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Mother-Child Synchrony is High Across Child Executive Function Levels for both Physical and Digital Spatial Play

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Abstract

Play is a powerful influence on children's learning and parents can provide opportunities to learn specific content by scaffolding children's play. Parent-child synchrony (i.e., harmony, reciprocity and responsiveness in interactions) is a component of parent-child interactions that is not well characterized in studies of play. We tested whether children's executive function relates to mother-child synchrony during physical and digital play in sixty mother-child dyads. Mother-child synchrony did not relate to children's executive function or differ by play type (physical, digital), though during digital play mother-child synchrony was higher for girls relative to boys. The findings suggest that mother-child synchrony is not influenced by children's executive function and physical and digital play can be similarly beneficial in offering the opportunity for responsive, reciprocal, dynamic interactions. The sex difference suggests that further factors should be explored as influences of play synchrony.

During early childhood, play is one of the most powerful influences on children's learning (e.g., Hughes, 2010; Zosh et al., 2017; Yogman et al., 2018). The interactive and constructive nature of playful experiences is especially effective in promoting learning and development (e.g., Singer et al., 2006; Vygotsky, 1967; Weisberg et al., 2016). Quality of play is important (e.g., Levine et al., 2012) and parent interactions and engagement contribute to the quality of children's play (e.g., Broadhead et al., 2010). Parent scaffolding during play can support young children's learning (e.g., shape and color names; Ferrara et al., 2011; Verdine et al., 2019; Zosh et al., 2015), and can promote more basic cognitive skills (e.g., spatial thinking and executive function; Rogoff, 1990). It is important, then, to understand what factors might relate to positive interactions during play.

We explore whether two possible factors relate to the quality of parent-child interactions: children's executive function (EF), and whether play takes place as a physical or digital activity. We extend prior work by looking at a dynamic measure of parent-child interactions, synchrony, which involves responsiveness and harmonious interactions (Feldman et al., 1999; Feldman, 2015a). Because synchrony is found to be associated with EF in non-playful interactions (Davis et al., 2017) and EF relates to children's play behaviors more generally (e.g., Berk & Meyers, 2013; Hughes & Devine, 2019; Kelly et al., 2011), we were interested in how EF would relate to parent-child synchrony during play. Further, because children's play is becoming increasingly digital (i.e., screen-based; Rideout & Robb, 2020), and differences have been observed between parent-child play with physical and digital activities (e.g., Griffith & Arnold, 2019; Lee & Wood, 2021; Schnieders & Schuh, 2022), we were also interested in whether parent-child synchrony would differ between physical and digital activities.

Parent-Child Synchrony During Playful Interactions

Many types of play involve parent-child interactions. For example, parents provide high levels of support and engagement during free play with their children (Vandermaas-Peeler et al., 2009). Adding scaffolding by an adult towards a specific learning goal or objective during child-driven play might enhance these interactions (Weisberg et al., 2013; Weisberg et al., 2016; Zosh et al., 2018), creating play that falls somewhere between unstructured free play and adult-driven instruction (Weisberg et al., 2016). Integrating adult guidance within child-driven play can provide important scaffolding for learning (Wood et al., 1976; Vygotsky, 1978; Mermelshtine, 2017). Rather than classifying and comparing types of play (e.g., free play vs. guided play), this study explores factors expected to be associated with the quality of playful interactions. Some research has explored this by focusing on parent input as scaffolding that can support children's learning (e.g., Aspland & Gardner, 2003; Schnieders & Schuh, 2022). For example, adults can use content-focused language and gestures to promote specific types of learning, such as spatial learning (e.g., Cartmill et al., 2010; Ehrlich et al., 2006; Pruden et al., 2011; Szechter & Liben, 2004). We extend this prior work by using an approach of studying mother-child interactions that considers the quality of interactions during play in a more dynamic way: mother-child synchrony.

