudes, prior mathematics knowledge, and prior experiences with digital math games. Thus, the purpose of this study was to explore the associations among three pre-existing attributes (children's attitudes, mathematics knowledge, and frequency of digital game use), children's perceptions of affordances, and transfer to out-of-game mathematics posttest performance.

Literature Review

Educators utilizing digital games in the classroom are interested in children's ability to transfer learning from the digital game context to performance outside of the digital environment to paper/pencil tests and real-world contexts. Transfer of learning between two different contexts requires high levels of abstract thinking and cognitive demand (Paek, Hoffman, Saravanos, Black, and Kinzer, 2011; Uttal et al., 2013). Children's awareness and perception of different features and affordances in digital games, as well as their prior attitudes and experiences, may influence the transfer of intended learning outcomes from digital math games to out-of-game performance.

Affordances of Digital Games

Digital games are designed with a variety of built-in features. Three different meta-analyses, reviewing a combined total of 205 studies, showed that well-designed digital games have a high potential for transfer of in-game learning to other contexts (Hays, 2005; Randel, Morris, Wetzel, & Whitehill, 1992; Vogel et al., 2006). This is likely due to the affordances for learning made available to the player through the design features of the games. Burlamaqui and Dong (2014) define affordances as "cues of the potential uses of an artefact by an agent in a given environment" and refer to possibilities that the agent has for action (p. 13). For example, *DragonBox Elements*, one of the digital math games used in the current study, has a variety of design features that may afford different learning opportunities for a child (see Figure 1).

1. Words and shape outline afford a link between the created shape and the mathematical term
2. Dragon monsters, rainforest and music afford a positive immersive environment
3. Bubbles of expected tasks afford directions for efficient interactions
4. Motivational feedback affords positive attitude for perseverance
5. Polydex (guidebook) affords additional mathematical and gaming scaffolds

Figure 1. Sample of affordances in the Dragon Box Elements digital math game.

Each design feature within the game provides a variety of potential affordances for mathematical learning when learners perceive and interact with them. For example, the white words "equilateral triangle" (Figure 1, feature 1) appear when a child traces and taps the sides of a triangle with three sides of equal length (same color = same length). This affords a link between the characteristics of the shape's sides and the words, which can promote a deeper understanding of geometric properties through visualization of the equilateral triangles (Authors, 2013).

Although all of the affordances in Figure 1 exist within the design of *DragonBox Elements*, Norman (1999) explains that there is a difference between designed affordances and perceived affordances. It is more important to understand "what actions the user perceives to be possible than what is true" (Norman, 1999, p. 39). For example, Ladel and Kortenkamp (2012) found that the aspects of gameplay in the technology with which children interacted affected their experience and out-of-game performance. In his evaluation of seven digital math games, Kosko (2017) found that the affordances of scaffolds in the digital game *CandyDepot* supported children's learning, however not all children accessed these affordances. Harrison and Lee

(2018) noted, “How these apps are used can have as large an impact on student’s learning as which app is used” (p. 168). These studies suggest that the same digital math game does not affect all children in the same way. Rather, children’s interactions with the features may play a larger role in learning transfer.

Children’s Perceptions of Helping and Hindering Affordances

Children’s perceptions of affordances can determine whether a feature is interpreted as helping or hindering. During interviews with sixth graders following their engagement with five different virtual manipulatives, McLeod, Vasinda, and Dondlinger (2012) found that children identified some of the built-in scaffolds as helping while others hindered their learning. For example one child, Elizabeth, noted, “The hint button [helped me] because then I knew what I was doing” (McLeod et al. 2012, p. 293). This scaffold was a helpful affordance in the game for her. However other scaffolds that were intended to be helpful were hindering to other students. For example, a scaffold that broke down multi-step problems into smaller pieces was hindering to several students who “could not envision how the questions were related to each other” or “was kind of too much” (McLeod et al., 2012, p. 295).

Authors (2016) also found that digital game affordances (hypothesized to help or hinder preschool, kindergarten, and second-grade children) had different effects, based on children’s personal perceptions of the affordances. For example, preschoolers who were counting blocks along with the game often recognized the simultaneous linking affordance and connected the visual image of the blocks, the symbolic representation of the number of blocks, and the auditory number name. Preschoolers who perceived this connection progressed between the pre- and post-test, which helped their performance. Conversely, other preschoolers exhibited an overreliance on the audio feedback and celebration sparkles affordances (meant to indicate a correct response). Because of the delay in the celebration sparkles, children frequently counted one too many blocks and this hindered their performance (Authors, 2017). These studies indicate that children's perceptions of the affordances may be more important than the intended design. As such, we hypothesized that perception of features and affordances, as helping or hindering, would partially mediate relationships among children's prior attitudes about mathematics, knowledge of mathematics, and frequency of digital game use and out-of-game mathematics performance.

Attitudes about Mathematics

Children's attitudes about mathematics can affect how they interact with mathematics tasks, such as those in digital games (Barkatsas, Kasimatis, & Gialamas, 2009). Lerch (2004) found that the individual beliefs and experiences of college students influenced how they approached mathematics tasks. Flores, Hinton and Strozier (2014) reported that children's attitudes about mathematics affected their willingness to participate in early intervention tasks. Children attributed their reluctance to a dislike for mathematics and poor mathematics skills. Although these two studies looked at tasks in a non-digital environment, research on digital environments has shown that more favorable positive attitudes can increase engagement. For example, Lee and Yuan (2010) found that children's attitudes about mathematics, based on gender, influenced their perception of in-app affordances. Male children focused on features of virtual manipulatives that afforded motivation and enjoyment, while female children focused on features of virtual manipulatives that afforded understanding the mathematics.

