The Role of Cognitive Abilities and Eye-Movement in Storytelling Proficiency Among Prereaders in Digital Storytelling

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https://doi.org/10.54855/callej.2526410

Received: 22/01/2025 Revision: 16/04/2025 Accepted: 08/06/2025 Online: 22/09/2025

ABSTRACT

This study examines the relationship between cognitive skills and eye-movement patterns towards the storytelling performance among pre-readers in the context of digital storytelling. 42 Mandarin-based kindergarten children aged 5 to 6 years took part in the study. Children listened to a story read aloud along with congruent pictures and text on a digital screen. Then, they were asked to retell the story after playing a game. Their storytelling performance was rated using rating scales, and their eye movements were measured using an eye tracker. These children were given three cognitive tests to determine their visual attention, auditory attention, and verbal fluency. The data were analysed using the partial least squares structural equation modelling (PLS-SEM) methodology. The findings found that fixation duration fully mediates the relationship between visual attention and storytelling performance. The auditory attention emerged as a secondary factor contributing to storytelling performance. These findings provide new insights into the cognitive mechanisms underpinning early literacy development in digital environments.

Keywords: cognitive, attention, eye movement, children, literacy

Introduction

As digital tools become more and more integrated into education, more and more people have begun to focus on how technology can be used to aid in early literacy development. Although several studies have been done on the topic of literacy skills among young children, little has been done on the cognitive mechanisms that support these skills, especially in prereaders. Literacy acquisition depends mostly on cognitive processes, which include the capability of the brain to process environmental information (Atkinson and Shiffrin, 1968; Sweller, 1988). Prereaders are defined as young children who have not received formal reading instructions. The inability of the prereaders to articulate their thinking, however, presents problems to

CITATION | Loo, F. L., Thang, S. M., Wong, H. K., & Rosalind, A. (2025). The Role of Cognitive Abilities and Eye-Movement in Storytelling Proficiency Among Prereaders in Digital Storytelling. *Computer-Assisted Language Learning Electronic Journal (CALL-EJ)*, 26(4), 193-212. DOI: https://doi.org/10.54855/callej.2526410

researchers, and therefore, new methodological means to understand the cognitive activities of prereaders need to be developed, like eye-tracking.

Eye-tracking studies have emerged as an effective method to study cognitive mechanisms, with a significant contribution to the study of visual attention and fixations. As an example, Takacs and Bus (2018) studied how prereaders read picture storybooks as they listened to narration. Their findings confirmed that congruent pictures and congruent narration play a vital role in enhancing the story comprehension function and retelling skill; therefore, the importance of the multimodal learning environment. Similar methodologies were used by Thang et al. (2022), who noted that prereaders were challenged to work in text-only situations, especially those who had low storytelling skills. This is consistent with evidence that young children tend to focus on visual over textual information in storybooks (Wong et al., 2023). These observations lead to the interaction of thinking skills and narrative, and the necessity to address the process of developing literacy with the assistance of auditory and visual means.

Moreover, previous studies have indicated that, in general, preschoolers are less attentive compared with older children (Akshoomoff, 2002; Corkum et al., 1995). The level of language proficiency and verbal communication also affects their cognitive interest in storytelling activities (Justice et al., 2008; Kaefer et al., 2017). These issues are important to the development of any effective intervention that can use technology to promote early literacy.

Literature review

Cognitive Theories and Digital Storytelling

Storytelling is a complex mental process that involves attention, memory, and language comprehension. The processes allow children to comprehend, memorise, and describe narrative information. Several cognitive theories, such as the Information Processing Theory, the Executive Functioning Theory, Dual Coding Theory, and Cognitive Load Theory, describe the processes that influence the performance of storytelling in prereaders and determine the performance of digital storytelling settings. The Information Processing Theory (Atkinson & Shiffrin, 1968) requires that attention is significant during the encoding, storage, and retrieval of information. Prereaders have to use visual and auditory attention to decode a visual and auditory message, i.e., illustrations and oral stories, that are stored in the working memory to be accessed when retelling the story. Digitally told stories using synchronised audio and visual elements fall within this theory to improve the impact of encoding.