Parent-child playful interactions are bidirectional and contingent, and this dynamic nature of parent-child interactions during play makes them both reciprocal and transactional, referred to as synchronous (van Geert & Steenbeek, 2005). Like other indicators of play quality, parent-child synchrony is associated with positive outcomes for children (e.g., Feldman, 2015a; Harrist & Waugh, 2002). For example, a meta-analysis of studies on parent-child synchrony (i.e., level of harmony, reciprocity, and responsiveness in interactions), showed positive associations between parent-child synchrony and both concurrent and prospective self-regulation in children (Davis et al., 2017). Parent-infant synchrony is a biobehavioral mechanism that supports children's social growth, seems to be relatively stable (Feldman, 2015b), and facilitates self-regulation (Atzil et al., 2018). Higher levels of reciprocal parent-child interactions early in development are associated with adolescent adjustment (Feldman, 2010), suggesting that there are long-term benefits of early synchronous interactions. Thus, it is important to understand what factors relate to positive synchronous interactions between parents and children.

Many studies have shown the importance of parent-child synchrony in preschool children, though some have also explored this synchrony in slightly older children during parent-child conversations (e.g., Criss et al., 2003; Hinnant et al., 2013). Because young children spend much of their time engaged in play, and play is an ideal format for their learning, more research is needed to understand the factors associated with positive synchronous interactions during play. We explore two of these factors: the relation between children's executive functions and mother-child synchrony during play, and differences in mother-child synchrony when engaging in physical and digital play activities. We explore interactions during spatial play specifically, which research has consistently shown to be associated with spatial development (Jirout & Newcombe, 2015; Verdine, Golinkoff, et al., 2014; Verdine et al., 2016) and is a context in which parent-child interactions hold particular importance (e.g., Pruden & Levine, 2017; Levine et al., 2012).

Executive Function and Parent-Child Synchrony during Play

Executive function refers to a set of cognitive processes that underlie self-regulatory thoughts and behaviors, generally broken into three categories: inhibitory control, working memory, and cognitive flexibility or attention (see Diamond, 2013). These capacities are also collectively referred to as behavioral regulation or self-regulation (McClelland et al., 2007; Ponitz et al., 2008). EF is crucial for academic skills and predicts math and literacy abilities (e.g., Blair & Razza, 2007; Duncan et al., 2007). EF is also related to spatial reasoning, which underpins other STEM domains (Verdine, Irwin, et al., 2014). The relation between EF and play is unclear, with mixed findings in correlational and experimental studies (see Lillard et al., 2013). Both physical and digital play are frequently suggested to be promising means of supporting the development of EF (e.g., Coelho et al., 2020; Kulman et al., 2014; Yogman et al., 2018), with interventions presented as play or games possibly having a specific benefit for developing EF in children with initially lower ability (Flook et al., 2010). However, it is also likely that EF could influence children’s play, potentially through its influence on parent-child interactions (Blair et al., 2014; Merz et al., 2017). Thus, it is possible that there are bidirectional associations between EF development and parent-child interactions during play (i.e., child EF influences parent-child interactions, and parent-child interactions influence child EF). Examining the association between EF and synchrony in mother-child interactions was the first aim of this study.

Spatial play was chosen as the context to study synchrony of parent-child interactions, and we provided an optional guided play activity that the dyads could engage in if they chose to, as guided play may encourage both parents and children to play a role in promoting playful learning (Weisberg et al., 2016). During play, interactions are not unidirectional; synchrony between parents and children is driven by the reciprocal nature of the parent-child interactions and is most effective when parents' behavior and language is responsive to children's needs and actions (Davis et al., 2017). Executive function, including children's ability to control their behavior and keep their goals in mind, likely influence their interactions during play (Berk & Meyers, 2013; Kelly et al., 2011). The play context allows children to exercise their developing executive function skills and provides opportunities for parents to support these skills by directing their attention, supporting them during frustration, promoting inhibitory control or cognitive flexibility, and practicing co-regulation (Bernier et al., 2010; Bibok et al., 2009; Hammond et al., 2012; Hughes, 2019; Landry et al., 2002). For example, when their child is frustrated, a parent may help co-regulate their emotions through responsive support, thereby providing synchrony, or simply complete the frustrating task themself, which may relieve the frustration, albeit in a less synchronous way. Indeed, EF has been shown to serve as a mediator between parental scaffolding during play and children's academic ability (Devine et al., 2016). Thus, it is possible that children's general EF is associated with parent-child synchrony during play, but to our knowledge no studies have yet explored this.