In turn, those interactions may affect learning transfer. Flores et al. (2014) found that, as children's attitudes about mathematics became more favorable, their engagement with mathematics tasks increased, ultimately resulting in increased learning. Ashcraft (2002) found that students with less favorable attitudes about mathematics had increased levels of anxiety, which disrupted their awareness of affordances and contributed to lower achievement.

Reed, Drijvers, and Kirschner (2010) found that children's general mathematics attitudes were associated with significant increases in posttest scores following an app-based mathematics intervention. The qualitative sample of four cases within their study demonstrated that children with high positive attitudes about mathematics were also more likely to exhibit an understanding of tool affordances within the apps. They recommend more research to understand the relationship between attitudes, in-app behavior, and improved learning.

Prior Knowledge of Mathematics

Children's prior knowledge of mathematics can influence how they engage with the features and affordances in a digital math game. Garris, Ahlers, and Driskell (2002) explain that children are less likely to fully engage with tasks that are too easy or too difficult; when children already have high prior knowledge of the mathematics in a game, it decreases the level of challenge and may result in boredom or disengagement. Similarly, children without a baseline understanding of the mathematics in a game may become frustrated and disengage during the game because it is too challenging (Jabbar & Felicia, 2015; Riconscente, 2013).

Several studies have noted the positive influence of children's prior knowledge on larger posttest gains after an app-based intervention for fractions (Riconscente, 2013) and for geometry (Lee & Chen, 2014). Authors (2012) also noted children's prior knowledge positively influenced perception and access of affordances in mathematics apps.

Frequency of Digital Game Use

Frequency of digital game use significantly affects children's attitudes towards technology use (Levine & Donitsa-Schmidt, 1998; Shook, Fazio, & Eiser, 2007). However, there is conflicting research regarding whether increased use of digital math games has a positive or negative effect on children's in-game experience and transfer of intended learning outcomes.

Kiili's (2006) experiential gaming model shows that children's frequent use of digital math games can promote more favorable attitudes towards technology and promote active experimentation, reflection, and construction of knowledge. Similarly, Van Eck (2015) reports that prior exposure to digital games, and digital math games specifically, can promote awareness of affordances in a novel app. Each of these studies promotes the general consensus that an increase in frequency of digital math game use would also result in an increase in awareness of feature affordances and improve posttest performance.

In contrast, Reed et al. (2010) were surprised to find that an increase in frequency of children's use of digital math tools promoted less favorable attitudes towards technology and had a negative effect on learning transfer. They compared this phenomenon to an expertise reversal effect (Kalyuga, Ayres, Changler, & Sweller, 2003). Essentially, as expertise with a tool increases, the child's ability to use the tool efficiently and objectively decreases (Guin & Trouche's, 1999). Similarly, Barkatsas et al. (2009) found that children with extremely high expertise with technology were less interested in experimenting or interacting with the mathematics learning technology. These studies promote the position that an increase in frequency of digital math game use would result in a decrease in awareness of feature affordances and posttest performance.

With the recent surge in frequency of use of educational digital math games, understanding whether this surge has positive or negative effects on learning is of particular urgency to ensure that the current generation is using technology to support learning. This study addressed this issue by examining relationships among children's prior attitudes, prior mathematics knowledge, and frequency of digital game use, with children's perceptions of game affordances, and transfer to out-of-game performance.

Gender

Many studies have examined the potential differences between male and female students regarding mathematics achievement and attitudes, and technology perceptions and access. Fennema and Sherman's (1977) early studies examining gender differences in mathematics achievement and attitudes yielded complex results with few achievement differences, but several attitudinal differences. Later studies narrowed these examinations to specific domains of mathematical reasoning, showing girls performing slightly better in computation and boys performing slightly better in problem solving later in life (Hyde, Fennema, & Lamon, 1990). As Leder (2019) noted in her historical overview of gender and mathematics education, the differences have narrowed and "there seems to be at best limited consensus on the size and direction of gender differences in mathematics performance" (p. 301). Indeed, several recent studies have shown that gender differences in mathematics achievement became non-significant when other factors were controlled. For example, Hemmings, Grootenboer, and Kay (2011) found that gender was non-significant regarding mathematics achievement after controlling for prior math knowledge and math attitudes.

Gender may also influence children's perceptions and access of features and affordances in digital games (e.g., Mendiburo, Sulcer, Biswas, & Hasselbring, 2012) as well as children's technology preferences (Jackson et al., 2008). Mendiburo et al.'s (2012) study on different types of feedback affordances found that male children preferred feedback that allowed them to ignore the affordances, unless repeatedly incorrect, whereas female children preferred feedback that encouraged less dependence on the affordances. Due to these mixed results regarding the role of gender in a variety of mathematics factors, including achievement, attitudes, affordance access, and technology use, this study included gender as a control variable on the model.

Conceptual and Theoretical Framework

The current study is informed by attitude-behavior and social-constructivist learning theories. Figure 2 illustrates how these learning theories provide a framework that informs an individualized construction of knowledge for the learner. More specifically, Figure 2 shows how this framework may relate to the learning transfer of in-game mathematics to out-of-game performance.