Besides this, the Executive Functioning Theory (Ozonoff & Jensen, 1999) reveals the interaction between working memory, inhibitory control, and cognitive flexibility in the narration of a story. The narrative elements are stored in working memory, and inhibitory control helps prereaders focus on the corresponding details and eliminate distractions. Cognitive flexibility enables children to alternate their focus among the different parts of the narrative (e.g., between illustration and oral narration). These executive functions are developed over time, and the difference between the two influences the outcomes of storytelling at various developmental phases. These functions may be further enhanced by providing children with the chance to engage with narratives dynamically through digital tools that foster interactivity.

Moreover, the Cognitive Load Theory (Sweller, 1988) explains the association between overloaded cognitive schemas and learning and retention. Short-term working memory of prereaders is limited, and in an environment with too many visual or auditory stimuli, the process of processing and retaining narrative information is impaired. A well-designed digital storytelling platform simplifies the visual and audio input to be congruent, making cognitive load management the most effective method to maximise storytelling performance and comprehension. Another factor worth noting is that Dual Coding Theory (Paivio, 1990) notes that the employment of both verbal and visual stimulating factors is critical to ensure a higher level of understanding and remembrance. In this theory, the association of images with words leads to the formation of two memory traces that are easier to recall and improve the ability to understand stories. An excellent example of the benefits of this multimodal approach is digital stories that pair pictures with the text, particularly when working with multimedia learning and prereaders. One can have two processing channels being used, such as animated illustrations with text speech.

Cognitive Ability Test

The cognitive ability tests that will be used in the current research are based on NEPSY Neuropsychological Assessment Manual (Korkman et al., 1998), a commercial test of developmental and neuropsychological skills in preschool and school-aged children. The NEPSY model is a general assessment of 5 domains: attention/executive functions, language, sensorimotor functions, visuospatial processing, and memory learning. This study explores three cognitive skills that are relevant in the engagement of storytelling: visual attention, auditory attention, and verbal fluency.

Visual attention can be defined as the ability of a child to concentrate on visual images, which will be employed later to manipulate illustrations and other presentations during narration (Justice et al., 2008). The ability will enable the child to effectively encode the information presented in the form of a picture into a narrative, thereby matching the picture and the narrative. Auditory attention: this is the observation of the child in relation to his or her attention to sounds and is a prerequisite to processing and internalisation of oral stories. According to Sweller (1988) and Arslan-Ari and Ari (2021), auditory attention is the only way one can synthesise spoken information and develop successful representations of the story. Verbal fluency is a test that combines cognitive and linguistic potential to test whether a child can produce and organise words into semantic groups. This skill comes into play when one is creating logical anecdotes in development, as Kuperman and Van Dyke (2011) indicate, and this is one of the predictors of success as a narrator.

The tests are based on the cognitive theory and the empirical research that they are engaged in storytelling experiences. To develop this idea further, the integration of audio and visual attention is open to the dual coding theory (Paivio, 1990), which suggests that multimodal inputs contribute to memory and understanding. Further, NEPSY developmental design aligns with age-related cognitive variation in such tasks; thus, it is a versatile and valid tool that may be utilised to assess the cognitive abilities of prereaders within the context of digital storytelling.

Eye-Tracking Metrics and Cognitive Engagement

Eye-tracking can give the required data regarding the interaction of prereaders with verbal and visual storytelling features and allow the researchers to monitor the dynamics of cognitive interaction in real-time. The fixation time and the revisits are significant indicators of attentional attention. Fixation patterns can be a source of invaluable information on the cognitive processes underlying reading storybooks in children. These measures may demonstrate how children split their attention and the consequences of this splitting in learning when they are presented with multimedia texts, i.e., illustrated texts, educational videos, or interactive digital media (Alemdag & Cagiltay, 2018; Arslan-Ari & Ari, 2021; Sun et al., 2019). Specifically, the longer the obsession with specific objects, the more interested the mind is in the information and it is encoded (Henderson et al., 2015; Liu et al., 2020; Negi & Mitra, 2020). Alternatively, the high revisit counts may be an indicator of issues with information integration or active searching behaviour, which may indicate in what areas new instructional support is required. It is this type of low-key pattern that the visual stimuli are reacting to, particularly in terms of cognitive load, especially when learning multimedia in children.

