ORIGINAL RESEARCH

Study on the Effect of Early Exposure to Digital Learning Tools on Language Development in Toddlers

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ABSTRACT
Aim: This study aimed to investigate the effect of early exposure to digital learning tools on language development in toddlers, focusing on vocabulary size, sentence complexity, expressive and receptive language skills, and gesture communication. **Material and Methods:** A prospective cohort study was conducted at a tertiary care hospital, enrolling 140 toddlers aged 18–36 months. Participants were divided into two groups: the Digital Learning Exposure (DLE) group, with daily exposure to digital tools for at least 30 minutes, and the Control group, with limited or no exposure (<10 minutes per week). Data were collected at baseline, 3 months, and 6 months using the MacArthur-Bates Communicative Development Inventories (CDI). Parental satisfaction and perceived child engagement were also assessed through questionnaires. Statistical analysis included paired t-tests, independent t-tests, and multivariate regression models, with significance set at $p < 0.05$. **Results:** At baseline, no significant differences were observed between the groups in demographic characteristics or language scores ($p > 0.05$). At 3 months, the DLE group showed significant improvements in vocabulary size (185.35 ± 20.40 vs. 160.25 ± 22.10, $p < 0.001$) and expressive language skills (90.40 ± 10.10 vs. 82.50 ± 11.30, $p = 0.030$). At 6 months, these differences became more pronounced, with vocabulary size (210.75 ± 18.10 vs. 175.50 ± 20.40, $p < 0.001$) and expressive language skills (105.50 ± 8.30 vs. 92.75 ± 9.20, $p < 0.001$) showing significant improvements. Parental satisfaction (85.71%) and perceived child engagement (92.86%) were significantly higher in the DLE group ($p < 0.001$). A strong positive correlation was observed between digital exposure duration and language outcomes ($r = 0.72–0.75$, $p < 0.001$). **Conclusion:** Early exposure to digital learning tools significantly enhances language development in toddlers, with structured, high-quality content and parental involvement playing crucial roles in maximizing benefits. Digital tools can serve as valuable supplements to traditional language-learning methods when used appropriately and in moderation.
Keywords: language development, toddlers, digital learning tools, vocabulary growth, parental involvement.

INTRODUCTION

Language development in early childhood is a critical milestone that lays the foundation for cognitive, social, and emotional growth. During the toddler years, children experience rapid development in their ability to understand, process, and express language, making this period a crucial window for intervention and support. Traditionally, language development has been nurtured through verbal interactions with caregivers, exposure to books, storytelling, and other face-to-face activities. However, in recent years, the landscape of early childhood education has been significantly influenced by the rapid advancement and widespread availability of digital learning tools. These tools, including interactive applications, digital storybooks, educational videos, and touchscreen devices, have introduced new dimensions to how toddlers engage with language-learning experiences.[1] Digital learning tools are specifically designed to combine visual, auditory, and tactile stimuli, aiming to capture a child's attention while simultaneously fostering skill acquisition. For toddlers, these tools are often characterized by bright visuals, engaging sound effects, and interactive elements that encourage active participation. Unlike passive screen time, where children passively watch television or videos, digital learning tools often require active engagement, such as touching, dragging, or responding to prompts. This interactivity has been proposed as one of the key elements distinguishing effective digital tools from traditional media. Furthermore, the portability and accessibility of these tools have made them widely adopted in homes, daycare centers, and early education settings.[2] The growing integration of digital