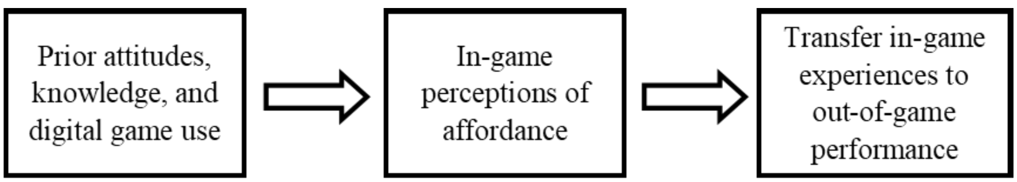


Figure 2. Framework on the Construction of Learning through Digital Math Games

Children bring their prior attitudes, mathematics knowledge, and digital game use experiences to their digital gameplay. Children's attributes can influence their in-game perceptions of features and affordances which can influence how they interact with the digital math game. In turn, how children interact with the digital math game can affect how they transfer what they learn in the game to their out-of-game performance.

Attitude-behavior learning theory posits that a child's attitudes and beliefs affect their behavior and interactions with an object or new environment, (Bagozzi & Warsaw, 1990; Fishbein & Ajzen, 1975; Fleener, 1996; Pajares, 1992). New environments can be found in digital games as well as in users' physical surroundings. Levine and Donitsa-Schmidt (1998) recommend that researchers consider the link between children's attitudes, behavioral experiences with technology, and the construction of knowledge. This is supported by current research indicating that children's attitudes can influence their perceptions of in-game features and affordances, which then influences out-of-game performance (e.g., Ashcraft, 2002; Flores et al., 2014; Lee & Yuan, 2010; Reed et al., 2010)

Research Question and Hypotheses

This study examined the following research question: When gender is taken into consideration, what are the associations among (a) children's attitudes, prior knowledge, and frequency of digital game use; (b) children's perceptions of features and affordances of digital games; and (c) children's mathematics posttest performance? Based on the literature, we developed a hypothesized model of learning transfer from digital math games (see Figure 3).

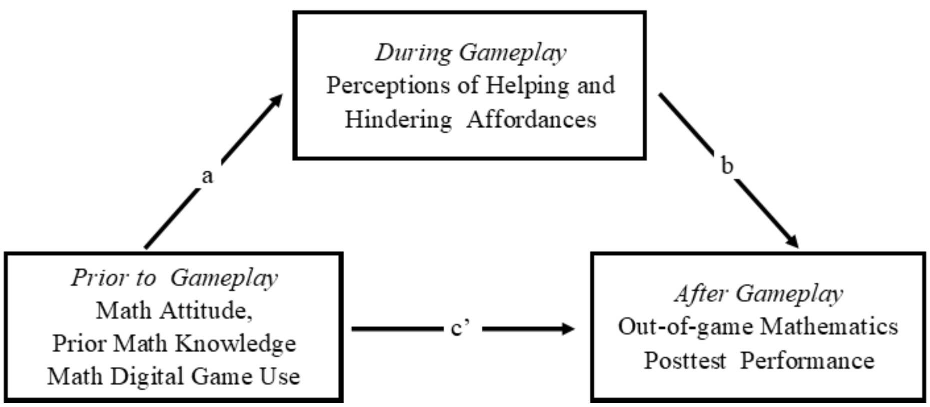


Figure 3. Hypothesized model of learning transfer from digital math games

We hypothesized that, with respect to gender, children's perceptions of helping and hindering features and affordances would partially mediate the relationship between prior mathematics attitudes, mathematics knowledge, and frequency of digital game use, and children's posttest performance. Researchers gathered three measures of children's attributes (attitudes, prior knowledge, and frequency of digital game use) *before* their interactions with the digital math games; video recorded children's perceptions of features and affordances (either helping or hindering) *during* their interactions with the digital math games; and, assessed children's mathematics performance *after* their interactions with the digital math games.

Methods

Research Design

To answer the research question, we conducted a mediation path analysis (Baron & Kenny, 1986; Hayes, 2013). This allowed us to test the significance and strength of direct (Fig. 3, a, b, c’) and indirect (Before →During→After) effects between prior mathematics attitudes, mathematics knowledge, frequency of digital game use, and feature and affordance awareness on far transfer of in-game mathematical objectives to an out-of-game posttest.

Participants

The participants in this study were 193 children (ages 8-12) recruited from local elementary schools, charter schools, and homeschool groups. Six children were removed from the study due to incomplete demographic surveys or interview transcriptions for a final *N* size of 187. Children were assigned to one of four groups based on age and grade level to reduce the likelihood of fluency with the intended in-game mathematics outcomes of the three digital games in that group, which were aligned with grade-specific intended learning outcomes (see digital math games). See Table 1 for participant demographics.