In accordance with the Dual Coding Theory (Paivio, 1990), the synergistic interdependence between the verbal and visual channels in enhancing memory retention and understanding is examined. The degree to which the children integrate these multimodal inputs is indicated objectively by patterns of fixation, which depend on eye-tracking. Patterns of effective fixation (concentrated and maintained attention to the visual scene) are strongly linked to improved recall and understanding of narratives. This is supported by the Multimedia Learning Theory formulated by Mayer (2005), which explains that the learning outcomes are significantly enhanced when both the verbal and the visual elements are combined in a reconciled manner. The importance of synchronised multimodal inputs can be justified by the fact that eye-tracking studies demonstrate these efficient patterns, and consequently, lead to the relevance of adequately aligned verbal and visual components in teaching devices designed to assist prereaders.

Moreover, fixation patterns, mainly when analysed with recall performance, can also indicate whether multimedia content activates relevant prior knowledge, a critical factor in learning. Children who can connect new information with what they already know might display different fixation patterns, such as more focused attention on novel information or quicker identification of relevant details. This connection between prior knowledge and fixation patterns underscores the importance of designing educational content that builds on learners' existing knowledge (Reich et al., 2019). Researchers can identify how these differences affect storybook reading processes by analysing fixation patterns and recall performance. For example, research by Goswami and Bryant (2012) highlights how variations in cognitive development stages influence attention and learning outcomes.

In the current experiment, eye-tracking data is compared with the images and target objects in images based on two areas of interest (AOIs). Mean fixation time on these AOIs will be a key parameter in visual attention allocation, which will inform about the role of prereaders in addressing the different parts of the storybook. In order to present the subject matter in the most simplified and advantageous way, we have reduced the objects of interest to five. The rationale behind this step is the findings of Eng et al. (2020), which stated that the support of early readers could be achieved through minimising distractions.

The Current Study

One of the fundamentals of child literacy development is storytelling, and it requires the application of some critical literacy skills, including language learning, imagination, empathy, and social awareness. On the one hand, retelling a story presupposes that a child is supposed to remember, sort, and retell the main facts, events, characters, and ideas of new texts read or heard in the recent past. It is a good test of the growth and development of literacy (Cunningham & Stanovich, 1997; Isbell et al., 2004; Qin et al., 2019).

Story retelling is an important part of cognition, including attention, processing, memory, and language. Narrative elements must be encoded and integrated through visual and auditory focus, as well as meaningful expression, which is presented through verbal fluency. The relevance of visual attention as the driver of narrative understanding has been recently proved through eye-tracking research on how preschoolers allocate their attention and process visual information when reading a story (Arslan-Ari & Ari, 2021; Evans & Saint-Aubin, 2005; Justice et al., 2008; Kaefer et al., 2017). Moreover, the working memory also promotes the ability of the child to relate the visual and auditory data to prior knowledge, which allows them to reconstruct stories successfully (Kuperman and Van Dyke, 2011).

With the increasing popularity of digital storytelling experiences, there is a need to investigate the impact of these influences on how prereaders respond to digital stories, and this is what will be examined in this research. Besides, the connection between cognitive skills, eye tracking, and the retelling of the story to prereaders has also been analysed with the newest methodological analysis tool, the Partial Least Squares Structural Equation Modeling (PLS-SEM), which is not commonly used in this type of research.

In this study, it is assumed that the duration of fixation and story-retelling performance directly depend on cognitive abilities, and that the duration of fixation mediates between cognitive abilities and narrative performance. The conceptual framework supports the following hypotheses of the research:

H1: Prereaders who have a higher level of visual attention have an improved performance at storytelling .

H2: Prereaders who have a higher level of auditory attention are better at storytelling H3: Prereaders who have superior verbal fluency perform better at - storytelling.

H4: Prereaders who have higher visual attention have a longer fixation.

H5: Prereaders who have a high level of auditory attention have a longer fixation time.

