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A New Way to Co-Play With Digital Media: Evaluating the Role of Instructional Prompts on Parent–Child Interaction Quality

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The quality of interaction between parents and children around a shared activity plays a significant role in what each party gets out of it. Many aspects of behavior are used to measure interaction quality, and consistent relations among them suggest the presence of an underlying latent variable. These insights from research in traditional shared contexts (e.g., mealtime, playtime, co-reading) may extend to the new context of interacting around digital media or joint media engagement (JME). In the current study, 4-year-old children ($n = 77$) and a parent were provided a digital co-play application for a 2-week period. Families were randomly assigned to receive an experimental version of the app that included brief, parent-focused tips ("nudges") before every activity or a control version without prompts. A Bayesian structural equation model indicated that a latent variable, interaction quality, underpinned measures of engagement, conversation, and behavior coded as dyads played two app games at pre- and posttest. Neither being assigned to use the app with nudges, nor parents' beliefs about digital media, had a significant effect on interaction quality. However, within the experimental condition, the duration of time the parent nudges were on-screen during the home play sessions was positively predictive of interaction quality at posttest. Principles for creating effective parent-focused interventions around JME are discussed.

What is the significance of this article for the general public?

The current research evaluates a relatively new shared play context (digital media co-play) through the lens of parent–child interaction behaviors. Evidence of a latent variable that has not previously been found within this context is presented, and its significance for future research on parent–child joint media engagement (JME) is discussed. The article describes a new digital feature built into a preschool game app (parent-directed tips or "nudges"), compares the effect of this feature to other efforts to increase JME, and discusses how optimizing parent-directed tips to maximize the value of JME will be useful for researchers and media industry companies interested in promoting positive parent–child outcomes.

Keywords: digital media, digital app, parent–child interaction, joint media engagement, structural equation model (SEM)

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Social interactions between parents and preschool children during daily activities benefit both parties when they contribute equally and cooperate (Mathis & Bierman, 2015). In traditional contexts such as sharing storybooks, toys, and meals, the quality of parent–child interaction

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determines the effect of shared experience on development (Hirsh-Pasek et al., 2015; Hoff, 2010; Rowe & Snow, 2019). With families now using digital media on a daily basis, fostering high-quality interactions during joint media engagement (JME) might promote positive development (Crain-Thoreson et al., 2001; Ewin et al., 2021). The current study explored the inclusion of parent-directed suggestions or "nudges" in a touchscreen game app to promote positive shared family interactions during digital co-play.

A second aim was to see if the same kinds of parent–child interaction behaviors observed in other contexts (shared reading, shared toy play, etc.) were also present when families shared a digital game app, and whether "interaction quality," as measured across several areas of behavior, can be construed as a single entity. In prior research involving shared activities such as reading and toy play, overlap has been reported between quality of conversation, joint engagement, and observable behaviors and their influence on parent–child outcomes (Hindman & Morrison, 2012; Hirsh-Pasek et al., 2015; Stuckelman et al., 2022). Therefore, it is possible that these measurable domains share an underlying central construct that drives the relations between them. We investigated the presence of a latent variable, *interaction quality*, which we hypothesized would underpin many behaviors (shared conversation, joint engagement, mutuality, etc.) during parent–child JME.

A number of interaction behaviors have important effects on developmental outcomes. For instance, when parents and children are warm and reciprocal toward each other, children have stronger emotion regulation and exhibit lower peer aggression (Ensor et al., 2011; Grolnick, 2009). During family time, shared positive affect (smiling and positive physical touch) strengthens parent–child bonds (Ensor et al., 2011; Landry et al., 2001) and is associated with later IQ and academic achievement (Estrada et al., 1987). During a shared activity, the number of parent–child conversational turns predicts language and brain development better than sheer quantity of language (Romeo et al., 2018). On the other hand, if parents are harsh or controlling, children are less likely to cooperate and learn (Grolnick, 2009; Landry et al., 2001). Likewise, if children act out or misbehave, parents exhibit more control, and the activity becomes less reciprocal and mutual (Grolnick, 2009; Nathanson & Rasmussen, 2011). Either party completely disengaging lowers motivation to repeat the experience (Landry et al., 2001).

In prior research, the behaviors parents used with their children depended on the activity and on their beliefs about the importance of shared engagement around that activity for supporting their children's development. According to Crain-Thoreson et al. (2001), different behaviors may be important for high-quality interaction during various daily activities: conversation may be more central to co-reading, and shared attention (eye contact, emotional reactions) foremost when watching a movie together. Belief that an activity enhances development may increase parental support (Lauricella et al., 2014; Rowe & Snow, 2019); for example, parents who value shared reading tend to use positive and responsive behaviors (Weigel et al., 2006). However, parents may not have strong beliefs that other shared activities (e.g., using digital media) will contribute to development, leading to little interaction (and limited interaction quality) in these contexts (Nathanson, 2001; Strouse & Ganea, 2017).

High-Quality Interactions During JME

Nevertheless, interaction quality may be integral to positive parent–child outcomes during JME, when two individuals share an interaction around digital content (Ewin et al., 2021), such as co-viewing videos or co-playing digital games (Griffith & Arnold, 2019; Strouse et al., 2013). Digital media is a nontrivial part of daily life for many families (Barr, 2019). In a 2020 survey, American parents reported that their 2- to 4-year-old children used screen media 2.5 hr per day on average (Rideout & Robb, 2021). Most (72%) parents report sometimes using JME behaviors with their child, although consistency varies (Connell et al., 2015). Recognizing the importance of parental support during digital activities for young children to learn from them, the American Academy of Pediatrics (AAP) recommended that, when possible, parents use digital media *together* with their 2- to 5-year-old children (AAP Council on Communications and Media, 2016).