Table 1
Participants’ Self-Identified Demographics

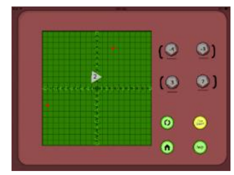
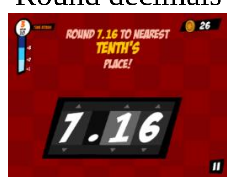
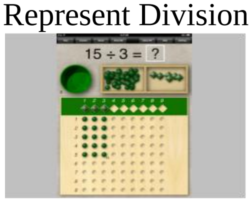
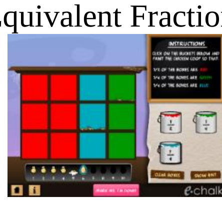
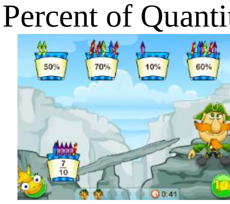
Characteristic	Overall N = 187	Group 1 N = 46	Group 2 N = 44	Group 3 N = 50	Group 4 N = 47
Gender					
Male	50.2%	58%	59%	48%	40%
Female	49.8%	42%	41%	52%	60%
SES					
Low	37%	43%	27%	34%	43%
Not Low	63%	57%	73%	66%	57%
Disability					
IEP	13%	18%	10%	9%	14%
None	87%	82%	90%	91%	86%
Ethnicity					
White	77%	77%	83%	83%	70%
Hispanic	13%	14%	7%	10%	17%
Asian	1%	2%	0%	2%	0%
Pacific Islander	1%	2%	0%	0%	2%

Other/Mixed	8%	5%	10%	5%	11%

Digital Math Games

Researchers identified 12 digital math games publicly available for purchase based on age appropriate elementary mathematics objectives that incorporated dynamic virtual manipulatives with a variety of affordances that support children's mathematics learning (Authors, 2013). Screenshots of the games by group allocation can be found in Table 2.

Table 2
Digital Math Games by Group and Intended Math Outcomes

Group 1	Group 2	Group 2	Group 4
Dragon Box Elements Recognize shapes 	Angle Asteroids Angles and Degrees 	Dragon Box Element Classify shapes 	Grid Lines Coordinate lines 
Motion Math Bounce Fraction Number Line 	Motion Math Zoom Decimal Number Line 	Math Planet P.V. Round decimals 	Motion Math Fish Add/Sub Rational 
Montessori Division Represent Division 	Chicken Coop Paint Equivalent Fractions 	Co-Ordinates Map Coordinates Q1 	Smart Pirate Percent Percent of Quantity 

Procedures

Children and their guardians signed assent/consent forms and jointly completed a demographic survey which reported each child's demographics, including their attitudes about mathematics and frequency of use of digital games. Researchers interviewed children in clinical interview rooms equipped with wall-mounted cameras and two-way mirrors. Children wore Go-Pro cameras to capture the child's hands interacting with the digital math games. Two video perspectives were used to capture a "broader view than one camera alone" (Roschelle, 2000, p. 10). Figure 4 shows an interviewer with a child in the clinical interview room.

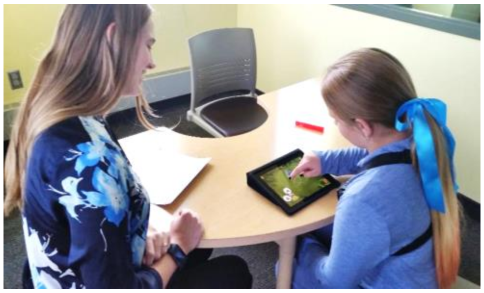


Figure 4. Interviewer and child in the clinical interview room

At the beginning of the interview, children completed a 24-question pretest based on the intended in-game mathematics in the three digital math games they played. There were six questions aligned with the intended mathematics of each of the three digital math games (6 questions x 3 games = 18 questions) and six additional control questions (24 questions total). The questions were piloted with five participants per group to test the reliability and alignment of the questions. Five questions across the four groups were revised and retested. Figure 5 provides an example of two questions from Group 1, aligned with the Motion Math Bounce game.

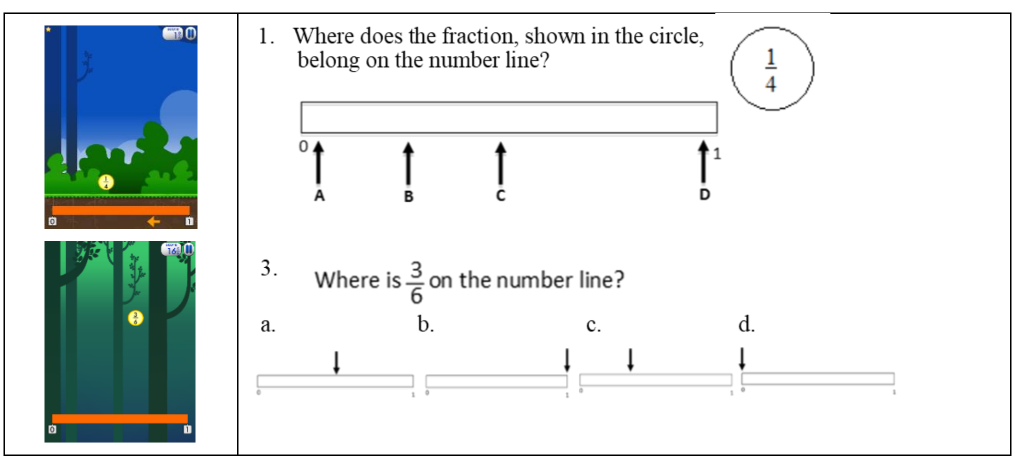


Figure 5. Mathematics alignment between games and tests.