In addition to parent-child interactions being associated with EF, there is evidence that digital play may provide opportunities for exercising executive function skills (e.g., Moron et al., 2022; Plass et al., 2019; Rachanioti et al., 2018; Yang et al., 2020). Although executive function can be negatively affected by children's screen media use (e.g., McHarg et al., 2020), particularly when viewing adult-directed or children's entertainment television (e.g., Barr et al., 2010; Lillard & Peterson, 2011; Nathanson et al., 2014), actively engaging with an app on a touchscreen device seems to be different from passively viewing videos on a screen (Huber et al., 2018; Li et al., 2018). Two- and three-year-olds who played with an educational app showed better working memory and delay of gratification afterward compared to those who watched television (Huber et al., 2018). Similarly, Li et al. (2018) found no depletion of inhibitory control in 4- and 6-year-olds after interacting with an app, whereas watching a video decreased inhibitory control and resulted in higher activation of the dorsolateral prefrontal cortex (dlPFC), indicating that watching the video demanded more cognitive resources than playing with the app. These studies examined EF during solo media engagement, but EF may also relate to how children and parents engage with media together and relate to the presence or absence of synchrony in their interactions.

Parent-Child Synchrony during Physical and Digital Play

Physical spatial toys, like blocks, puzzles, and shape sorters, are common across socioeconomic levels and support children's "spatial education" (Verdine, Golinkoff, et al., 2014). Spatial play is also a popular theme for digital games, with the spatial games *Tetris* and *Minecraft* currently the two top-grossing computer games of all time (Peckham, 2016). As digital devices are increasingly used for children's educational and entertainment needs (Rideout & Robb, 2020), it is important to understand how parents and children engage together in digital play. Digital play may afford important opportunities for learning (e.g., Berkowitz et al., 2016; Huber et al., 2016; Moron et al., 2022), particularly with a social partner, who can scaffold the experience and provide feedback (Eisen & Lillard, 2020; Hirsh-Pasek et al., 2015; Zimmerman et al., 2017; Zippert et al., 2019). Much of children's time playing digital games like *Minecraft* involves social play (Mavoa et al., 2018), with parents of children under eight consistently engaging to some capacity during children's digital play (Nikken & Schols, 2015). However, play quality is sometimes lower during engagement with digital games or electronic toys, for example less frequent and lower quality parent language (e.g., Verdine et al., 2019; Zosh et al., 2015). During play, parent-child interactions vary across dyads, with parents capable of making different types of roles for themselves, but this has been found to be more challenging during digital than physical play (Hiniker et al., 2018), so it is possible that parent-child interactions might differ between different formats of play.

Limited research has directly compared parental scaffolding during physical and digital play, but some differences have been observed in favor of physical play (Lee & Wood, 2021; Schnieders & Schuh, 2022). In one recent study, parents showed higher responsiveness to children when interacting in a physical play condition compared to digital play, but the two conditions involved somewhat different activities, and the measures were focused specifically on parents' behavior (Lee & Wood, 2021). In a similar study, researchers used an identical math game to compare parent-child interactions during physical and digital play and observed more parent scaffolding in the physical version, but they again focused on parent and child behavior separately (Schnieders & Schuh, 2022), as much prior research has (see Ewin et al., 2021b for a review on research on parent-child joint media engagement). Because digital games like *Minecraft* may offer rich opportunities for parents and children to interact with each other during play (Ellison & Evans, 2016; Lane & Yi, 2017) and even support family bonding (Wang et al., 2018), it is necessary to examine factors that could promote high-quality synchronous interactions during play, which we did using physical and digital versions of similar tasks.

Current Study

Prior work suggests that parent-child engagement in spatial play contexts can promote learning and development (e.g., Eason & Ramani, 2020; Ferrara et al., 2011). The aim of this work was to explore factors associated with this type of engagement by examining parent-child synchrony during digital and physical play to assess whether 1) EF is related to positive synchrony of these interactions and 2) whether synchrony differs between physical and digital activities. We chose to explore these questions in children ages 5-6 years old engaging in spatial play activities. To our knowledge, no study has looked at the relation between children's executive function and parent-child synchrony during play in children over age 4, despite this being a developmental period when adult interactions during play can be very beneficial for learning (Ferrara et al., 2011; Fisher et al., 2013; Weisberg et al., 2013). At this age, children's spatial reasoning skills develop extensively (Vasilyeva & Lourenco, 2012), and they spend an increased amount of time with digital devices (Rideout & Robb, 2020). There is strong potential for both physical and digital play to benefit learning and, with responsive scaffolding, parent-child synchrony during play interactions could support higher quality of play. Due to the novelty of our questions regarding parent-child synchrony, there was not sufficient support for directional hypotheses.