Evidence for the benefits of JME for young children's learning is particularly strong for preschoolers (Ewin et al., 2021; Lauricella et al., 2014; Stuckelman et al., 2022; G. Troseth et al., 2020). Parents' active engagement and

scaffolding support infants' and preschool-aged children's learning from touch screens, digital toys, and e-books (Fidler et al., 2010; Lauricella et al., 2014; Zack & Barr, 2016). The relative novelty of joint tablet play may foster collaboration and parent behavior intended to help toddlers and preschool children learn (Lauricella et al., 2014; Skaug et al., 2018). During JME with mobile games, when parents provided helpful guidance, children were positive and responsive and engaged in less conflict; parents observed that adopting healthy behaviors from other shared activities (reasonable limit setting, turn-taking, role assignment) led to more positive JME interactions (Sobel et al., 2017).

High-quality support is needed in the digital context because preschoolers are extremely attracted to digital media (Strouse et al., 2019) but are not very skilled at learning from it. Information they easily learn from direct experience is much harder for them to learn from screens (termed the "transfer deficit"—Barr, 2010; also see Anderson & Pempek, 2005; G. L. Troseth et al., 2006). Two major challenges of using digital media are navigating perceptual differences between small 2D images on screens and life-sized, 3D reality (Barr, 2010), and understanding the many relations that screen images can take to the real world (G. L. Troseth et al., 2019). For instance, video can show actual events in real time (e.g., video chat with Grandma), tape-delayed reality (e.g., home videos), or fictional events (e.g., cartoons) and can even combine fiction with reality (e.g., Snapchat filters that superimpose animal whiskers on real-time video of a child's face). Parent support can promote children's learning from digital media across this age range by pointing out and describing connections between the representation (screen image) and its referent (what the image stands for; G. L. Troseth et al., 2006). With personal knowledge of their child, the parent can help navigate the complexities of digital media with content-relevant questions, connect on-screen events to the child's life (or clarify differences between screen and reality), and let their child lead once they gain competence (Fidler et al., 2010; Strouse et al., 2013; Strouse & Ganea, 2017; Stuckelman et al., 2022).

However, not all families take advantage of JME. Both parents and preschoolers may view the use of digital media as a solo activity rather than one to be shared (Hiniker et al., 2018; Roberts et al., 1999; Strouse et al., 2019). The result may be children who are unwilling to engage in shared media experience, pushing their parent's hand away and placing their body between the parent and the device when reading an e-book (Munzer et al., 2019) and responding less to attentional bids from parents when playing with a tablet versus physical toys (Hiniker et al., 2018). Parents may view phones and tablets merely as ways to entertain or distract their child, or even as harmful to development (Cingel & Krcmar, 2013; Common Sense Media, 2013), or have less experience sharing digital media compared to print books (Ewin et al., 2021). These factors may create apprehension toward building an interaction around digital content, resulting in fewer high-quality behaviors if an interaction occurs (Yuill & Martin, 2016; Zosh et al., 2015). For these reasons, both encouragement to engage in shared interactions around digital content, and concrete information on how to do this may be needed for families to incorporate JME into their daily lives.

Promoting and Measuring High-Quality JME

Effective interventions for JME tend to offer parents specific information or examples to incorporate into their interactions. For instance, Strouse et al. (2013) trained parents to pause storybook videos while watching with their 3-year-olds, to ask questions sensitive to their child's development, and to expand on their child's responses. After 4 weeks of home co-viewing, children learned more story vocabulary and had higher story comprehension compared to families who watched "as usual" (i.e., almost never pausing the video or conversing). In another effective intervention, G. Troseth et al. (2020) incorporated a digital character into an e-book. "Ramone" provided a model of conversation prompts to springboard parent–preschooler reading interaction. When low-income families used the Ramone e-book, the amount of shared conversation, content-relevant talk, and cognitively challenging talk was significantly higher than for families who used a version without Ramone. After using the Ramone e-book for 2 weeks at home, parents and their 4- and 5-year-old children significantly increased their social responsiveness, reciprocity,

and positivity while reading another e-book and a print book (Stuckelman et al., 2022).

Giving Parents "Nudges"

A recent effective strategy to encourage positive behaviors is to offer parents "nudges" (bite-sized pieces of information). Often delivered as text messages, nudges have fostered long-lasting behavior change in both parents and children (Doss et al., 2019; Smythe-Leistico & Page, 2018). For instance, York et al. (2019) texted parents of prekindergarten students once a week for 8 months, suggesting high-quality, low-stress behaviors to promote everyday literacy interactions (e.g., during bath time). Parent involvement in their child's academics increased, and children had higher literacy skills and engagement. Brief tips during pediatrician visits also significantly increased parent–child literacy activities at home and improved preschool children's language skills (Mendelsohn et al., 2001). Placing conversation prompts around supermarkets in low-income areas increased the quality of adult–child talk while shopping (including conversational turns and amount of questioning; Ridge et al., 2015).

Nudges to Promote JME Interaction Quality

Similar to any other repeated daily context in which parents might not automatically engage in high-quality interaction with preschoolers, nudges during digital media use might promote JME. Past research documents how infrequently high-quality JME occurs (Ewin et al., 2021; Lauricella et al., 2014; Munzer et al., 2019). In the current research, we examined whether parent nudges within a digital game app designed to promote children's prosocial behavior could increase the quality of interaction between parents and 4-year-olds, an age targeted by educational apps (Rideout & Robb, 2021).

