

ORIGINAL RESEARCH

The Longitudinal Impact of Structured vs. Unstructured Digital Play on Preschoolers' Executive Function Development

[Evelyn Vance¹, Kenji Tanaka², Priya Sharma³, David Chen⁴]

¹ Evergreen University, Portland, USA

² Kyoto Institute of Technology, Kyoto, Japan

³ University of Mumbai, Mumbai, India

⁴ National University of Singapore, Singapore, Singapore

Volume	Issue	Year	Type
1	1	2023	Original Research
Published	Journal		
2023-01-31	IJCCL		

Abstract

This study investigated the longitudinal impact of structured versus unstructured digital play on the development of executive functions (EF) in preschoolers. Given the increasing integration of digital technologies into early childhood education, understanding the differential effects of play types is crucial. A cohort of 150 preschoolers (aged 4-5 years at baseline) was longitudinally assessed over 18 months. Participants were assigned to one of two digital play conditions: structured digital play (e.g., educational apps with clear goals and feedback) or unstructured digital play (e.g., open-ended digital creative tools). Executive function skills, including working memory, inhibitory control, and cognitive flexibility, were assessed using a battery of standardized tasks at three time points. Parental reports on children's EF were also collected. Preliminary analyses indicated that children in the structured digital play group showed significantly greater gains in inhibitory control and working memory compared to the unstructured group. Conversely, the unstructured group exhibited slightly larger improvements in cognitive flexibility, though this difference was not statistically significant. These findings suggest that the design of digital play experiences may differentially influence specific EF components. The results have implications for designing digital curricula and recommending screen time for young children, emphasizing the potential benefits of targeted, structured digital engagement for foundational cognitive skills. Further research is needed to explore mediating factors such as parental involvement and the specific features of digital environments.

Keywords: Preschoolers, Digital Play, Executive Function, Longitudinal Study, Structured Play, Unstructured Play, Cognitive Development

Introduction

The development of executive functions (EF) during the preschool years is a critical predictor of later academic success, social competence, and overall well-being (Conway & Stifter, 2012; Blair & Willoughby, 2013). Executive functions, a set of cognitive processes that control and regulate other cognitive processes, include key components such as working memory, inhibitory control, and cognitive flexibility (Slot et al., 2017). Play has long been recognized as a primary vehicle for fostering EF development in young children (Adams, 2018; Hamamcı & Dagal, 2021). Traditionally, research has distinguished between structured and unstructured play, with both offering unique developmental benefits (Shmukler & Naveh, 1985; Oncu, 2015). However, in the contemporary landscape, digital play has become increasingly prevalent, raising important questions about its impact on EF. The nature of digital engagement can vary significantly, from highly structured educational applications to open-ended creative platforms. Understanding whether these different forms of digital play have differential effects on EF development is

paramount for educators, parents, and policymakers. This study aims to longitudinally examine the impact of structured versus unstructured digital play on the development of key EF components in preschoolers. By comparing the trajectories of EF skills in children engaged in these distinct digital play environments, we seek to provide empirical evidence to inform the design and utilization of digital tools in early childhood settings. Previous research has explored the general benefits of play for EF (Gibb et al., 2021; Orr & Dorfberger, 2022) and the role of parental input (Lee & Baker, 2020; Toor & Hanif, 2022), but a direct, longitudinal comparison of structured versus unstructured **digital** play on EF development remains an underexplored area. This research addresses this gap by tracking EF development over an 18-month period in two distinct digital play conditions.

Literature Review

The foundational role of play in child development is well-established, particularly for the emergence of executive functions. Early research highlighted the distinct benefits of structured versus unstructured play. Structured play, often characterized by pre-defined rules, goals, and adult guidance, has been associated with the development of self-regulation and rule-following (Shmukler & Naveh, 1985; Unknown, 1972). Conversely, unstructured play, which allows for child-led exploration, imagination, and problem-solving, is thought to foster creativity, initiative, and cognitive flexibility (Oncu, 2015; Stern-Ellran et al., 2016). These distinctions, however, were primarily conceptualized within the context of physical and imaginative play, predating the digital revolution.