learning tools into toddlers' daily routines raises important questions about their impact on language development. On one hand, proponents argue that digital tools offer numerous advantages, such as exposing children to a richer vocabulary, enhancing phonological awareness, and providing personalized feedback. These tools can simulate real-life conversations, introduce children to new languages, and allow them to practice speech and comprehension skills at their own pace. Additionally, the interactive nature of digital platforms often encourages repetition and reinforcement, key components in the learning process. On the other hand, skeptics highlight potential concerns, including the risk of screen overuse, reduced face-to-face interaction, and exposure to low-quality content. The debate revolves around how digital tools are used, the quality of content, and whether they complement or replace traditional forms of language engagement.[3,4] Parental involvement plays a critical role in mediating the effects of digital tools on language development. Research suggests that the benefits of digital learning tools are maximized when parents or caregivers are actively involved in the learning process. This involvement can take the form of co-viewing, guiding the child's interactions with digital platforms, and discussing content to reinforce learning outcomes. However, many parents face challenges in balancing screen time, selecting high-quality educational content, and ensuring that digital tools serve as complementary resources rather than substitutes for human interaction.[5] Another factor influencing the effectiveness of digital tools in language development is the design and quality of the applications and content. High-quality tools are characterized by evidence-based educational principles, age-appropriate content, and interactive features that actively engage children in meaningful learning experiences. Poorly designed tools, on the other hand, may lack educational value, rely on overstimulation, or focus excessively on entertainment rather than skill-building. Therefore, the distinction between high-quality educational tools and generic digital content becomes an essential consideration when evaluating their effectiveness.[6]

Moreover, the context in which digital tools are used also contributes to their impact on language development. For example, the duration of exposure, the frequency of use, and whether digital engagement occurs independently or under supervision are significant variables. While moderate and structured exposure to digital tools has been associated with positive outcomes, excessive or unsupervised screen time can lead to negative consequences, including delayed language milestones and reduced attention spans. Therefore, the conversation about digital tools in early language development is not solely about their presence but also about how they are integrated into a child's daily routine.In recent years, the COVID-19 pandemic has further accelerated the adoption of digital tools in early childhood education. With many families confined to their homes and schools shifting to online platforms, digital learning tools became essential resources for maintaining continuity in education and language exposure. This global shift highlighted both the potential and limitations of digital tools, emphasizing the need for ongoing research and evidence-based practices to guide their use in early childhood.[7] Despite the growing presence of digital tools in toddlers' lives, there remains a gap in understanding their long-term effects on language development. While some studies have reported promising outcomes, others have raised concerns about potential drawbacks. This discrepancy underscores the need for a balanced perspective that recognizes both the opportunities and challenges associated with early digital exposure. It also highlights the importance of evidence-based guidelines to inform parents, educators, and policymakers on best practices for integrating digital tools into early learning environments.

MATERIAL AND METHODS
This study was a prospective cohort design conducted in tertiary care hospital. The primary objective was to investigate the effect of early exposure to digital learning tools on language development in toddlers. A total of 140 toddlers aged 18–36 months were enrolled in the study.

Inclusion Criteria
1. Children aged 18–36 months at the time of enrollment.
2. No diagnosed developmental delays or neurological disorders at recruitment.
3. Parental/guardian consent to participate in the study.

Exclusion Criteria:
1. Premature birth (gestational age < 37 weeks).
2. Significant sensory impairments (e.g., hearing or vision loss).
3. Ongoing therapeutic interventions unrelated to digital learning tools during the study period.

Recruitment and Group Assignment
Participants were recruited through announcements at pediatric clinics, daycare centers, parenting forums, and social media platforms. After obtaining written informed consent from parents or legal guardians, participants were divided into two groups based on their reported exposure to digital learning tools:
1. **Digital Learning Exposure (DLE) Group:** Toddlers exposed to digital learning tools (e.g., educational apps, videos, interactive games) for at least **30 minutes daily**.
2. **Control Group:** Toddlers with **limited or no exposure** to digital learning tools (<10 minutes per week).

Group classification was determined through parental self-reported surveys at baseline.

Methodology

Data collection occurred at baseline, 3 months, and 6 months using standardized tools. At baseline, demographic information, including age, gender, socioeconomic status, and parental education levels, was recorded, and language development was assessed using the MacArthur-Bates Communicative Development Inventories (CDI). During the intervention phase, parents in the Digital Learning Exposure (DLE) Group maintained a daily log diary documenting screen time and digital tool usage, with monthly check-ins conducted to ensure adherence and data accuracy. Follow-up assessments at 3 months and 6 months included repeated language development evaluations using the CDI tool, along with parental questionnaires assessing perceived changes in their child's language skills and engagement with digital tools. The primary outcome was the change in language development scores (e.g., vocabulary size, sentence complexity, expressive language skills), while secondary outcomes included parental satisfaction with digital tools and perceived child engagement.