Measuring JME Interaction Quality

Various methods have been used to define and measure parent–child interaction quality across traditional contexts such as reading and mealtimes with toddlers and preschoolers (Hirsh-Pasek et al., 2015; Lauricella et al., 2014; Munzer et al., 2019; Nathanson & Rasmussen, 2011). In the current study, we defined three key domains of JME: *quality of conversation*, *quality of shared engagement*, and *quality of observable behaviors* (Hindman & Morrison, 2012; Mathis & Bierman, 2015).

Conversational turns (back-and-forth exchanges) are an important measure of conversation quality (Hirsh-Pasek et al., 2015), also termed the "serve-and-return" approach of offering children openings to talk (Shonkoff & Bales, 2011). In one study, when the number of conversational turns between adults and 4-year-olds was high, children had stronger language skills (Romeo et al., 2018). Conversation quality has also been operationalized as "fluency and connectedness" of dyads' verbal and nonverbal expressions, which was a significant contributor to 2-year-olds' language development 1 year later (Hirsh-Pasek et al., 2015). Because conversation contributes to parent–preschooler interactions regardless of context, conversational quality will be important to consider when evaluating the quality of family interactions around digital media.

Quality of shared engagement has been defined and measured in several ways. For example, Zack and Barr (2016) measured the amount of joint visual attention (e.g., gaze following) during an interaction between infants and parents (Zack & Barr, 2016). Others have used joint engagement (coordinated behaviors around a shared object or activity) between parents and toddlers as the primary measure (Adamson et al., 2012; Hirsh-Pasek et al., 2015; Munzer et al., 2019). Regardless of how it is measured, quality of shared engagement is strongly associated with positive behavioral outcomes and early learning (Adamson et al., 2012).

Other observable behaviors also contribute to interaction quality. Shared mutuality (responsiveness, cooperation, reciprocity) and positivity-based behaviors (shared positive affect, warmth, physical touch) are strongly associated with children's socioemotional and cognitive development (Ensor et al., 2011). Responsive, sensitive parenting promotes positive development (Bernier et al., 2010) and children's positive affect and warmth often elicit similar parental behaviors (Ensor et al., 2011; Landry et al., 2001). In contrast, shared negative affect, parental control, and disengagement are linked to worse child outcomes (Landry et al., 2001).

In the current study, parent-directed nudges (or tips) to promote JME were built into the experimental version of a digital gameplay app and families used it for 2 weeks at home in a fully online study conducted during the COVID-19

pandemic. To increase the ecological validity of the study, families were allowed to use the app as they normally would any app they had downloaded from the internet, across 10 play sessions. We examined whether this "light touch" intervention increased parent–child interaction quality from pretest to posttest, compared to families who used the app without the nudges. In light of past research suggesting that various indicators of interaction quality are likely driven by a common underlying factor, our analyses also tested for the presence of a latent variable, which we hypothesized would underpin many observable behaviors (shared conversation, mutuality, joint engagement, etc.) during parent–child JME interactions.

Method

Participants

Participants were 77 children (37 female) 45–59 months old ($M = 52.57$ months, $SD = 3.96$ months) and a parent (71 female), recruited from social media posts, state birth records, and a university database of families interested in research participation. No children had significant developmental delays, and all were learning English as their primary language. Due to the software constraints of the app, all families needed to own an iPhone or iPad. Most parents reported their child's race as White (75%) or multiple races (17%). Annual family income ranged from under $75,000 (18%) to above $150,000 (29%), with a median income between $105,000 and $150,000. Parent education level was less than a 4-year degree (10%), college educated (35%), and graduate/professional (53%). Table S1 in the online supplemental materials has full demographic information. Seven other families began the study, but (due to attrition or experimenter error) their data were not included in analyses. The research was approved by the university Institutional Review Board and carried out with written parent consent. Data were collected between June and December 2021.

Materials

Families in both conditions downloaded a version of the OK Play app (okplay.co). OK Play was a commercial application designed to promote parent–child interaction with activities (drawing, picture taking, music creation; see Table S2 in the online supplemental materials) for parents and children to engage in together. Two of the nine game types (Drawing and "How to") explicitly prompted co-play or required parents to read the instructions; the rest could be played by the child solo or together with a parent. There were numerous individual activities under each activity type. For this study, a digital "nudge" feature was added before each activity in the experimental (but not the control) version to encourage the idea of co-play and give parents brief tips on structuring co-play interactions. The nudges were co-written by a developmental psychologist/app developer and a preschool teacher. Participants in the experimental group were unable to begin an activity until they scrolled through four nudge slides that oriented parents to the activity, suggested how to extend the play beyond the app, and provided information on enhancing development (see Table 1 for a description and examples).

Pre- and Posttest Activities

At pretest, families played two OK Play games without nudges, which varied in how explicitly they called for JME. In a drawing game, families interacted with their device to create a shared drawing. After one partner completed part of the drawing, they were prompted to "pass the drawing to your partner" to complete the next part. The other game (Silly Word Club) was a brief video that could be co-viewed or watched alone, during which a character provided audible suggestions (e.g., "spin around whenever you hear the word *pineapple*"). At posttest, families played the same two games without nudges. Because the Silly Word Club game did not explicitly require co-play, it was chosen to provide a strong test of whether families exposed to the nudges might increase their postintervention co-playing and interaction quality across different kinds of games.

At-Home Digital Devices

At pre- and posttest, families used their own iPhone or iPad to play the app and a separate device (e.g., laptop or another phone) for Zoom calls with the researcher. Researchers guided parents to set up their video-chat cameras to best capture a view of the parent–child interaction during the two OK Play games.