H6: Prereaders who have longer fixation times perform better at storytelling

Methods

Participants

The participants in this study were 42 children of 5-6 years of age who were recruited in one Chinese-medium kindergarten in Selangor, Malaysia. The first language and medium of instruction of the participants was Mandarin. The given age bracket was chosen to address pre-readers who had not yet been taught how to read. In the context of ethical research, ethical permission was granted by parents prior to the collection of data.

Research Ethics

This research followed the provisions of research ethics in studies involving human subjects. Informed consent was signed in writing by the principals and teachers of the involved kindergarten and their parents or guardians after being fully informed of the objectives of the study, the procedures, as well as their right to withdraw at any time without any penalty. In the research, confidentiality and anonymity of the participants were strictly observed. Information was kept safely and employed only as part of the academic intention according to the institutional and ethical norms.

Cognitive Ability Tests

The three cognitive ability tests to be used in this study were derived based on the NEPSY Neuropsychological Assessment Manual (Korkman et al., 1998). Visual Attention (VA) and Auditory Attention (AA) are the first two tests of the Attention/Executive Functions domain. These tests evaluate the ability of the children to maintain visual and auditory attention, which are skills that are considered to be necessary to perform best in eye-tracking experiments. It is theorised that children with good results in the VA and AA tests will show better sustained attention in the eye-tracking tests.

Verbal Fluency (VF) is the third test that is based on the Language domain of NEPSY. This is an evaluation of word production on memory power within particular semantic categories, which are directly connected to the coherent storytelling capabilities of the children. It is expected that better performance in the VF test should be associated with better storytelling skills as assessed in the narrative tasks conducted as part of the study. These three tests are consistent with the purpose of the study, which is to assess the auditory, visual, and verbal skills of prereaders. Every child was randomly given one of the three cognitive tests as shown in Table 1. How these tasks are to be done is given in detail in Appendix A.

Table 1

Assignment of children to different tasks

	Auditory	Visual Attention	Verbal Fluency
Description	To investigate the child's listening ability	To investigate the child's visual ability	To investigate the child's ability to express ideas
Randomly assigned	Child A	Child B	Child C
	Child B	Child A	Child D
	Child C	Child D	Child A
	Child D	Child C	Child B

Eye-Tracking Procedure

Eye-tracking data were collected using a Gazepoint GP3 HD eye tracker, operating at a 150Hz sampling rate with an accuracy of 0.5 degrees. A chinrest, positioned 60 cm from the monitor, was used to minimise head movement and ensure consistent data collection. To ensure the validity of the eye-tracking data, a five-point calibration procedure was individually conducted for each child before the storytelling session. Only sessions achieving successful calibration and minimal data loss (less than 10%) were included in the final dataset. Before calibration, a brief familiarisation session was provided to help children become comfortable with the equipment and task requirements. Data collection occurred in a quiet, child-friendly environment to reduce distractions and optimise participant engagement. The Gazepoint Analysis software was used to record key metrics, including fixation durations within predefined Areas of Interest (AOIs), designed to capture attention distribution and engagement with visual and textual storytelling elements. Children were exposed to a congruent storytelling condition. They listened to narrated stories while viewing synchronised text and illustrations on a computer monitor. Figure 1 provides an example of the materials used during the session.

Figure 1.

Sample Storytelling Material

Condition	On-screen	Oral narration
Congruent	 Matching picture and text	Matching Oral Narration It is a windy day. Mama and John are sitting in the back garden. They are eating a bowl of green bean porridge. "Look at the wind blowing the shirts and pants around", mama says. "Yes, they look like people flying around," John shouts happily. Mama has her pink and white shopping bag by her side. She plans to go shopping with John after this. They are having a good time, enjoying the breeze and looking at the cabbage patch.

Note. The story segment shown was part of the digital storytelling task.

Storytelling *Task*

Following the distraction task (e.g., building a Lego toy), children were invited to tell the story. When necessary, open-ended prompts such as "Can you tell me more?" were provided to encourage detailed narratives. Three independent raters with advanced degrees in education transcribed and evaluated the retellings. They used a five-point scale to assess the performance, and consensus was reached through discussion to ensure reliability.