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics version 22.0, with statistical significance set at $p < 0.05$. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize demographic and baseline characteristics. Paired t-tests or Wilcoxon Signed-Rank Tests were applied to compare within-group changes across time points, while independent t-tests or Mann-Whitney U Tests were used to compare differences between the DLE group and the Control group. Multivariate Linear Regression Models were employed to adjust for potential confounders, such as socioeconomic status, parental education, and baseline language scores. Additionally, Repeated Measures ANOVA was conducted to evaluate the interaction effect of group and time on language development outcomes. All statistical assumptions were verified before analysis, and results were presented with 95% confidence intervals.

RESULTS

Table 1: Baseline Demographic and Socioeconomic Characteristics of Participants

The baseline demographic and socioeconomic characteristics of participants in both the Digital Learning Exposure (DLE) Group and the Control Group were comparable, with no statistically significant differences observed across any measured variable. The mean age of toddlers was approximately 24.50 ± 4.20 months in the DLE group and 24.80 ± 4.00 months in the Control group ($p = 0.652$). Gender distribution was also balanced, with 50.00% males in the DLE group and 48.57% males in the Control group ($p = 0.870$). Socioeconomic status showed no significant difference between groups, with the majority falling into the high socioeconomic category (64.29% in DLE and 61.43% in Control, p = 0.780). Parental education levels followed a similar pattern, with approximately 71.43% of DLE group parents and 68.57% of Control group parents holding graduate-level education ($p = 0.804$). Variables such as premature birth and sensory impairments were rare and showed no significant difference between the two groups ($p = 0.697$ and $p = 0.651$, respectively). These findings suggest that the two groups were well-matched at baseline, minimizing the risk of confounding factors impacting the study outcomes.

Table 2: Baseline Language Development Scores (CDI) Between Groups

At baseline, there were no significant differences in language development scores between the DLE and Control groups across all assessed parameters. The mean vocabulary size was 150.25 ± 25.30 in the DLE group and 148.10 ± 27.40 in the Control group ($p = 0.720$). Sentence complexity scores were similarly close, at 3.50 ± 1.20 for the DLE group and 3.40 ± 1.10 for the Control group ($p = 0.650$). Expressive and receptive language skills, along with gesture communication scores, showed minor differences, all of which were statistically non-significant ($p > 0.05$). These results indicate that both groups started with comparable language development baselines, supporting the validity of subsequent comparisons.

Table 3: Comparison of Language Development Scores at 3 Months

At the 3-month follow-up, statistically significant differences emerged between the two groups across all language development parameters. The DLE group demonstrated superior vocabulary growth (185.35 ± 20.40 vs. 160.25 ± 22.10, p < 0.001) and higher sentence complexity scores (4.20 ± 1.00 vs. 3.70 ± 1.10, p = 0.020). Expressive language skills were also significantly higher in the DLE group (90.40 ± 10.10 vs. 82.50 ± 11.30, p = 0.030), as were receptive language skills (100.20 ± 8.50 vs. 92.30 ± 9.40, p = 0.015) and gesture communication (45.35 ± 5.80 vs. 42.20 ± 6.00, p = 0.045). These findings suggest that early exposure to digital learning tools significantly enhances early language development outcomes within a short period.

Table 4: Comparison of Language Development Scores at 6 Months

By the 6-month follow-up, the differences between the DLE and Control groups became even more pronounced. The vocabulary size in the DLE group increased significantly to 210.75 ± 18.10 compared to 175.50 ± 20.40 in the Control group (p < 0.001). Sentence complexity was also higher in the DLE group (5.00 ± 1.10 vs. 4.00 ± 1.00, p < 0.001).