Material and Methods

Participants

Sixty children (M = 71.3 months, SD = 7.4 months; 30 female) and their mothers participated in the study. Race and ethnicity information for child participants was collected from the mothers; 10% did not report race and of the remaining participants, 74% were White, 15% were biracial or multiracial, 7% were Black, 2% were Asian, and 2% were Native Hawaiian or Pacific Islander. For ethnicity, 15% did not report; of the remaining participants, 94% were non-Hispanic and 6% were Hispanic. Mothers provided written consent and children provided verbal assent to participate, in line with the study’s approval from the University of Virginia’s Institutional Review Board.

Measures

Executive Function. Executive function was measured with Head, Toes, Knees, Shoulders (HTKS), which was chosen because it is a reliable and valid measure of behavioral regulation for this age range (McClelland et al., 2007; Ponitz et al., 2008). In this task, children must inhibit a dominant response and provide an alternative, correct response. The task also requires children to shift flexibly between different rules and use working memory to keep task demands in mind. First, children were taught that when asked to touch their head, they must touch their toes, and vice-versa. They were subsequently tested on 10 trials, with 2 points awarded for each correct response and 1 point awarded if they began to respond incorrectly but then corrected themselves (20 points possible). If children passed this level by receiving at least 10 points, they moved on to the next level which involved 10 trials with a new pairing (knees-shoulders) added to the previous one (head-toes). If children scored at least 15 points on the second level, they moved on to a final level of 10 trials in which the pairings were switched (head-knees, shoulders-toes). Total scores ranged from 0 to 60.

Verbal Ability. Verbal ability was assessed with the Receptive Vocabulary subtest of the WPPSI-IV (Wechsler, 2012). In this test, children must select the correct image out of an array of four that best represents a vocabulary word read aloud by the experimenter. Scores ranged from 0 to 31.

Parent-Child Synchrony. Parent-child synchrony during both digital and physical play was measured using an adapted version of the *Positive Synchrony* scale, a macro-level observational coding system for dyadic interactions (Criss et al., 2003). In the original scale, each coded interaction is assigned a single value between 1 and 9 according to detailed criteria regarding the dyad's level of engagement, reciprocity, and responsiveness. We used an 8-point version of the scale because we expected that two of the original scale points (7 and 8) were too similar to yield reliable differences in the context of the current study. In the revised scale, lower scores (1-4) were given to dyads who interrupted or ignored each other, made critical comments, were dominated by one dyad member, and/or otherwise were not attuned to one another. For instance, if a child played with blocks while their parent looked through example photos, and neither attempted to interact with the other or comment on what the other was doing, that dyad would receive a rating of 1. Higher scores (5-8) indicated balance, shared affect such as laughing or mutual surprise, and/or responsiveness to each other's affect and cognitions. A dyad in which parent and child took turns, responded to each other's actions and comments, and commented on the other's thoughts and feelings (instead of just what they were building) would be rated as an 8.

The synchrony measure was used to code 120 videos of parent-child playful activities (one physical play and one digital play for each of the 60 dyads). The 120 videos were split into the first five-minute and the second five-minute segments to be coded separately, resulting in four segments per dyad (first/second half of digital play, first/second half of physical play). Two trained research assistants coded videos for each dyad, with excellent reliability (ICC .90 - .93). In the case of coder disagreement, final codes were derived from the average of both coders' ratings and the first and second videos were averaged for the synchrony scores. There were no differences between the first and second five-minute segments ($p = .259$), so we averaged them into a single score. Additionally, while most of the 120 videos were 10 minutes long, they ranged in length from 3 minutes, 30 seconds to 11 minutes, 41 seconds ($M = 9.96$ minutes). To ensure that video length was not a confounding factor, we repeated the analyses without the 6 videos that were shorter than 10 minutes and confirmed that all reported results remained the same, so we report results from the full sample of videos below.