During individual interviews, children interacted with the three digital math games in randomized order, for approximately 5-7 minutes per game. This time was determined based on piloting the games, which found that children were able to complete all levels associated with the intended mathematics objective within this time frame, while limiting fatigue from playing the games and answering questions about the games. Following a child's interaction with each game, the interviewer conducted a semi-structured interview to determine each child's awareness of game features and affordances. After interacting with all three games, children completed a posttest, which included the same questions from the pretest in a randomized order.

Measures

The five measures in this study were: children's attitudes about mathematics, prior mathematics knowledge (pretest), frequency of digital game use per week, children's perceptions of affordances and features in the games, and mathematics achievement (posttest). For the purposes of the research questions in this paper, we only looked at the pretest questions, affordance perceptions, and posttest questions aligned with the first randomized game that each child interacted with.

Frequency of digital game use per week. Researchers analyzed survey data to determine the number of days each week and hours per day children played any educational apps/digital games as well as mathematics-specific digital games. The number of days that parents/children reported the child engaged with mathematics-specific digital games per week (0-7) was multiplied by the reported hours per day (0-4) to identify the numbers of hours per week children engaged with digital mathematics games (0-28). Higher scores indicated more frequent game use.

Attitudes about mathematics. Researchers used a 7-point scale (1-7) to code survey data on children's prior attitudes about mathematics using the following open survey question: "How would you (the child) describe mathematics?". For example, a response of "I hate math, I don't get it" with parent qualification of "screaming, bawling, tantrums" was coded as a 1, "I don't like it cause it's really hard" was coded as a 2, "it's boring" was coded as a 3, "not sure" was coded as a 4, "I guess it's ok" was coded as a 5, "good" was coded as a 6, and "love it" was coded as a 7. Higher scores indicated more favorable attitudes about mathematics. Coding aligned with keywords from Alken's (1974) Enjoyment of Mathematics Scale measuring mathematics attitudes and were double coded with over 95% agreement to increase validity of the measurement.

Perceptions of helping and hindering affordances. Researchers quantitized a count of game features and a count of affordances that children verbalized as helping (0-8) or hindering (0-5), to define the mediation variables. This count was obtained in two phases. In the first phase, researchers transcribed and categorically coded (Saldaña, 2015) video data of children's interview responses to interview questions regarding features that helped or hindered them with the mathematics.. In the second phase, researchers highlighted unique perceived features or affordances within the categorical codes (helping and hindering) for ease of quantization. For example, when asked what helped him in the Angle Asteroids game, one child identified four features that helped him: "There were *things at the points that said the angle* [pointing to the axis]; There were these four lines and at the *end of each line it said the angles of those*, the lines. Then *in the back you could see the number* and then some *asteroids had the angle* that you needed to shoot, they had little numbers." When another child was asked what hindered him in the Math Planet Place Value game, he identified two negative affordances of a feature in the app that beeped every 5 seconds to indicate a loss of time bonus points: “There were a *bunch of beeps*. That is usually means you are wrong which was *making me think I was wrong* and the bunch of sounds *made it hard for me to think*.” Ten percent of the data were double-blind coded with over 95% agreement.

Prior knowledge and mathematics performance. Prior mathematics knowledge was determined using children’s scores on pretest questions aligned with the in-game mathematics objectives (0-6). Posttest Mathematics performance was determined using children’s scores on the same randomized posttest questions (0-6). Higher scores indicated better performance.

Control Variables

In order to increase the confidence in our model, we controlled for several important control variables as dictated by previous research and literature, including frequency of non-mathematical digital game use (Levine & Donitsa-Schmidt, 1998), game design (Clark, Tanner-Smith, & Killingsworth, 2016), and important demographics: age, grade level, ability, ethnicity, SES, and gender (Authors, 2012; Becker, 2000; Lee & Yuan, 2013; Sung, Shih, & Chang, 2014).

Analytic Plan

Researchers ran an SEM mediation path analysis using MPlus software (Muthén & Muthén, 2006). This path analysis allowed researchers to test direct and indirect effects of each pathway within the hypothesized model (see Figure 3) using simultaneous regression analyses (Kline, 2016; Muthén & Muthén, 2006). Control variables (i.e., non-mathematical digital game use, game design, and demographics) were regressed on the model to identify significant moderators. Model fit was evaluated with the model chi-square (χ^2), the comparative fit index (CFI), Tucker-Lewis Index (TLI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR) with a non-significant chi-square, values greater than .95 for CFI and TLI and smaller than .06 and .08 for RMSEA and SRMR suggesting good fit (Hu & Bentler, 1999). Finally, the indirect paths were tested with bootstrapping procedures at the 95% confidence interval using 2,000 samples (Preacher & Hayes, 2008).

We also tested a nested alternative full mediation model by removing direct paths from prior mathematics attitudes, prior mathematics knowledge (pretest), and digital game use to posttest performance. A chi squared difference test was used to determine which model was the better fit (Kline, 2016).

Results

The hypothesized model fit, after accounting for control variables, was acceptable according to existing conventions typically used to assess the fit of SEM models to the data (Kline, 2016): χ^2 (7) = 2.325, p = .93; RMSEA = .001 (90% CI: 0.029 to 0.041), TLI = 0.944, and CFI = .974, SRMR = .01. Table 3 shows the results from regressing control variables on the model.