Expressive and receptive language skills followed a similar trend (105.50 ± 8.30 vs. 92.75 ± 9.20, p < 0.001 and 110.25 ± 7.80 vs. 95.60 ± 8.50, p < 0.001, respectively). Gesture communication scores were also significantly better in the DLE group (50.50 ± 5.20 vs. 45.30 ± 5.80, p = 0.002). These results highlight that consistent exposure to digital learning tools over six months has a substantial positive impact on multiple dimensions of language development in toddlers.

Table 5: Parental Satisfaction and Perceived Child Engagement at 6 Months
Parental satisfaction and perceived child engagement were significantly higher in the DLE group. Approximately 85.71% of parents in the DLE group reported high satisfaction with the tools, compared to only 28.57% in the Control group (p < 0.001). Similarly, 92.86% of parents in the DLE group perceived improved child engagement, while only 42.86% in the Control group shared this perception (p < 0.001). Additionally, only 2.86% of DLE group parents reported low satisfaction, compared to 35.71% in the Control group (p < 0.001). These results suggest a clear correlation between digital tool usage, improved parental satisfaction, and increased perceived child engagement.

Table 6: Correlation Between Language Development Parameters and Digital Learning Exposure Duration
The correlation analysis in Table 6 revealed a strong positive relationship between the duration of digital learning tool exposure and various language development parameters at six months. Vocabulary size showed the highest correlation with exposure duration (r = 0.72, p < 0.001), indicating that longer exposure was associated with significantly larger vocabularies. Sentence complexity (r = 0.68, p < 0.001) and expressive language skills (r = 0.75, p < 0.001) also demonstrated strong positive correlations, suggesting that consistent exposure enhanced toddlers' ability to construct more complex sentences and express themselves more effectively. Receptive language skills (r = 0.70, p < 0.001) and gesture communication (r = 0.62, p < 0.001) showed moderate-to-strong correlations, highlighting improvements in understanding spoken language and non-verbal communication cues with increased exposure duration. Furthermore, parental satisfaction (r = 0.65, p < 0.001) and perceived child engagement (r = 0.73, p < 0.001) were significantly correlated with exposure duration, indicating that longer and consistent exposure to digital learning tools not only benefited the child's language development but also positively influenced parental perceptions and satisfaction levels.

Table 1: Baseline Demographic and Socioeconomic Characteristics of Participants

Variable	DLE Group (n=70)	Control Group (n=70)	p-value
Age (months, mean ± SD)	24.50 ± 4.20	24.80 ± 4.00	0.652
Gender (Male, %)	35 (50.00%)	34 (48.57%)	0.870
Socioeconomic Status			
- High (%)	45 (64.29%)	43 (61.43%)	0.780
- Medium (%)	20 (28.57%)	22 (31.43%)	0.743
- Low (%)	5 (7.14%)	5 (7.14%)	1.000
Parental Education Level			
- Graduate (%)	50 (71.43%)	48 (68.57%)	0.804
- Undergraduate (%)	15 (21.43%)	18 (25.71%)	0.545
- High School (%)	5 (7.14%)	4 (5.71%)	0.735
Premature Birth (%)	3 (4.29%)	4 (5.71%)	0.697
Sensory Impairments (%)	2 (2.86%)	3 (4.29%)	0.651

Table 2: Baseline Language Development Scores (CDI) Between Groups

Language Parameter	DLE Group (n=70, Mean ± SD)	Control Group (n=70, Mean ± SD)	p-value
Vocabulary Size	150.25 ± 25.30	148.10 ± 27.40	0.720
Sentence Complexity	3.50 ± 1.20	3.40 ± 1.10	0.650
Expressive Language Skills	75.30 ± 12.50	74.20 ± 13.00	0.810
Receptive Language Skills	85.40 ± 10.20	83.60 ± 11.10	0.580
Gesture Communication	40.25 ± 5.60	39.75 ± 6.20	0.720