Parent Questionnaire. Mothers completed a questionnaire asking about their child's play experience related to the materials in the current study. Specifically, we asked parents whether their child had ever played digital Minecraft or with physical Minecraft blocks, and about frequency of play with blocks and touchscreen devices (response scale included the following options: once a month or less, several times a month, once a week, several times a week, once a day, several times a day). These questions were asked within a list of other playful activities in data acquired for a dissertation project (see Eisen, 2020).

Procedure

Mother-child dyads came into the laboratory for two play sessions one week apart and engaged in two forms of interactive play: physical and digital. Dyads engaged in one form of play (physical or digital) at the first session and engaged in the other at the second session, with the order of activities counterbalanced across the sample. Digital play involved the app *Minecraft* presented on a 1st generation Apple iPad Air, whereas physical play involved a set of physical *Minecraft* blocks produced by Mattel, Inc. to resemble the different blocks in the *Minecraft* app. *Minecraft* was chosen as the activity because it is a highly popular digital game (Peckham, 2016) in which players build environments out of individual blocks. Although *Minecraft* has several play modes, for this study we used only the Creative Mode wherein players have unlimited blocks with which to build. For the physical play activity, participants were provided with 60 plastic one-inch blocks and an 8 inch by 13 inch plastic base onto which the blocks fit. For both the digital and the physical activities, participants were also given 20 laminated images of block structures built in the *Minecraft* app that they could attempt to replicate, if desired.

Dyads were video recorded while they played with both the physical and digital activities. Before they began, the experimenter explained how to manipulate the blocks and move around the environment on the app or the physical base. After being instructed on the materials, dyads were given the images of block structures and were told that they could attempt to replicate them or build anything they wanted. Videos were later coded using the synchrony measure described above. Children's executive function was measured at the first session while mothers filled out the questionnaire and receptive vocabulary was measured at the second session. Importantly, both were assessed before the parent-child play activity. This study involved additional measures and activities as part of dissertation research that is not included here.

A repeated-measures ANCOVA was implemented to test the associations between parent-child synchrony and EF and play format. Although the parent-child dyads were the focus of our study, our measure of interest results in a single score based on the observations of play for each play type. Accordingly, the synchrony score during physical vs. digital play was analyzed as a within-subject variable, and child EF, age, and gender as between-subjects variables.

Results

Performance across tasks

All mother-child dyads completed both study sessions (physical and digital play). Children's scores on the HTKS ranged from 0 to 60, with a mean of 40.6 (SD = 16.6).

Average synchrony ratings (collapsing across digital vs. physical play) ranged from 3 to 7.75 on the 8-point scale, with a mean of 5.2 (SD = 1.0). Table 1 shows correlations between age and other variables and Table 2 shows results of independent *t*-tests of differences between boys and girls. We include age and gender in subsequent analyses, as both showed associations with EF (see age in Table 1, gender in Table 2). Since receptive vocabulary was not of interest to the study and did not relate to any other variables of interest, we do not include it in further analyses.

Table 1

Pearson Correlations Between All Measures

Variable	Age	Receptive vocabulary	EF (HTKS)	Physical play synchrony
Receptive vocabulary	.111 $p = .224$			
EF (HTKS)	**.456** $p < .001$	.126 $p = .337$		
Physical play synchrony	-.003 $p = .980$	.067 $p = .611$	-.058 $p = .662$	
Digital play synchrony	-.047 $p = .726$	.177 $p = .180$	-.010 $p = .942$	**.479** $p < .001$

Note. Receptive vocab (RV) and EF were slightly non-normally distributed (skewness = -0.69 for RV and -1.06 for EF; Kendall's Tau-B correlations showed the same relational patterns.