Table 3.
Results of Control Variable Regression

	Helping		Hindering		Post	
Control Variable	*B*	*p*	*B*	*p*	*B*	*p*
Non-Math Game Use	-*.12*	p = 0.69	*.11*	p = 0.22	*.01*	p = 0.90
Design	*.09*	p = 0.28	*.05*	p = 0.52	*.01*	p = 0.94
Age	-*.15*	p = 0.15	-*.14*	p = 0.28	*.02*	p = 0.82
Grade Level	*.00*	p = 0.97	*.25*	p = 0.17	*.20*	p = 0.28
Ability	-*.06*	p = 0.48	*.12*	p = 0.12	*.12*	p = 0.14
Ethnic	-*.03*	p = 0.77	*.02*	p = 0.74	*.13*	p = 0.12
SES	*.10*	p = 0.46	*.11*	p = 0.50	-*.09*	p = 0.61
Gender	-*.30*	p = 0.02*	-*.08*	p = 0.21	-*.26*	p = 0.03*

As seen in Table 3, results indicated that gender was the only significant control variable. See Table 4 for descriptive statistics of the six main variables, organized by gender.

Table 4
Descriptive Statistics (N = 551)

Variables	Male (N=94)	Female (N=93)	Total (N=187)

	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Digital Game Use	5.14	5.63	0-28	5.98	6.40	0-28	5.55	6.01	0-28
Math Attitude	4.53	1.69	1-7	3.95	1.79	1-7	4.25	1.76	0-7
Helping Affordances	1.52	1.16	0-8	1.37	1.05	0-8	1.45	1.11	0-8
Hindering Affordances	0.78	0.74	0-4	0.71	0.76	0-5	0.75	0.81	0-5
Pretest	2.65	1.49	0-6	2.71	1.91	0-6	2.68	1.70	0-6
Posttest	3.21	1.66	0-6	3.53	1.94	0-6	3.36	1.80	0-6

We conducted a multiple group analysis (Kline, 2016) to test for significant differences of pathways between male and female children. Results indicated that Digital Game Use →Helping or Hindering pathways could be constrained to be equal between male and female children (did not significantly differ). However, the remaining pathways were moderated by gender, suggesting pathways between male and female children should be allowed to be freely estimated. Therefore, results are reported by gender.

Direct Effects

There were significant direct effects between all variables within the model, for both males and females. Full results for the model are shown in Figure 6.

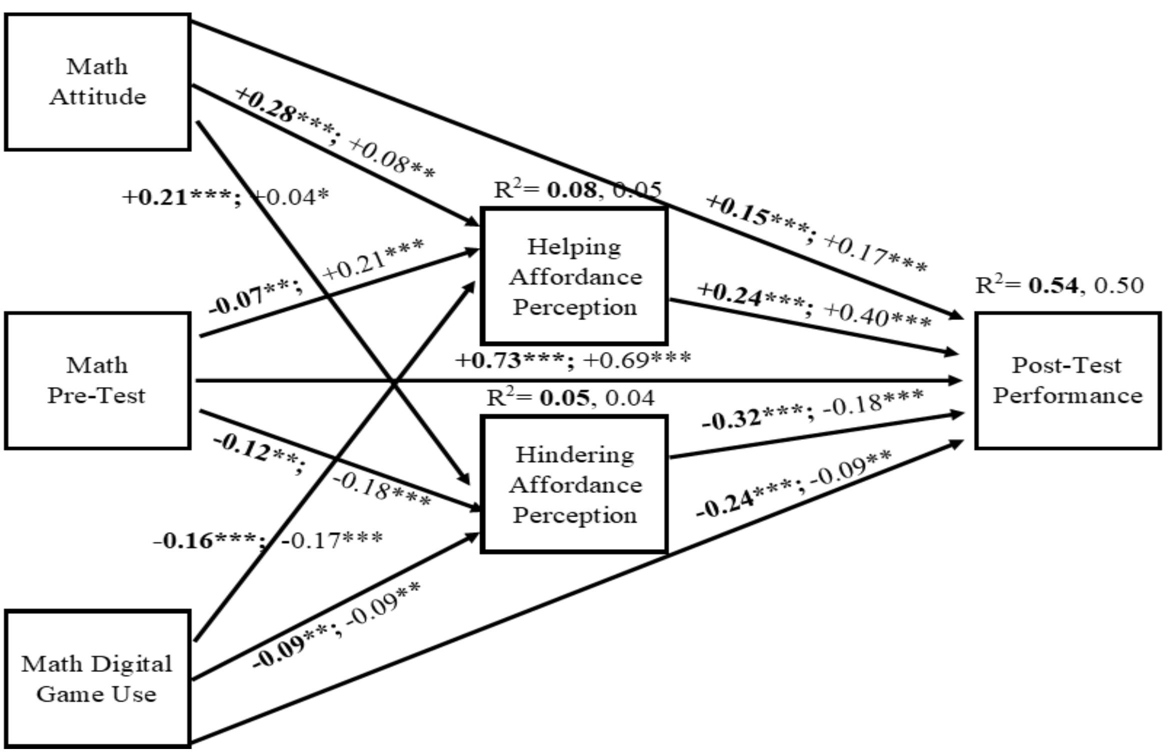


Figure 6. Model Results by Gender
Note: Standardized estimates shown. Model fit indices: χ^2 (7) = 2.325, p = 0.93; RMSEA = .001 (90% CI: 0.029 to 0.041), TLI = 0.944, and CFI = .974, SRMR=.015. *p<.05 **p<.01 ***p<.001. Male pathways are first in bolded font, female pathways are second, non-bolded.