Table 1
Descriptions and Examples of Nudges From Experimental Version of OK Play

Nudge	Purpose	Examples
Get Ready	Gives parents a brief description of the activity; explicitly mentions playing with a partner	Record your words and sounds with your partner Take turns drawing with your partner Take a series of photos with your partner
Play Tip	Specific parent recommendations for ways to interact during the activity	Try making the different faces together Discuss what disappointed means to you Encourage your child to say the commands out loud
Extend the Play	Ways to connect between the activity and the child's own life	Throughout the day, name the shapes of objects you see Make up a story about your drawing Talk with your child about times they have felt angry
Parent Insight	Explains importance of the activity or provides ways for parents to extend the activity	Listening without judgment helps us learn about others Talk about how you created the drawing using teamwork Understanding facial expressions helps in perspective taking

Parent Survey

In the pretest online survey, parents supplied demographic information and reported their perceptions of the importance of both play and the parent's role in child development and their opinions of digital media's influence on their child's development. Survey questions were taken from published measures (Fogle & Mendez, 2006; Hembacher & Frank, 2020). The posttest online survey probed parent and child enjoyment of the OK Play app and its features. Parents in the experimental condition were asked about the influence of the nudge feature on their and their child's experience with OK Play.

Design

After completing the pretest session, participants were randomly assigned to use the app with nudges (experimental condition, $n = 38$) or without nudges (control, $n = 39$) for 10 play sessions during the next 2 weeks. Due to temporary OK Play app glitches, eight experimental group families did not experience any nudges during the intervention; these families were reassigned to the control group and replaced with eight more experimental group families once the app had been fixed. Three additional families had inconsistent exposure to the nudges before games due to a programming error: one family only had nudges for their first two play sessions, another family had no nudges on their first and third sessions, and a third family lacked nudges on their fifth and sixth sessions. Because the inclusion of data from these families did not significantly alter the results, they remained in the experimental condition.

Procedure

Before the pretest, all parents received emails containing links to their personalized study Zoom room, the online consent form, and pretest survey, and to download the control version of the OK Play app without nudges for the pretest through TestFlight (an app for beta testing digital applications). The same procedure was used to send the posttest Zoom link, app link, and exit survey. On the pretest and posttest days, the parent and child joined the Zoom room. After the consent/assent process, researchers muted their Zoom camera and audio to give families the illusion of greater privacy (though families could still be observed and the session recorded). Families played the Word Club and Drawing games on their devices as they normally would at home, either together or the child playing alone, whatever made the most sense for them. To keep the procedure consistent between conditions, at the conclusion of the pretest Zoom visit, all families were told to close the app "in order to install updates." The experimental families were told to download the app again, receiving the version with nudges for use in the intervention play sessions. When families in the control group reopened the app, they had the control version (without nudges) to use for their play sessions. All families were instructed how to use the screen capture and audio recording feature on their device to record their play sessions. For the

posttest, experimental families were told to keep OK Play closed for updates (and were switched to the control version when they redownloaded and opened the app). Control families were given similar instructions for keeping the app closed and then restarting, without being asked to redownload. The pre- and posttest sessions were recorded on Zoom by the researchers, and the videos were uploaded to a secure server. At the end of the posttest visit, families were compensated for their time with a gift card.

During the intervening 2 weeks, parents were told to use OK Play (their assigned version) 10 times, for at least 10 min per session and to use the app as they normally would, either together or the child playing alone. Families audio- and screen-recorded each play session and emailed the recording link to the researcher. The screen capture recordings showed the nudges that appeared and which games were played along with audio, but there was no video recording of the parties playing the games. A member of the research team contacted families at specific intervals during the 2 weeks to check in, ensure they were following study protocols, offer technical assistance, and remind them to upload recordings.

Measures

Interaction Quality

During the pre- and posttest sessions, three major domains of interaction quality were assessed: quality of conversation, quality of shared engagement, and quality of observable behaviors. Three pairs of coders (one per domain) blind to the study hypotheses coded the pre- and posttest play sessions for interaction behaviors. Coders separately evaluated interactions during each game, and the codes were averaged across games to create a composite for each behavior. Coders independently double-coded ~25% of videos to establish reliability, and the rest were single-coded. Interrater reliability was assessed by a single-measures intraclass correlation (ICC) from a two-way mixed model. All final composites maintained the 7-point scale ($1 = no\ presence\ of\ behavior$, $7 = consistent\ presence\ of\ behavior$) on which they were based.

Quality of Conversation

Using the Communication Play Protocol (Adamson et al., 2012; Hirsh-Pasek et al., 2015), coders evaluated parent–child talk and behaviors on a 7-point Likert-type scale for the fluidity of conversation. Interrater reliability (ICC) was 0.87.

Quality of Shared Engagement

Based on an adaptation of the "coordinated joint engagement" item from the Communication Play Protocol (Adamson et al., 2012), raters coded behaviors when the child and parent were seamlessly interacting with both the shared activity and their partner (ICCs ranged from 0.90 to 0.98). We averaged the child and parent coordinated engagement codes to create a composite for *coordinated engagement* at pre- and posttest (Cronbach's $\alpha = .74$ and .71, respectively).

Quality of Observable Behaviors

Interaction behaviors were coded using an adaptation of the Parent–Child Interaction System (PARCHISY; Deater-Deckard et al., 1997), which has been validated for assessing target behaviors in shared play and used for digital storybook reading (Atzaba-Poria et al., 2017; Stuckelman et al., 2022). ICCs ranged from .86 to .94. Two composites were created from PARCHISY codes. A *mutuality* composite comprised the average of parent and child responsiveness (engagement and behavioral/verbal responses to the partner, etc.), the dyad's reciprocity (joint positive affect, turn-taking, etc.), and cooperation (joint decision making, shared agreement, etc.; Ensor et al., 2011). Cronbach's $\alpha = 0.86$ at pretest and 0.88 at posttest. We also created a *positivity* composite by averaging parent-positive control (prompting the child, positive feedback, etc.), parent-positive affect (smiling, physical affection, etc.), and child-positive affect (smiling, physical affection, etc.; Atzaba-Poria et al., 2017). Cronbach's $\alpha = .81$ at pretest and .80 at posttest.