Executive functions, encompassing working memory, inhibitory control, and cognitive flexibility, are crucial for adaptive functioning and are particularly malleable during the preschool years (Conway & Stifter, 2012; Broomell & Bell, 2022). Research has demonstrated a strong link between play experiences and EF development. For instance, pretend play has been shown to support the development of self-regulation and EF (Slot et al., 2017; Faja et al., 2016). Play-based interventions have been developed to specifically target and enhance preschoolers' EF skills (Gibb et al., 2021; Adams, 2018; Gejl et al., 2021). Furthermore, the home environment's influence on EF, including parental scaffolding and communication, has been documented (Korucu et al., 2019; Lee & Baker, 2020; Toor & Hanif, 2022).

The advent of digital technologies has introduced new forms of play. Digital environments can range from highly structured, goal-oriented applications designed to teach specific skills (Axelsson et al., 2016) to open-ended digital sandbox environments that allow for creative exploration. While some studies have explored the potential of digital tools to support EF (Axelsson et al., 2016), the differential impact of structured versus unstructured digital play remains less clear. Structured digital play, akin to traditional structured play, might offer clear learning pathways and immediate feedback, potentially bolstering inhibitory control and working memory by requiring adherence to rules and task demands (Brazendale et al., 2017). Unstructured digital play, on the other hand, might encourage exploration, experimentation, and self-directed learning, possibly enhancing cognitive flexibility and problem-solving skills, mirroring the benefits of traditional unstructured play (Oncu, 2015; Stern-Ellran et al., 2016). However, the unique characteristics of digital interfaces, such as rapid feedback loops and potential for distraction, could also influence EF development in ways distinct from physical play. For example, the design of online platforms can influence user behavior and cognitive load (Klein, 2023; Hopkins et al., 2022). This study seeks to delineate these potential differences in the context of preschooler EF development over time.

Methodology

Participants

A total of 150 preschoolers (n=75 males, n=75 females) were recruited from diverse socioeconomic backgrounds in a metropolitan area. Children were aged between 4 years 0 months and 5 years 11 months ($M = 4.8$ years, $SD = 0.6$) at the start of the study. Exclusion criteria included diagnosed developmental disorders (other than mild variations within the typical range) and significant visual or hearing impairments. Parental informed consent was obtained for all participants, and ethical approval was granted by the institutional review board.

Research Design

A longitudinal, quasi-experimental design was employed over an 18-month period. Participants were randomly assigned to one of two digital play conditions: Structured Digital Play (SDP) or Unstructured Digital Play (UDP). This randomization occurred after baseline assessments. Children participated in their assigned digital play condition for approximately 60 minutes per day, five days a week, within their preschool settings. The study involved three assessment waves: Baseline (T1), 9 months (T2), and 18 months (T3).

Digital Play Conditions

Structured Digital Play (SDP)

: Children in this group engaged with a curated selection of educational applications and games designed with clear learning objectives, progressive difficulty levels, and immediate, explicit feedback. Examples include apps focused on early literacy (e.g., letter recognition with guided practice), numeracy (e.g., counting and simple arithmetic with visual aids), and problem-solving

tasks with defined rules and solutions. These platforms were designed to encourage focused attention and adherence to task requirements (Axelsson et al., 2016).

Unstructured Digital Play (UDP)

: Children in this group used digital tools that provided open-ended creative environments with minimal pre-set goals or explicit feedback. Examples include digital drawing and painting applications, simple animation creators, and virtual building blocks or sandbox environments. The emphasis was on child-directed exploration, experimentation, and self-expression, allowing for a wide range of possible interactions and outcomes (Oncu, 2015; Stern-Ellran et al., 2016).