As seen in Figure 6, more favorable math attitudes were associated with stronger perceptions of helping and hindering affordances, with greater effects for males. More favorable math attitudes were also associated with higher posttest performance, with greater effects for females. Higher pretest scores were associated with weaker perceptions of hindering affordances, with greater effects for females. Higher pretest scores were also associated with higher posttest performance, with greater effects for males. Higher pretest scores were associated with weaker perceptions of helping affordances for males and stronger perceptions of helping affordances for females. Higher digital game use was associated with weaker perceptions of helping and hindering affordances, with similar effects by gender. Higher digital game use was also associated with lower posttest performance, with greater effects for males.

Indirect Effects

Results for indirect effects indicated that children's perceptions of helping and hindering affordances mediated multiple pathways between children's prior attitudes, prior mathematics knowledge, digital game use, and posttest performance. The nested alternative full mediation model was tested and rejected based on chi squared difference tests indicating that the alternative model was not a good fit for the data (Kline, 2016). This aligned with our hypothesis that perceptions of affordances would only partially mediate the model. Table 5 shows the results for total indirect effects (product of the two direct pathways) along with the p-values and confidence intervals by gender.

Table 5
Indirect Effects of the Statistical Model

	Male	Female

Indirect Effects	β	p	95% [C.I.]	β	p	95% [C.I.]
Attitude →Help→ Posttest	.07*	.000	0.055, 0.074	.03*	.000	0.021, 0.042
Pre →Help→ Posttest	-.02*	.024	-0.057, -0.001	.08*	.000	0.077, 0.115
Game →Help→ Posttest	.04*	.005	0.004, 0.054	-.07*	.000	-0.081, -0.004
Attitude →Hinder→ Posttest	-.07*	.000	-0.071, -0.043	-.01	.051	0.000, 0.032
Pre →Hinder→ Posttest	.04*	.002	0.013, 0.068	.03*	.003	0.017, 0.049
Game →Hinder→ Posttest	.03*	.000	0.021, 0.035	.02*	.028	0.029, 0.051

Note. *Significant Indirect Paths based on *p*-value and 95% [C.I.]

As seen in Table 5, results for males indicated four significant positive indirect effects and two significant negative indirect effects. The greatest effects were the positive indirect effects of attitude on posttest performance via helping affordances and negative indirect effects of attitude on posttest performance via hindering affordances. The positive indirect effects via helping affordances can be interpreted as follows: A one standard deviation unit increase in favorable math attitude was associated with a .07 decrease in posttest performance via the prior positive effect of attitude on hindering affordances. Results for females indicated four significant positive indirect effects and one significant negative effect. The greatest effect was the positive indirect effect for frequency of prior digital math game use on posttest performance via strength of perceptions of helping affordances.

Discussion

Overall, our results supported our hypothesized model, with the full model accounting for approximately 54% of the variance for posttest performance. This indicates that relationships among children's prior attitudes about mathematics, prior knowledge of mathematics, frequency of digital game use, and perceptions of helping and hindering affordances play an important role in the transfer from in-game to out-of-game performance. Significant indirect effects indicated that children's perceptions of the features and affordances in a digital game play an important role in the relationship between children's experiences *before* engaging with the digital math games and children's learning transfer *after* engaging with the digital math games. The results of this study also bring forward considerations relating to gender differences.

Influence of Children's Prior Experiences on Intended Learning Outcomes

Results relating to children's attitudes and prior knowledge of mathematics were consistent with prior research indicating that more favorable attitudes and increased prior knowledge can support increased posttest performance after engaging with digital games (Lee & Chen, 2014; Reed et al., 2010; Riconscente, 2013). Results relating to children's frequency of digital game use add support to prior research that increased frequency of digital game use can have a negative impact on transfer of in-game to out-of-game posttest performance (Reed et al., 2010). These results also add to the literature by showing that the negative impact of the frequency of math digital game use had a greater impact on the male children in this study than the female children. This indicates that educators should carefully consider how and when digital games are used in and out of their classrooms.

Children's Perception of Helping and Hindering Affordances

Results show that children's perceptions of the features and affordances in a digital game play a significant mediating role in children's performance outcomes. The results support prior research that children's experiences *before* engaging with a digital math game may influence their perceptions about the features and affordances *during* interactions with the digital math game (e.g., Authors; Flores et al., 2014; McLeod et al, 2012; Van Eck, 2015). Specifically, more favorable attitudes towards mathematics were associated with stronger perceptions of helping affordances, which allowed students to take advantage of those affordances, thereby promoting a positive mediating effects on posttest performance. This indicates a need to promote practices that help facilitate positive perceptions and attitudes towards mathematics for young children.

The results also support previous literature that children's personalized experiences and perceptions of digital math game features and affordances influence the potential for learning transfer *after* engaging with the digital math game (Authors, 2013; Baccaglini-Frank & Maracci, 2015; Berger & Luckmann, 1966; Ladel & Kortenkamp, 2012). Importantly, children's perceptions of helping affordances had positive effects on their posttest performance, with stronger effects for female children. In contrast, perceptions of hindering affordances had negative effects on posttest performance, with stronger effects for male children. To support children in becoming aware of helping mathematical features and affordances in a game, classroom educators may want to bring awareness to specific affordances within the games to focus on how they support the intended mathematics (Falloon, 2014). This could be accomplished through an introduction or debrief where educators highlight specific connections between the features and affordances and the intended mathematics (Bakker et al., 2015).