Co-Play and Solo Play During Pre- and Posttest Sessions

To check if there were condition differences in how many parents played the Word Club and Drawing games with their children during the pretest and posttest, versus the child playing solo, the 7-point scales for two measures from the PARCHISY (parent on-task behavior and dyadic reciprocity) were collapsed to a 2-point co-play/solo play measure reflecting the active engagement of the parent for at least half of the game.

Parent Beliefs Measures

Responses were averaged to create composites as informed by previous research (Fogle & Mendez, 2006; Hembacher & Frank, 2020). A composite was made from parent responses to six survey questions (each on a 7-point Likert-type scale) that evaluated beliefs about the parents' role in child development, such as the perceived importance of being "hands-on" (drawn from Hembacher & Frank, 2020; Cronbach's $\alpha = .57$). The internal consistency of this composite was lower than some rough cutoffs for acceptability (e.g., .70). We elected to keep the measure in later analyses in order to meet the aims of the research, but acknowledge that results must be interpreted with caution. Next, a composite made of 12 questions from the Parents Play Belief Scale (Fogle & Mendez, 2006) assessed parents' belief in the positive role of play in their child's development (Cronbach's $\alpha = .74$). Parents also answered two questions created for this study that assessed the perceived importance of actively co-using media with their child ($r = .37, p < .001$). Finally, 12 items from a previously used survey about digital media made a composite focused on parents' overall positive beliefs about their child's digital media use (Stuckelman et al., 2022; Cronbach's $\alpha = .95$).

Nudge Exposure

Because we did not have a video of the home sessions, determining whether or not parents co-played with children at home was challenging. If parents read the nudges, the nudge duration on the screen in the screen capture recordings was likely to be longer than if the parent, or the child playing solo, swiped through them to get to the game. Using the home screen capture recordings from experimental group families, one scorer recorded the duration (in fractions of seconds) that each nudge was on the screen for every game played during home play sessions, creating an average nudge exposure duration per session for each dyad, ranging from 1.92 to 25.87 s per session ($M = 7.54$ s).

Analytic Plan

The *interaction quality* latent variable was hypothesized to exist at both pretest (*IQUAL1*) and posttest (*IQUAL2*), with mutuality, positivity, coordinated joint engagement, and connectedness of conversation serving as its observed indicators. These indicators each captured key attributes of interaction quality during JME. Predictors of *IQUAL2* were experimental group, *IQUAL1*, parents' perceived role in child development, views on the importance of play, positive digital media beliefs, and beliefs about co-playing media. Of key interest was the effect of the experimental group on *IQUAL2*, and the remaining predictors were included as controls.

We used a Bayesian structural equation model (SEM) to evaluate the study hypotheses. SEM generally requires large samples and suffers from poor accuracy and power when the sample size is small. To offset these problems, Bayesian estimation is recommended, as it allows the inclusion of *priors* (Smid et al., 2020). Prior distributions are often based on past research, reflecting the researcher's informed expectations about the values each parameter may take. For example, to choose a prior for the effect of the experimental group on *IQUAL2*, we considered eight studies that examined the effects of similar digital interventions on parent–child shared activity. Four showed positive associations (Lauricella et al., 2014; Skaug et al., 2018; Strouse et al., 2013; Stuckelman et al., 2022) and four reported negative or null associations (Hiniker et al., 2018; Munzer et al., 2019; Ross et al., 2016; Wooldridge & Shapka, 2012). Thus, we chose a Normal distribution centered at zero to account for mixed evidence. We followed a similar approach for other regression effects and factor loadings. For technical details concerning prior choices, see online supplemental material A and Table S3 in the online supplemental materials for all priors used in the model.

Bayesian models were fit using the R package *blavaan* (Merkle et al., 2021), which uses three chains, 300 warmup iterations, and 1,000 sampling iterations. Multiple criteria were examined to evaluate the model. Convergence was assessed via the Gelman–Rubin statistic for each parameter, where a value close to 1 is ideal, as well as trace plots, posterior density plots, and autocorrelation plots. Model fit was assessed with the posterior predictive p value (*ppp*); the ideal *ppp* is 0.50, whereas values <0.025 or >0.975 indicate poor fit. Significance of each parameter estimate was assessed by whether its highest posterior density interval (HPDI) contained zero; in Bayesian estimation, the HPDI is interpreted similarly to a confidence interval. Finally, we conducted a sensitivity analysis to

investigate the impact of our chosen priors on parameter estimates (Depaoli & van de Schoot, 2017; Smid et al., 2020). We refit the model twice, replacing our chosen priors with weakly informative and noninformative priors (Table S4 in the online supplemental materials), comparing parameter estimates across models.

We then fit an additional Bayesian SEM, using only data from participants in the experimental group. This model was identical to the one described above, but the experimental group was replaced by average time spent with app nudges as a predictor of *IQUAL2*. We also conducted a regression to assess whether any self-report items in this group predicted average time spent with app nudges; predictors were positive digital media beliefs, perceived role in child development, beliefs about play as learning, and parent involvement in digital media.