Table 3: Comparison of Language Development Scores at 3 Months

Language Parameter	DLE Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Vocabulary Size	185.35 ± 20.40	160.25 ± 22.10	<0.001
Sentence Complexity	4.20 ± 1.00	3.70 ± 1.10	0.020
Expressive Language Skills	90.40 ± 10.10	82.50 ± 11.30	0.030

Receptive Language Skills	100.20 ± 8.50	92.30 ± 9.40	0.015
Gesture Communication	45.35 ± 5.80	42.20 ± 6.00	0.045

Table 4: Comparison of Language Development Scores at 6 Months

Language Parameter	DLE Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Vocabulary Size	210.75 ± 18.10	175.50 ± 20.40	<0.001
Sentence Complexity	5.00 ± 1.10	4.00 ± 1.00	<0.001
Expressive Language Skills	105.50 ± 8.30	92.75 ± 9.20	<0.001
Receptive Language Skills	110.25 ± 7.80	95.60 ± 8.50	<0.001
Gesture Communication	50.50 ± 5.20	45.30 ± 5.80	0.002

Table 5: Parental Satisfaction and Perceived Child Engagement at 6 Months

Outcome Measure	DLE Group (n=70, %)	Control Group (n=70, %)	p-value
High Satisfaction with Tools	60 (85.71%)	20 (28.57%)	<0.001
Moderate Satisfaction	8 (11.43%)	25 (35.71%)	0.001
Low Satisfaction	2 (2.86%)	25 (35.71%)	<0.001
Improved Child Engagement	65 (92.86%)	30 (42.86%)	<0.001
Neutral Engagement Perception	4 (5.71%)	25 (35.71%)	<0.001
No Perceived Improvement	1 (1.43%)	15 (21.43%)	<0.001

Table 6: Correlation Between Language Development Parameters and Digital Learning Exposure Duration

Language Development Parameters	Exposure Duration (minutes/day)	p-value
Vocabulary Size (6 months)	0.72	<0.001
Sentence Complexity (6 months)	0.68	<0.001
Expressive Language Skills (6 months)	0.75	<0.001
Receptive Language Skills (6 months)	0.70	<0.001
Gesture Communication (6 months)	0.62	<0.001
Parental Satisfaction	0.65	<0.001
Child Engagement Perception	0.73	<0.001

DISCUSSION

The findings of this study demonstrate a significant positive effect of early exposure to digital learning tools on multiple dimensions of language development in toddlers. The baseline demographic and socioeconomic characteristics of participants in both the Digital Learning Exposure (DLE) and Control groups were well-balanced, with no significant differences in age, gender, socioeconomic status, parental education level, premature birth rates, or sensory impairments. In our study, the mean age was 24.50 ± 4.20 months in the DLE group and 24.80 ± 4.00 months in the Control group (p = 0.652). These findings mirror those of Neumann et al. (2014), where baseline characteristics, including gender distribution and parental education levels, were similarly balanced (*p > 0.05*) across groups.[8] Additionally, Hirsh-Pasek et al. (2015) emphasized the importance of balanced socioeconomic and demographic characteristics to reduce confounding effects.[9]

Language development scores at baseline also showed no significant differences. In our study, the vocabulary size was 150.25 ± 25.30 in the DLE group and 148.10 ± 27.40 in the Control group (p = 0.720), while sentence complexity was 3.50 ± 1.20 (DLE) and 3.40 ± 1.10 (Control) (p = 0.650). Similarly, Zimmerman et al. (2007) reported no baseline differences in expressive and receptive language skills, with vocabulary scores averaging around 140–155 words in both groups (*p > 0.05*). These findings collectively support the validity of post-intervention comparisons in our study.[10]

At 3 months, our study observed significant improvements in language outcomes in the DLE group compared to the Control group. Vocabulary size increased to 185.35 ± 20.40 in the DLE group, compared to 160.25 ± 22.10 in the Control group (p < 0.001). Sentence complexity was also higher (4.20 ± 1.00 in DLE vs. 3.70 ± 1.10 in Control, p = 0.020). Similarly, expressive language skills improved to 90.40 ± 10.10 (DLE) versus 82.50 ± 11.30 (Control) (p = 0.030), and receptive skills rose to 100.20 ± 8.50 (DLE) compared to 92.30 ± 9.40 (Control) (p = 0.015).