Considerations Relating to Gender Differences

Results indicated that, all factors related to performance outcomes after interacting with a digital game showed differences between male and female children in the study. For example, the model showed stronger connections for male children between frequency of digital game use, prior mathematics knowledge, and hindering affordances to the posttest; while female children showed stronger connections between attitude and perception of helping affordances to the posttest. This contrasts prior research showing non-significant differences (e.g., Hemmings et al., 2011; Leder, 2019). Differences in the mediating effects of children's perceptions of affordances on the relationship between children's prior experiences and posttest performance are of particular importance for educators when selecting digital games.

As male children's prior mathematics knowledge increased or frequency of digital game use increased, their perceptions of affordances decreased. The lack of engagement due to decreased perception of affordances also decreased access to the positive mediating effects of helping affordances within the game and on the out-of-game posttest for male children. One explanation for these negative results could be that male children experienced boredom due to expertise with either the mathematics content or the gaming format of the digital games. Research shows that children are less likely to fully engage with tasks that are too easy or too difficult (Garris et al., 2002; Jabbar & Felicia, 2015; Riconscente, 2013).

In contrast, as female children's mathematics knowledge increased, their perceptions of helping affordances also increased which allowed them access to the positive mediating effects of helping affordances within the game and on the out-of-game posttest. Additionally, as female children's prior mathematics knowledge increased, their perceptions of hindering affordances decreased, mitigating the negative mediating effects of perception of hindering affordances on posttest performance.

These results indicate the need for educators to carefully consider the level of challenge when selecting games for male and female children in their classrooms. When selecting digital math games for male children, educators may want to consider novel digital games that provide a higher level of challenge in relation to prior mathematical content knowledge, such as those that extend learning to new representations or higher order thinking. In contrast, when selecting digital math games for female children, educators may want to consider digital games that provide a level of challenge that aligns with children's prior mathematical content knowledge, such as those that help solidify the content and representations or those that contain scaffolds that will reduce their dependence on the affordances (Mendiburo et al., 2012).

Strengths, Limitations & Future Research

Strengths. One of the strengths of this study is that it looks across multiple grade levels to support the generalization of previous, grade level specific, research with digital math games. Additionally, this research adds to the field of current knowledge on children's interactions with digital math games by looking at children's perceptions of helping and hindering affordances as well as prior attributes and gender, which may help to explain some of the performance outcome discrepancies in prior research on digital games. By identifying factors associated with increases and decreases in intended learning outcomes, these results may help to explain inconsistencies in prior or future studies on digital math games.

Limitations and future research. The results of this study should be considered in light of several limitations. First, it is important to note the amount of time children spent with the digital math games. In this study, each game was played for about 5-7 minutes. Although this was enough time for children to complete all game levels associated with the intended learning outcomes, these results are not generalizable to longitudinal effects of game interaction. Future research should replicate our findings using longer game interactions.

Second, these results are limited to majority white populations in suburban and rural-urban areas, and as such cannot be generalizable to other heterogeneous populations or regions. Future research using more heterogeneous samples is recommended to extend understanding of the mediating relationship of design features and affordance awareness.

Finally, most of the current research regarding gender differences in gaming is focused towards online entertainment gaming (e.g., Vermeulen, Loy, De Grove, & Courtois, 2011;

Richard, 2013). A review of the digital math games that were listed by children on their surveys reveals that the majority of games children frequently used were multiple-choice practice games (e.g., Splash Math), designed to increase mathematics fact fluency through repetition. All of the digital games in this study included dynamic virtual manipulatives (Authors, 2016), with only two of the games in this study including multiple-choice options as part of the game. The structural differences between the games the children used previously and the games in this study may have created conflicting schemes, which could explain the differing results (Kalyuga et al, 2003; Sweller, van Merrienboer, & Paas, 1998). However, a causal understanding of the negative relationship between the frequency of prior digital game use and learning transfer, as well as possible connections between the results and frequency of practice-focused digital games were beyond the scope of this study.

Conclusions

In summary, children's experiences such as prior attitudes about mathematics, prior mathematics knowledge, and frequency of digital game use play an important role in how children engage with digital math games and the transfer of learning to out-of-game performance. Perceptions of helping affordances had significant positive direct and indirect effects on children's mathematics out-of-game performance. Thus, it is important for educators to bring forward helping features and affordances in digital games to support children's learning, monitor how and when digital games are used, and perpetuate a positive cultural attitude about mathematics.

Results relating to gender illustrate the importance for educators of carefully selecting digital games that provide an optimal level of challenge. Male children may benefit more from novel games that provide high levels of challenge, while female children may benefit more from games that offer levels of challenge that solidify or reinforce prior knowledge.

In conclusion, this study confirms prior qualitative and quantitative research on specific paths within the full model, while also providing a larger picture of the complex relationships among attributes children bring with them to their gameplay, perceptions of in-game affordances, and out-of-game performance. Additionally, it poses directions for future research relating to gender differences, children's perceptions of affordances, and types of digital math games children engage with at home and in classrooms.

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