Results

On average, families recorded ~8 play sessions during the 2 weeks (experimental: $M = 8.43$, $SD = 2.50$, range = 2–12; control: $M = 7.66$, $SD = 2.93$, range = 0–11). A one-way analysis of variance revealed no significant difference by the experimental condition in the number of recordings submitted. We ran a series of t tests to establish whether there were differences across the control and experimental groups in terms of parent co-play (co-play vs. no co-play, computed from collapsing the 7-point PARCHISY codes into a dichotomous indicator) during the Silly Word Club and Drawing games at pretest and at posttest. There were no significant condition differences. At pretest, during the Silly Word Club game, 57% of parents in the experimental group and 59% of parents in the control group exhibited co-play behaviors. During the drawing game, 92% experimental group parents and 90% of the control group parents co-played. At posttest, during Silly Word Club, 46% of parents in the experimental group and 62% of parents in the control group co-played and for Drawing, 84% of parents in the experimental group and 87% of parents in the control group co-played. For a graph of these results, see Figure S1 in the online supplemental materials.

Correlations

As shown in Table 2, most indicators of interaction quality were highly correlated. Perceived importance of parents' role in child development and the importance of play for development were highly correlated and were correlated with a number of the indicators of interaction quality at pre- and posttest. Positive digital media beliefs were strongly correlated with the perceived importance of sharing digital play with children, but neither of these measures were strongly correlated with indicators of interaction quality.

Bayesian SEM

Model Convergence and Fit

Visual inspection of trace plots indicated that convergence was successful. The Gelman–Rubin statistic was close to 1 for all parameters (min = 0.999, max = 1.003), again indicating that the model converged. Posterior density plots were

Table 2
Correlations Among Study Variables

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Mutuality T1	—										
2. Mutuality T2	.664**	—									
3. Positivity T1	.885**	.590**	—								
4. Positivity T2	.620**	.773**	.712**	—							
5. Coordinated T1	.554**	.390**	.412**	.291**	—						
6. Coordinated T2	.533**	.562**	.447**	.441**	.568**	—					
7. Connectedness T1	.570**	.480	.545**	.468**	.504**	.467**	—				
8. Connectedness T2	.552**	.671**	.501**	.581**	.408**	.619**	.708**	—			
9. Parent digital co-play beliefs	.070	.180	.079	.110	.240*	.205	.112	.097	—		
10. Parent play support	.258*	.210	.336**	.242*	.222	.239*	.181	.174	.331**	—	
11. Parent role child dev	.241*	.094	.241*	.258*	.207	.133	.133	.125	.065	.499**	—
12. Positive digital media beliefs	.122	.098	.122	−.033	.289**	.193	.090	.007	.607**	.302**	.102

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

smooth and followed the expected shape and boundaries for each parameter. Autocorrelation plots showed that autocorrelation quickly dropped to zero as lag increased, indicating little dependency across iterations. The *ppp* was 0.236, indicating adequate model data fit. Figures S2 and S3 in the online supplemental materials show posterior density plots and trace plots for all regression parameters.

Posterior Estimates

Figure 1 shows the full model with standardized estimates for factor loading and regressions. Table S5 in the online supplemental materials shows posterior means, posterior *SD*s, HPDIs, and Gelman–Rubin statistics for all parameters. At both timepoints, factor loadings relating the four indicators to *IQUAL* were strong and positive. Posterior means for standardized loadings ranged from 0.533 to 0.987. None of the HPDIs contained zero, indicating that all factor loadings were significant and supporting the existence of an *interaction quality* latent variable at each timepoint. The posterior mean for the effect of condition on *IQUAL2* was 0.015, HPDI = [−0.174, 0.205], meaning we did not detect a significant difference in interaction quality at posttest between families who received the nudges and those who did not.

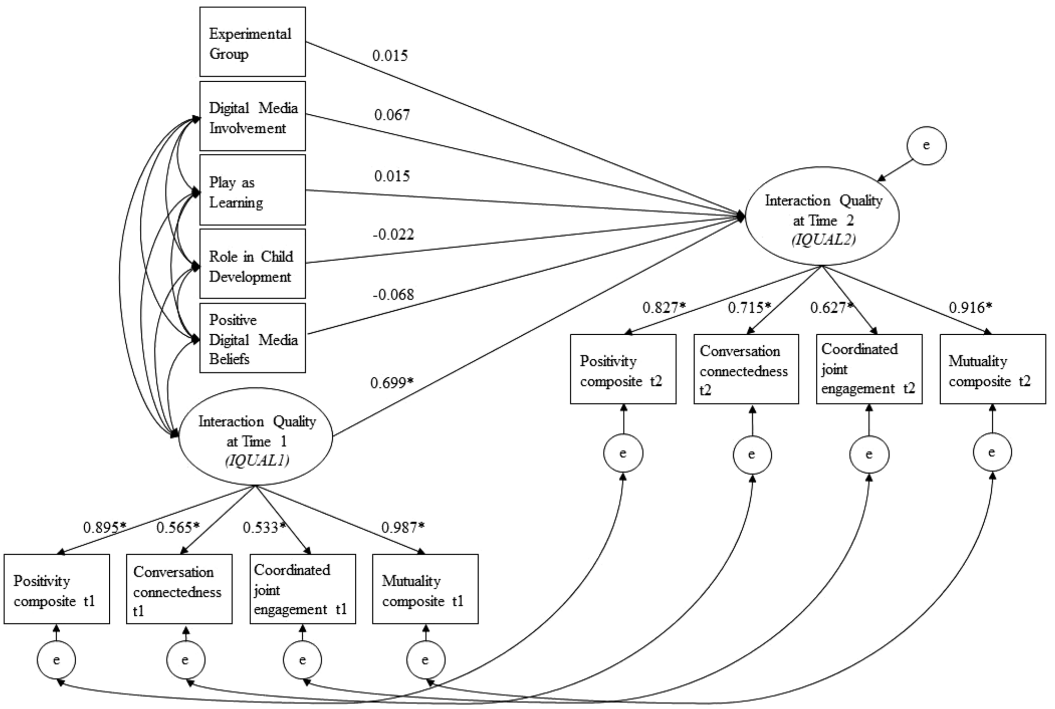
The HPDI boundaries for the effect of *IQUAL1* on *IQUAL2* did not contain zero, indicating a significant association between interaction quality at pretest and posttest (posterior mean = 0.699, HPDI = [0.508, 0.887]). HPDIs for the effects of all other covariates contained zero, indicating they did not significantly predict posttest interaction quality.