Our primary research questions were 1) whether mother-child synchrony is associated with children's EF and 2) whether mother-child synchrony differs during physical versus digital play. In this within-subjects design, parent-child dyads played with both physical and digital materials, so we ran a repeated-measures ANCOVA. To test for a relation between EF and mother-child synchrony during play, we included the independent variable of child's EF score as a covariate, as well as including age as a covariate and gender as a fixed effect, and synchrony scores for each play type (physical vs. digital play synchrony) was the repeated-measures dependent variable to assess the difference between the play types. We observed no significant main effects of EF ($F(1,55) = 0.577$, $p = .451$; $h_p^2 = .010$), age ($F(1,55) = 0.022$, $p = .883$; $h_p^2 = .000$), or gender ($F(1,55) = 3.307$, $p = .074$; $h_p^2 = .057$) on play synchrony, and the difference between synchrony scores for physical and digital play did not differ ($F(1,55) = 0.052$, $p = .821$; $h_p^2 = .001$). However, we did observe a significant gender X play type interaction ($F(1,55) = 4.277$, $p = .043$; $h_p^2 = .072$).

Table 2

Results of Independent t-tests of Gender Differences

	Girls		Boys		*t*-value	*df*	*p* – value
	M	*SE*	*M*	*SE*			
Age	71.91	1.3	70.64	1.4	0.65	58	.516
Receptive vocab	21.93	1.1	19.73	1.2	1.40	58	.176
EF (HTKS)	45.37	2.1	35.80	3.6	2.308*	47.42*	.025
Physical play synchrony	5.72	0.2	5.63	0.2	0.29	58	.775
Digital play synchrony	5.23	0.2	4.44	0.2	2.63	57	.011

Note. Two-sided *p*-values reported.

*Corrected for unequal variances based on Levene's test, $F = 14.45$, $p < .001$

To explore the gender X play type interaction, we conducted two univariate tests, one for each play type, with synchrony score as the dependent variable, EF and age as continuous covariates, and gender as a between-subjects factor. When playing with physical toys, mother-child synchrony did not differ between boys and girls and their mothers (blocks *M* boys = 5.59, SE = .23; *M* girls = 5.75, SE = .23; $F(1,56) = 0.207$, $p = .651$; $h_p^2 = .004$). During digital play, mother-daughter play synchrony was significantly higher than mother-son synchrony (*Minecraft M* boys = 4.41, SE = .22; *M* girls = 5.27, SE = .22; $F(1,55) = 7.410$, $p = .009$; $h_p^2 = .119$).

As described earlier, parents were surveyed about their child's typical play experience. To further explore the observed gender difference, we ran exploratory post-hoc comparisons of gender differences in mother-reported experience with materials related to those used in this study using Chi-Square tests. Only 14 children in the current study had prior *Minecraft* experience and boys were overrepresented in this group (10 boys vs. 4 girls; $\chi2 = 3.35$, $p = .063$). Boys were also overrepresented in prior experience with physical Minecraft blocks as well (3 boys vs. 0 girls; $\chi2 = 3.16$, $p = .076$). Further, while most parents reported their children played with blocks, frequencies of playing with blocks often (more than once per week) was reported significantly more for boys (80%) than girls (30%; $\chi2 = 15.15$, $p < .001$), which is consistent with prior research (Jirout & Newcombe, 2015). Boys and girls had similar levels of play with touchscreens, with frequencies of playing often (more than once per week) reported as 50% for girls and 57% for boys ($\chi2 = 0.27$, $p = .605$).

Discussion

The current study assessed whether children's executive function relates to the level of mother-child synchrony observed during digital and physical play with comparable materials. While there are potential benefits of various types of play for different components of learning and development (Schlesinger et al., 2020; Singer et al., 2006; Hirsh-Pasek et al., 2004), further research is needed to better understand the specific role of adult-child interactions as a mechanism to support learning from play. One reason play can promote learning is that it involves constructive engagement with ideas and information, and interactions that support this engagement through responsiveness and reciprocity provide an even deeper level of cognitive engagement (Chi & Wylie, 2014). Parents can guide play through responsive interactions that support learning (e.g., Weisberg et al., 2016), but importantly, the quality of such play matters (Levine et al., 2012). We explored whether two potential factors were related to play quality, defined here as mother-child synchrony: children's level of executive function (EF) and whether play takes place as a digital or physical activity. Mother-child synchrony was independent of children's EF and was similarly positive between play types, though mother-child synchrony was higher for girls than boys during digital play but not physical play. We discuss these results within the context of prior literature, identify limitations of the current study, and highlight future directions for research on this topic.