Data Analysis

Descriptive statistics were computed using IBM SPSS (Version 28) for cognitive test scores (visual attention, auditory attention, verbal fluency), eye-movement patterns (fixation duration on images and objects, recorded in milliseconds), and storytelling performance (STP) scores. Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed via SmartPLS (Version 4.0) to explore the relationships between cognitive abilities, fixation behaviours, and STP outcomes. PLS-SEM was selected for its appropriateness for small samples and complex path modeling. The analysis included evaluating the measurement model (validity and reliability) and the structural model (hypothesis testing) using bootstrapping with 5,000 resamples. An Importance-Performance Map Analysis (IPMA) was also conducted to identify factors most critical to storytelling performance.

Results

Homogeneity of Variance Test

This study included 42 participants divided into two age groups: 25 children aged 4+ (60%) and 17 children aged 5+ (40%). Levene's Test for Equality of Variances (Levene, 1960) was employed to ensure comparability across groups. Following this, an independent samples T-test was conducted using SPSS statistical software (version 28). The p-values for cognitive processing measures in both age groups were greater than 0.05 ($p > 0.05$), indicating that the assumption of equal variances was met. Consequently, the null hypothesis was accepted, positing no significant difference in variances. It is concluded that there is no statistically significant difference in variances between 4+ and 5+ year-old children. The results confirm that cognitive and eye-movement measures can be reliably compared within the two age groups. The results of cognitive and eye-movement tests are shown in Table 2.

Table 2.

Summary of Cognitive and Eye-movement Test results (N=42)

Measure	Min	Max	Mean	SD
Cognitive tests				
Visual attention	1	23	7.12	4.24
Auditory attention 1	1	47	26.02	11.78
Auditory attention 2	-2	46	25.88	12.07
Verbal fluency 1	1	15	8.64	3.05
Verbal fluency 2	2	16	8.12	3.40
Eye-movement patterns (ms)				
Fixation duration on the image	0.27	30.74	19.97	6.86
Fixation duration on objects	1.16	14.01	7.48	3.58
Storytelling				
Storytelling score	1	5	2.14	1.05

Note. Eye-movement durations are reported in milliseconds (ms). Verbal fluency and attention scores reflect raw scores from NEPSY assessments. Storytelling scores were rated on a 5-point scale by trained raters based on retelling quality.

Structural Equation Model (SEM) Analysis

Data analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) techniques. The PLS path model was examined using Smart PLS 4.0 software (Ringle et al., 2022). It involved an evaluation of the reliability and validity of both the measurement and the structural models. The measurement model's characteristics were scrutinised to ascertain the validity and reliability of the relationships between the indicators and latent constructs. A structural model analysis was carried out to assess the significance of the path coefficients within the primary model. Finally, bootstrapping was employed to examine and validate the proposed model and the hypothesised constructs.

(a) Measurement Model Assessment

Several aspects were assessed to validate the measurement model, including indicator loadings, convergent validity, internal consistency reliability, and discriminant validity.

1. Indicator reliability

The reliability of individual indicators was evaluated by examining their outer loadings. As shown in Table 3, all loadings exceeded 0.700, signifying that the indicators exhibited substantial reliability (Hair et al., 2022).

Table 3.

Indicator Loadings

Indicators	Visual attention	Auditory attention	Verbal fluency	Eye-movement	Storytelling
Visual	1.000				
Auditory 1		0.773			
Auditory 2		0.842			
Verbal 1			0.825		
Verbal 2			0.798		
Image				0.928	
Objects				0.862	
Storytelling					1.000

Note. All indicator loadings ≥ 0.70 indicate acceptable reliability (Hair et al., 2022).

2. Convergent validity and reliability

The internal consistency reliability of the measures was assessed using the composite reliability coefficient. The obtained values for composite reliability (ρc) ranged from 0.790 to 0.890, indicating a level of reliability considered 'satisfactory to good' (Hair et al., 2022) in Table 3. These values affirm the adequate internal consistency and reliability of the measurements. Additionally, convergent validity was evaluated using the Average Variance Extracted (AVE). In Table 4, the AVE values for the latent constructs ranged from 0.653 to 0.803, surpassing the recommended minimum threshold of 0.50 (Hair et al., 2022). Since both constructs, visual attention and storytelling, are assessed using a single measure, convergent validity and reliability applications are not applicable in this context.