Sensitivity Analysis

The sensitivity analysis indicated that none of our substantive conclusions were dependent upon the informative priors chosen in our model. Whether informative, weakly informative, or diffuse priors were used for the regression parameters and factor loadings, mean posterior estimates and HPDIs were very similar (Table S6 in the online supplemental materials).

Figure 1

Full Model With Standardized Estimates for Factor Loadings and Regressions



*$p < .05$.

Bayesian SEM and Regression Involving Time Spent With App Nudges

Table 3 displays the regression results from the second Bayesian SEM. Among families in the experimental group, average time spent with nudges was significantly predictive of *IQUAL2* (posterior mean = 0.032, HPDI = [0.007, 0.060]). A brief sensitivity analysis also showed that this result was not dependent upon our chosen prior for this effect, which was *Normal*(0.1, 2). However, given the limitations of the nudge exposure data as a measure of parent exposure to the tips, this finding requires further follow-up (as noted in the Discussion). In the regression model, none of the predictors were significantly related to average time spent with nudges; see Table S7 in the online supplemental materials.

Feedback Survey

Most parents (62%) said their child always enjoyed using OK Play across the 2 weeks, but only 40% always enjoyed playing the app with their child, with an additional 23% enjoying it as they became more familiar with the content. More than half (57%) of parents said they were either "almost always" or "always" with their child while they were using OK Play. On average, parents also reported that they initiated the use of OK Play 75% of the time. See Figure S4 in the online supplemental materials.

Of parents exposed to the nudges, 55% reported that the nudges were either "sometimes" or "almost always" helpful but no parent said that the nudges were "always" helpful. However, 55% said the nudges were never distracting, while just 5% reported they were always distracting. Ultimately, this feedback demonstrates that parents had mixed feelings about their utility.

Discussion

This study explored whether parent-directed nudges would influence parent–child interaction while using a digital app following a 2-week intervention. The overall pattern of results was that families' interactions around the OK Play app remained stable from pretest to posttest. The strong consistency of individual dyads' interaction quality across timepoints replicates and extends prior research that used narrower measures within one context (Hoff, 2006). For instance, parents and young children who tend toward mutuality-based behaviors use them consistently throughout the early years (Kochanska & Aksan, 1995). Also of interest are the correlations between parents' beliefs about both the importance of direct involvement in their children's development and the importance of play on development, and many of the individual indicators of interaction quality while playing the two app games during the pre- and posttests. Parents with these beliefs appeared to bring an involved, reciprocal, and supportive parenting style to the relatively new context of JME with a digital app. Yet parent beliefs did not predict duration of nudge use during the 2-week intervention, possibly because our instructions allowed families to choose between co-play and solo child play, and many parents were working from home while caring for young children during those weeks of the COVID-19 pandemic.

We hypothesized that a latent variable, *interaction quality*, would emerge in this JME context,

Table 3
Regression Results From Bayesian SEM on Participants in Experimental Group, Predicting Interaction Quality at Posttest

Predictor	Posterior mean	Posterior *SD*	HPDI	Gelman–Rubin statistic
Time spent with app nudges	0.032	0.013	[0.007, 0.060]	1.001
IQUAL1	0.816	0.181	[0.490, 1.209]	0.999
Digital media involvement	0.039	0.048	[−0.056, 0.137]	1.000
Play as learning	0.308	0.192	[−0.092, 0.687]	1.001
Role in child development	−0.198	0.245	[−0.671, 0.278]	1.001
Positive digital media beliefs	−0.118	0.064	[−0.252, 0.003]	0.999

Note. Average time spent with app nudges was measured in seconds. SEM = structural equation model; HPDI = highest posterior density interval.

and that the presence of nudges would positively influence interaction quality. Using a Bayesian SEM incorporating key covariates, we obtained strong evidence for the existence of the latent variable at both timepoints, as well as its stability across timepoints. In the main analysis, the nudge intervention did not significantly contribute to interaction quality at posttest. However, in a second SEM focused on the experimental group, families' exposure to the nudges on the screen of their device during the 2 weeks (ranging from under 2 s per play session to over 26 s) did predict posttest interaction quality.

Longer nudge duration may suggest that parents were involved in the app play with their children and were reading the nudges, whereas short durations may be interpreted as parents (or children playing solo) swiping past the nudges to get to the games. This analysis does not allow strong claims that exposure to the nudges resulted in higher interaction scores at posttest; rather, parents who interacted more with their children at both pretest and posttest may have been more likely to co-play the app with their children during the intervening weeks, to encounter the nudges, and to choose to read them. Or parents who saw the nudges may have been reminded of the value of shared interaction, and applied their own repertoire of co-play strategies to the digital context (Sobel et al., 2017), rather than being influenced by the content of the nudges.

The importance of parent–child interaction is clear, but there is no universal method for evaluating interaction quality across contexts, including JME. Our findings point to the existence of a single latent variable underlying measures of parent–child mutuality, positivity, coordinated joint engagement, and connectedness of conversation. Thus, interaction quality is revealed by multiple indicators that each capture aspects of parent–child interactive behavior.