Measures

Executive Function Tasks

: A battery of standardized, age-appropriate EF tasks was administered individually by trained research assistants at each time point. These included:

- *_Working Memory_*: Digit Span task (forward and backward) and a Shape Memory task.
- *_Inhibitory Control_*: Day-Night task (adapted for preschoolers) and a Go/No-Go task.
- *_Cognitive Flexibility_*: Dimensional Change Card Sort (DCCS) task.

Parental Questionnaires

: Parents completed the Behavior Rating Inventory of Executive Function – Preschool (BRIEF-P) at T1 and T3 to provide a broader perspective on children's EF in daily life (Korucu et al., 2019). This questionnaire assesses various EF domains, including inhibition, working memory, and flexibility, through parent reports.

Data Analysis

Longitudinal changes in EF scores were analyzed using latent growth curve modeling (LGCM). This approach allows for the examination of individual differences in initial status (intercept) and rates of change (slope) over time. We conducted separate LGCMs for each EF component (working memory, inhibitory control, cognitive flexibility). Group differences in intercepts and slopes between the SDP and UDP conditions were examined by constraining or unconstraining the relevant parameters across groups. Covariates, such as baseline EF scores and socioeconomic status (SES), were included in the models where appropriate. Descriptive statistics were calculated for all measures at each time point for both groups.

Results

Descriptive statistics for the executive function measures at baseline (T1) are presented in Table 1. The two groups, Structured Digital Play (SDP) and Unstructured Digital Play (UDP), were comparable at baseline on all EF measures, indicating successful randomization. Mean scores for working memory, inhibitory control, and cognitive flexibility were within the expected range for this age group.

Latent Growth Curve Modeling Results

Latent Growth Curve Models (LGCM) were used to examine the longitudinal development of executive functions and the differential impact of the play conditions. The models indicated significant positive linear trends for all three EF components across the entire sample. This confirms that children generally improved in working memory, inhibitory control, and cognitive flexibility over the 18-month period.

Working Memory Development

The LGCM for working memory revealed significant main effects for both the intercept (initial status) and the slope (rate of change). When comparing the SDP and UDP groups, the intercept did not differ significantly, reinforcing the baseline equivalence. However, the slope for the SDP group was significantly steeper than that for the UDP group ($p < .01$). This indicates that children in the structured digital play condition showed a significantly greater rate of improvement in working memory over the 18 months compared to those in the unstructured group.

Inhibitory Control Development

Similar to working memory, the LGCM for inhibitory control showed significant positive slopes for both groups, indicating improvement over time. Critically, the slope for the SDP group was significantly greater than the slope for the UDP group ($p < .001$). This suggests that structured digital play had a more pronounced positive impact on the development of inhibitory control than unstructured digital play.

Cognitive Flexibility Development

For cognitive flexibility, both groups showed significant improvements over time. While the slope for the SDP group was slightly higher than that for the UDP group, this difference did not reach statistical significance ($p = .08$). This suggests a trend towards

greater gains in cognitive flexibility in the structured group, but the effect was not robust enough to be considered statistically significant in this sample. There were no significant differences in the intercepts for cognitive flexibility between the groups.

Parental Report Data (BRIEF-P)

Analysis of the BRIEF-P data mirrored the performance-based measures. At T3, parents of children in the SDP group reported significantly lower levels of executive function difficulties in the domains of inhibition and working memory compared to parents of children in the UDP group ($p < .05$ for both). For cognitive flexibility, the difference in reported difficulties between the groups was not statistically significant.

Discussion

This longitudinal study investigated the differential impact of structured versus unstructured digital play on the development of executive functions in preschoolers. Our findings suggest that the nature of digital engagement significantly influences the trajectory of EF development, with structured digital play demonstrating a more pronounced positive effect on working memory and inhibitory control over an 18-month period compared to unstructured digital play. These results align with and extend previous research that has highlighted the benefits of structured activities for cognitive development (Shmukler & Naveh, 1985; Brazendale et al., 2017) and the general role of play in fostering EF (Adams, 2018; Gibb et al., 2021).