Table 4.

Convergent validity and reliability

Construct	Composite Reliability (ρc)	AVE
Auditory attention	0.790	0.653
Verbal fluency	0.794	0.658
Eye-movement	0.890	0.803

Note. AVE = Average Variance Extracted; ρc = Composite Reliability.

3. Discriminant validity

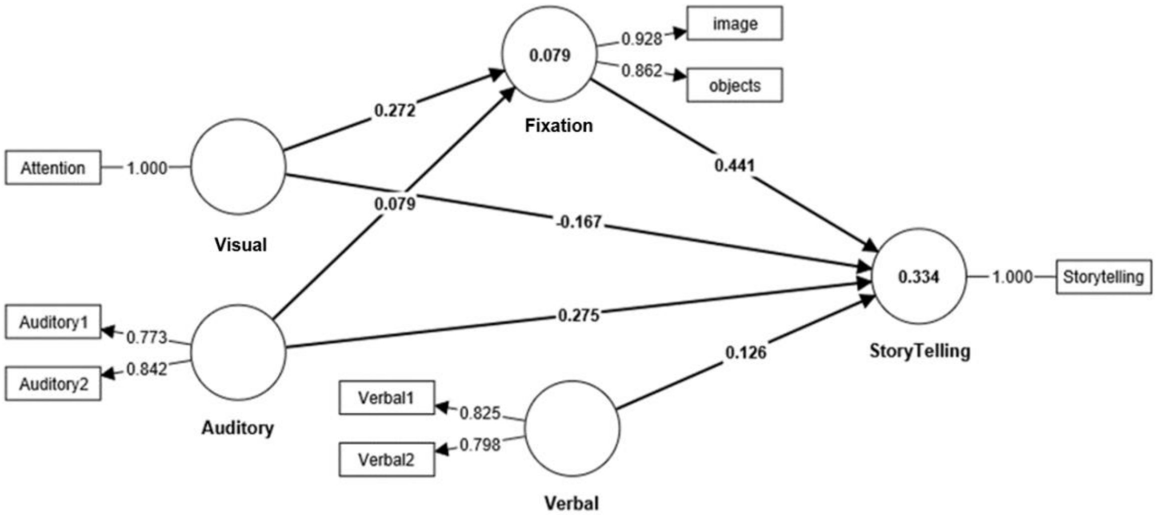
Heterotrait-Monotrait ratio (HTMT) determines discriminant validity among the latent constructs. All the HTMT ratios indicated in Table 5 are below the threshold, 0.90, indicating an adequate discriminant validity between the constructs.

Table 5.
Heterotrait-Monotrait Ratio (HTMT)

Construct	Visual attention	Auditory attention	Verbal fluency	Eye-movement	Storytelling
Visual attention	-				
Auditory attention	0.092	-			
Verbal fluency	0.251	0.564	-		
Fixation duration (FD)	0.305	0.108	0.443	-	
Storytelling	0.031	0.497	0.408	0.507	-

Note. HTMT values below 0.90 indicate adequate discriminant validity.

Figure 2.
Structural Model



(b) Structural Model Analysis

Partial least squares regression was utilised to explore the significant effects of prereaders' cognitive abilities and eye movements on storytelling performance. Table 6 presents the path coefficients (β), t-values, and p-values derived from the PLS algorithm and bootstrapping tests. Figure 2 illustrates the structural model for the study, and Figure 3 illustrates the path coefficients and p-values.

Two significant pathways emerged: visual attention → fixation duration ($\beta = 0.272$; t = 2.351; $p = 0.019$) and fixation duration → storytelling performance ($\beta = 0.441$; t = 3.221; $p > 0.001$), supporting H4 and H6, respectively. These findings suggest that fixation duration fully mediates the relationship between visual attention and storytelling performance. Conversely, the direct pathway from visual attention → storytelling performance ($\beta = –0.167$; t = 1.518; $p = 0.129$) was not significant, leading to the rejection of H1.