Further Clarity on Effective JME Nudges

In previous research, giving parents nudges (small pieces of information) resulted in significant changes in the quality of behavior (Doss et al., 2019; Ridge et al., 2015; Stuckelman et al., 2022). In the current study, families who were offered the nudges chose to spend varying amounts of time using them, and there was no overall effect of the intervention on increasing interaction quality. Differences between the nudges in the experimental OK Play app and in earlier interventions, as well as specifics of the app play context, may suggest principles for promoting high-quality JME.

In prior interventions, when nudges were sent via text messages to a parent's phone, this notification format was effective at getting them to read and process the information and integrate it during everyday activities with their child (Smythe-Leistico & Page, 2018). In research with an e-book, immediately after the story narration on a page, an on-screen character offered verbal and written conversation prompts that played automatically and could not be skipped over (Stuckelman et al., 2022; G. Troseth et al., 2020). The character also addressed parents directly on the title page, briefly encouraging parent–child talk and sharing. With this support, parents and children increased their conversation and positive and mutual behaviors toward one another while reading other books. In contrast, the nudges in the OK Play app were not compulsory nor formatted as notifications; users could swipe through by pressing a "Next" button without reading them. There was no narration, nor did parents need to interact with the app to confirm they understood the tips.

Because this intervention was incorporated into a commercial app (with great forbearance and generosity exhibited by the development team and programmers), we researchers were limited in what modifications we could request. The value of this study, in part, is showing what did not work. For parent tips in a digital medium to promote JME, they need to be compulsory or include checks to make sure parents read them.

The OKPlay app became unavailable during the summer of 2022 (in part, due to economic fallout from the COVID-19 pandemic). Although future studies modifying the nudges in this app are not possible, similar apps could be developed improving on this model.

Co-play with a digital application may not have been as natural or familiar for parents and children as JME while watching television (e.g., Strouse et al., 2013) or interacting while reading or playing with toys (Strouse et al., 2019; Zosh et al., 2015). When parents believe that an activity (such as shared reading) enhances development, they tend to engage in it more with their children (Lauricella et al., 2014; Rowe & Snow, 2019; Weigel et al., 2006). Given that many parents

view screen time as a solo activity (Hiniker et al., 2018), and study instructions allowed for parent–child shared or child-solo use, some parents may not have consistently been exposed to the nudges, or children may have limited their parent's access to the screen by turning away with the phone or tablet, as has been found with other digital media (Munzer et al., 2019).

Because families used a commercial app at home on their own device for 2 weeks, this study had a relatively high degree of ecological validity in reflecting how families normally use children's educational apps, but it was not as tightly controlled as one completed in a lab with a lab-designed product. For instance, there was some lack of consistency in families completing the play sessions and submitting their home recordings. Some OK Play activities offered verbal directions (e.g., the Silly Word Game) and could be completed by playing solo, whereas other activities (e.g., the Drawing game) and the nudges directly encouraged playing together.

The mixed feelings many parents have about JME may have contributed to the lack of overall pre- to posttest change in interaction quality (Nathanson, 2001; Strouse et al., 2019). For instance, belief that print books are more educational than e-books (and that their children prefer print) directly impacts how parents and children read together with these formats (Strouse & Ganea, 2017). Entrenched behavior patterns around digital media, therefore, may call for more explicit information and intervention to promote higher quality JME interaction.

Limitations

Among families in the experimental condition, more average time spent with nudges was predictive of better interaction quality at posttest. However, this result should be interpreted with caution. During at-home play sessions, we did not collect video data that would allow us to confirm that greater time spent with nudges was a reliable indicator of greater parent participation with the app. Therefore, this result requires future follow-up to confirm whether greater engagement with nudges is indeed related to enhanced interaction quality.

The OK Play experimental versions were only compatible with Apple devices. Because Apple products are expensive, the current participants did not represent all socioeconomic groups. Additionally, our methods of online recruitment may have favored families who already were relatively heavy users of technology, including children with previous experience using Apple devices. Family experience with technology likely could have influenced behaviors with the OK Play application, as well as expectations around a digital media interaction, and, therefore, should be looked into further to see whether it could impact outcomes during digital application co-play. As educational apps and digital devices continue to be widely adopted across the socioeconomic spectrum (Rideout & Robb, 2021), diverse participants should be included in future JME research. Additionally, participant families represented Western cultures and were mostly (∼75%) of European American descent. Because cultural background and values affect parent–child behaviors and child outcomes (e.g., Chao, 1994; Dearing, 2004), interventions for JME might be targeted to support culturally valued high-quality parenting practices (Nathanson, 2001).

Data collection took place during the COVID-19 pandemic, which could have influenced parents' time and emotional bandwidth for full engagement with OK Play. Participation may have provided a break for some parents while their child played—a common choice for family engagement with digital media (Guernsey, 2007). Finally, sample size was relatively small in the Bayesian SEM conducted on experimental participants, though still within the range of sample sizes for which Bayesian SEM has been shown to be an acceptable method.

Conclusion and Take-Aways

Future innovations are needed for optimal JME interventions that are: (a) accessible for a wide range of families, (b) neither intrusive nor distracting, and (c) strong enough to promote long-lasting, positive behavior change (Doss et al., 2019; Stuckelman et al., 2022; G. Troseth et al., 2020). For an intervention to promote high-quality parent–child interaction in this new context, parent-directed information and/or modeling offered automatically might be more helpful than optional nudges (Strouse et al., 2013; G. Troseth et al., 2020). Alternatively, tips sent as notifications to the parent's phone as part of the app service, but outside of shared app play, might be effective.

Parents play a critical role in helping their young children navigate screen media, due to their knowledge of their child (Fidler et al., 2010; Strouse et al., 2013) and willingness to apply their parenting strategies to new contexts (Sobel et al., 2017). Well-designed digital features may support that process, transforming negative beliefs about digital media to more wide-reaching acceptance of JME interactions as another valuable context for family engagement.

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