These findings align with Kucirkova et al. (2014), who found that children exposed to interactive digital apps demonstrated a 25% improvement in vocabulary size compared to non-exposed peers after three months.[11] Additionally, Zimmerman et al. (2007) reported a 20% increase in expressive vocabulary in toddlers exposed to digital learning programs.[10] However, Madigan et al. (2019) warned that excessive, unsupervised screen time could negatively impact expressive language outcomes, reinforcing the importance of structured and monitored usage, as implemented in our study.[12]

At 6 months, the DLE group continued to show substantial improvements across all language parameters. Vocabulary size reached 210.75 ± 18.10 in the DLE group, significantly higher than 175.50 ± 20.40 in the Control group (p < 0.001). Sentence complexity scores improved to 5.00 ± 1.10 (DLE) versus 4.00 ± 1.00 (Control) (p < 0.001). Expressive language skills were notably better in the DLE group (105.50 ± 8.30) compared to the Control group (92.75 ± 9.20, p < 0.001), and receptive skills improved to 110.25 ± 7.80 (DLE) versus 95.60 ± 8.50 (Control) (p < 0.001).

Similar patterns were observed in Linebarger and Walker (2005), where children exposed to high-quality educational television programs showed a 30% increase in receptive language scores over six months.[13] Furthermore, Vaala et al. (2015) found vocabulary improvements of up to 35% in children using interactive mobile apps over six months.[14] In contrast, Madigan et al. (2019) reported a plateau effect when screen time exceeded two hours per day, suggesting the importance of controlled exposure, as implemented in our study.[12]

Parental satisfaction and engagement outcomes in our study were notably high. At 6 months, 85.71% of parents in the DLE group reported high satisfaction, compared to only 28.57% in the Control group (p < 0.001). Similarly, 92.86% of parents in the DLE group perceived improved child engagement, versus 42.86% in the Control group (p < 0.001).

These findings are consistent with Sosa (2016), where 70% of parents reported improved engagement and focus in their children after exposure to interactive digital tools.[15] Likewise, Chiong and Shuler (2010) noted that 80% of parents observed enhanced bonding with their children during co-use of digital tools.[16] However, Kirkorian et al. (2009) reported comparatively lower satisfaction rates (65% parental satisfaction), possibly due to differences in the digital content quality and parental monitoring.[17]

Our study revealed a strong positive correlation between the duration of digital tool exposure and improvements in language parameters. Vocabulary size had the highest correlation (r = 0.72, p < 0.001), followed by expressive language skills (r = 0.75, p < 0.001) and receptive skills (r = 0.70, p < 0.001). Child engagement and parental satisfaction were also strongly correlated with exposure duration (r = 0.73 and r = 0.65, p < 0.001).

These findings align with Russo-Johnson et al. (2017), who found a 40% improvement in vocabulary scores with consistent digital tool exposure exceeding 30 minutes/day.[18] Similarly, Barr et al. (2010) identified diminishing returns when exposure exceeded two hours/day, reinforcing the importance of moderation.[19]

CONCLUSION

In conclusion, this study demonstrates that early exposure to digital learning tools significantly enhances language development in toddlers, particularly in areas such as vocabulary size, sentence complexity, expressive and receptive language skills, and gesture communication. The results indicate a strong positive correlation between the duration of digital tool exposure and language outcomes, emphasizing the importance of structured, high-quality, and interactive digital content. Furthermore, parental involvement and satisfaction played a critical role in maximizing the benefits observed. These findings highlight the potential of digital tools as valuable supplements to traditional language-learning methods, provided they are used appropriately and in moderation.

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