Executive Function

The first factor we explored as a potential factor related to mother-child synchrony during play was children's executive function skills. Prior work has found that mother-child interactions may influence children's EF (Merz et al., 2017), and that EF mediates the association between parent interactions and academic performance (Devine et al., 2016). Less is known about the association between children's EF and parents' responsiveness during play, though parents do adjust their scaffolding during play interactions based on children's domain-specific cognitive abilities (Ji, 2019). As discussed above, highly structured activities with explicit goals could rely strongly on working memory to keep those goals (and any rules of the task) in mind and maintain inhibitory control over behavior that does not relate to the goals. Alternatively, less-structured play offers a more open-ended context to interact, during which there is no 'right way' of doing something, the goals are undefined and driven by children's interests, and parents expect their children to lead. These factors allow children to act independently during play, so there may be little reliance on inhibitory control or working memory and create opportunities for parents to adjust their scaffolding to the child's needs. Arguably, the play contexts in our study were less-structured because mother-child dyads were invited to build whatever they wanted, although they were given example structures they could choose to replicate. This may explain why we observed no association between the child's EF and mother-child synchrony, because children were able to play freely, and parents were not expected to redirect them.

Physical and Digital Play

Our second factor of interest was whether play took place using physical materials or a digital app. The lack of an observed difference in mother-child synchrony between physical and digital play suggests that both play types can be similarly beneficial by offering opportunities for responsive, reciprocal, and dynamic interactions. This is important, as parents rate physical spatial play as having much higher educational value than digital play, and these beliefs can influence their children's play experiences (Eisen et al., 2021; Lauricella et al., 2015). Although parents differ in their beliefs about the educational value of types of play (i.e., physical play as more educational; Eisen et al., 2021), our results show that the synchrony of interactions during play is not different between physical and digital play. This is in contrast to other recent research (Lee & Wood, 2021; Schnieders & Schuh, 2022) but could be at least partially due to the fact that the Minecraft game didn't involve any audio that might have replaced mother-child communication or game features that provided strong responsive scaffolding (Ewin et al., 2021a), and also because there were few restrictions to the game design that could reduce co-play interactions (Hiniker et al., 2018).

Surprisingly, we observed a significant gender difference in mother-child synchrony for digital play (*Minecraft* app), with higher synchrony among mother-daughter dyads than mother-son dyads, but this was not observed for physical play (*Minecraft* blocks). This stands in contrast to prior research on parent-child language, in which gender differences observed in interactions favor boys, with parents using more unique spatial words with boys than girls (Pruden & Levine, 2017) and more spatial talk during spatial play specifically (Verdine et al., 2019). However, Ferrara and colleagues (2011) observed no gender differences in parents' language during spatial play. The lack of difference in the current study between genders during physical play could be because our measure of synchrony is based on the dynamic, reciprocal nature of mother-child interactions and not the specific language used.

Recent work suggests that both parents and children do not report gendered beliefs about preferences for or ability related to digital play (Eisen et al., 2021), but the gender difference observed in the current study for parent-child synchrony during digital play could be related to the specific game used in this study, *Minecraft*. As reported in our exploratory analyses, boys were more likely to have had prior *Minecraft* experience, which is consistent with prior research (Mavoa et al., 2018). However, they were also more likely to have higher levels of prior experience with physical blocks and the *Minecraft* physical blocks specifically, so prior experience alone can’t explain this gender by play type interaction. Girls perform similar to or better than boys when engaging in digital spatial play (Polinsky et al., 2021), and we observed comparable levels of experience with touchscreen devices reported by parents, so it is likely also not due to different digital experience more generally. We did observe an advantage for girls on the EF measure, though there was no indication in the prior analysis that EF influenced synchrony differently for physical vs. digital tasks, and prior research found no association between EF and digital spatial play in 3- and 4-year-olds (Polinsky et al., 2021). Perhaps the gender difference in EF may have influenced synchrony differently for boys and girls in some way, or there may have been other differences related to gender that we weren’t able to capture in our measures. Prior work associating parent-child interactions and children’s EF during digital activities was specific to using a computer mouse, which is not relevant for play on touchscreen devices (Lauricella et al., 2009). Touchscreen devices may instead be a more flexible means of digital play for varying levels of children's EF, but there could be other factors that influence synchrony related to child gender. While one study found that mothers are more likely to be restrictive of girls' digital play than boys' digital play but co-played with girls and boys similarly often (Nikken & Jansz, 2006), another study did not find the same gender differences and instead showed that mothers' ideas about digital play are associated with mediating behavior (e.g., co-use and restrictions; Nikken & Schols, 2015). It is important for future research to explore whether the observed interaction replicates and, if so, to explore what might explain it in more depth.