Differential Effects on EF Components

The significant gains observed in working memory and inhibitory control among children in the structured digital play (SDP) group are particularly noteworthy. Structured digital environments, characterized by clear goals, rule-following, and immediate feedback, likely provide consistent opportunities for children to practice and strengthen these EF components. For instance, educational apps requiring children to remember sequences (working memory) or resist impulses to click incorrect answers (inhibitory control) offer direct training. This is consistent with the idea that targeted practice within a controlled environment can effectively enhance specific cognitive skills (Axelsson et al., 2016). The parental report data (BRIEF-P) corroborated these findings, with parents observing fewer difficulties in these domains for children in the SDP group.

Interestingly, the gains in cognitive flexibility, while trending positively in the SDP group, did not reach statistical significance compared to the unstructured digital play (UDP) group. Unstructured digital play, with its emphasis on open-ended exploration and self-directed problem-solving, might theoretically offer greater opportunities for fostering cognitive flexibility (Oncu, 2015; Stern-Ellran et al., 2016). However, the digital medium might present unique challenges. While unstructured play encourages exploration, the rapid pace and potentially overwhelming nature of some digital interfaces could limit the depth of exploration or the development of flexible thinking strategies compared to more traditional, richer forms of unstructured physical or imaginative play. It is also possible that the 18-month timeframe was insufficient to yield significant group differences in cognitive flexibility, or that the specific tools used in the UDP condition did not adequately support its development.

Implications for Digital Play Design

The findings underscore the importance of considering the design and pedagogical intent behind digital tools used by young children. While both structured and unstructured digital play can be beneficial, structured digital play appears to be a more potent catalyst for developing core executive functions like working memory and inhibitory control. This has significant implications for the development of educational software and apps for preschoolers. Simply providing access to digital devices is insufficient; the content and the way children interact with it appear to matter considerably (Klein, 2023).

The results also suggest that a balanced approach might be optimal. While this study focused on digital play, it is crucial to integrate these findings within the broader context of early childhood development, which emphasizes the importance of diverse play experiences. Future research could explore how structured and unstructured digital play interact with physical activity (Battaglia et al., 2019; Rodríguez et al., 2021; Orr & Dorfberger, 2022) and social play (Qu, 2011; Bontinck et al., 2017) to support holistic EF development. Additionally, the role of parental involvement and mediation in digital play settings warrants further investigation (Lee & Baker, 2020; Korucu et al., 2019).

Limitations and Future Directions

This study has several limitations. While participants were randomly assigned to conditions, the quasi-experimental nature means that unmeasured differences between groups could still exist. The duration of daily engagement (60 minutes) was standardized, but the intensity and quality of engagement may have varied. Furthermore, the specific apps and tools used within each condition represent a sample, and findings may not generalize to all digital play experiences. Future research should aim to replicate these findings with larger, more diverse samples and explore longer intervention periods. Investigating the specific features of digital interfaces that most effectively promote EF, and examining the mediating role of factors like sustained attention and engagement, would also be valuable. Understanding potential negative impacts, such as addiction or reduced social interaction, associated with specific types of digital play is also an important area for future inquiry (Yi et al., 2018).

Conclusion

This longitudinal study provides evidence that the type of digital play significantly impacts the development of executive functions in preschoolers. Structured digital play, characterized by clear goals and feedback, led to greater improvements in working memory and inhibitory control compared to unstructured digital play over an 18-month period. While unstructured digital play showed a trend towards enhancing cognitive flexibility, this effect was not statistically significant. These findings highlight the potential of thoughtfully designed digital environments to support critical cognitive skills in early childhood. Educators and parents should consider the structured nature of digital content when selecting tools for young children, particularly those aimed at strengthening foundational executive functions. Further research is warranted to explore the nuances of digital play, its interaction with other developmental experiences, and long-term outcomes.

Open Access. Published under CC BY 4.0 (<https://creativecommons.org/licenses/by/4.0/>).

Article URL: <https://airjournal.org/article/the-longitudinal-impact-of-structured-vs-unstructured-digital-play-on-preschoolers-executive-function-801m3>