Limitations

The current study looked at mother-child interactions during specific playful activities, and it is very possible that additional factors pertaining to the activities (beyond physical or digital modes) might also relate to synchrony. For example, children may have varying levels of prior experience with or preferences for different activities, which could impact interactions with their parents. However, it did not appear that the children who had prior experience were different in any of the measures we investigated, including the three children who had prior experience with *Minecraft* physical blocks and the 14 children who had played the *Minecraft* digital app. The small number of participants with prior experience may have limited our ability to detect any changes, and further research could explore whether familiarity or prior experience with specific playful activities does impact mother-child behavior during those activities.

Our findings are also limited in that only mother-child interactions were observed. We are unsure whether our findings would generalize to father-child interactions and suggest this as an important area for future studies to address. Some research finds that the associations between child outcomes and father-child synchrony are not significant or are lower than those of mother-child synchrony (Kim & Kochanska, 2012; Kochanska & Kim, 2014), but there is even less research on what factors relate to father-child synchrony during playful interactions than mother-child synchrony (Davis et al., 2017).

Contributions and Future Directions

Parent-child engagement during play can support children's learning (e.g., Fisher et al., 2013; Schlesinger et al., 2020; Weisberg et al., 2013), but less is known about what this looks like during digital play, despite most children engaging frequently in digital play (Rideout & Robb, 2020). Further, while the quality of play with physical materials has been well-explored (e.g., Ferrara et al., 2011; Fisher et al., 2013), less is known about digital apps and what makes them high-quality. A 2015 article highlighted research-informed methods of defining the educational value of apps and suggested that active engagement and social interaction during digital play indicates higher quality (Hirsh-Pasek et al., 2015). The *Minecraft* app invites active engagement and we observed similar positive social interaction with mothers during play as with physical materials.

This study addresses gaps in research exploring mother-child interactions as a component of play quality, with results suggesting that one component of play quality, mother-child synchrony, is similarly positive for physical and digital play. However, children often play *Minecraft* independently or with peers (Nikken & Jansz, 2006), and it would be interesting to explore whether an association between EF and play behavior might be more pronounced during independent play, and whether similar patterns of results for EF and synchrony would be observed for peer-peer dyads rather than parent-child pairs. This could be especially relevant in early educational contexts, in which children are often engaging in guided play with their peers, and could build on the current work as parent-child synchrony relates to peer interactions (Criss et al., 2003). Relatedly, it would also be interesting to explore how the results observed in this study might vary in relation to the level of parent guidance during play.Although not tested in this study, it is also important for future research to explore the ways in which different types of playful activities provide opportunities for children (and parents) to practice EF skills, such as turn-taking and remembering rules during game play. EF skills were likely needed in some way during both physical and digital play in the current study, and mothers interacted with children with positive synchrony independent of children's EF levels. This is consistent with other findings that parents can and do support children by adjusting scaffolding during play to children's levels (Ji, 2019). Both physical and digital play offer unique contexts for parent-child interactions that can adjust to children's evolving EF abilities; for example, in physical play, children and parents can each use their own materials rather than share a digital device, or in digital play, the game can include automated reminders about turn-taking and rules, allowing parents to focus on other forms of scaffolding. Because playful interactions seem to be positive across children's EF levels, future research could explore how these experiences could be used to support developing EF both for physical and digital play (e.g., Hahn-Markowitz et al., 2017; Towe-Goodman et al., 2014; Yogman et al., 2018).

We are encouraged to participate in this special issue on play, as research clearly shows that play holds incredible potential for supporting children's learning and development and should have a role in formal education (e.g., Hirsh-Pasek et al., 2009; Weisberg et al., 2013; Yogman et al., 2018; Zosh et al., 2017). As digital devices become increasingly prevalent as a modality of play, it is important to continue to explore the ways in which they are similar to or different from physical play across contexts.

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