Additionally, auditory attention → storytelling performance ($\beta = 0.275$; t = 1.806; $p = 0.071$) and verbal fluency → storytelling performance ($\beta = 0.126$; t = 0.918; $p = 0.358$) were not significant, resulting in the rejection of H2 and H3. Similarly, auditory attention → fixation duration ($\beta = 0.079$; t = 0.463; $p = 0.643$) was not significant, leading to the rejection of H5.

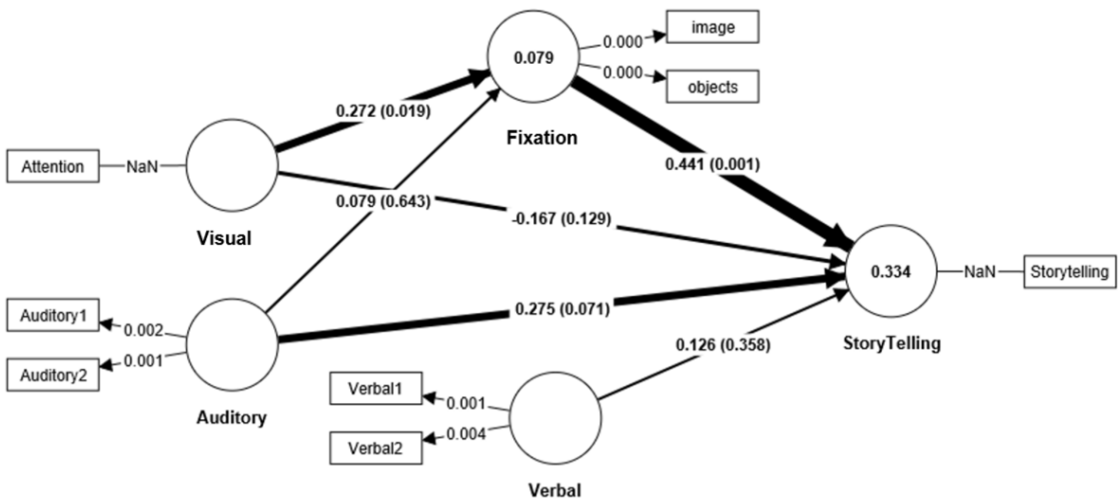
Table 6.

Path Coefficient for Structural Model

Hypothesis	Pathway	Path Coefficient (β)	t-Value	p-Value	Hypothesis Testing
H1	Visual attention → Storytelling	–0.167	1.518	0.129	Rejected
H2	Auditory attention → Storytelling	0.275	1.806	0.071	Rejected
H3	Verbal fluency → Storytelling	0.126	0.918	0.358	Rejected
H4	Visual attention → Fixation duration	0.272*	2.351	0.019	Accepted
H5	Auditory attention → Fixation duration	0.079	0.463	0.643	Rejected
H6	Fixation duration → Storytelling	0.441**	3.221	0.001	Accepted

Note. * $p < .05$, ** $p < .001$

Figure 3.
Path Coefficient and P-value



(c) Importance-performance matrix analysis (IPMA)

The IPMA technique was employed to identify key constructs contributing to storytelling performance and assess their performance levels. As shown in Table 7 and Figure 4, fixation duration emerged as the most critical factor influencing storytelling performance (Importance = 0.441; Performance = 59.391). It highlights the significant role of sustained attention in visual processing and its impact on narrative comprehension.

Auditory attention (Importance = 0.310; Performance = 55.060) ranked second, reinforcing the importance of attentiveness during story narration. Verbal fluency (Importance = 0.126; Performance = 48.442) also contributed positively to storytelling, albeit with lower performance. In contrast, visual attention (Importance = -0.047; Performance = 27.381) ranked lowest, suggesting limited direct influence on storytelling outcomes.

These findings underscore the critical role of fixation duration and auditory attention in enhancing prereaders' storytelling performance. Educational strategies should prioritise activities that cultivate these abilities within digital storytelling contexts.

Table 7.

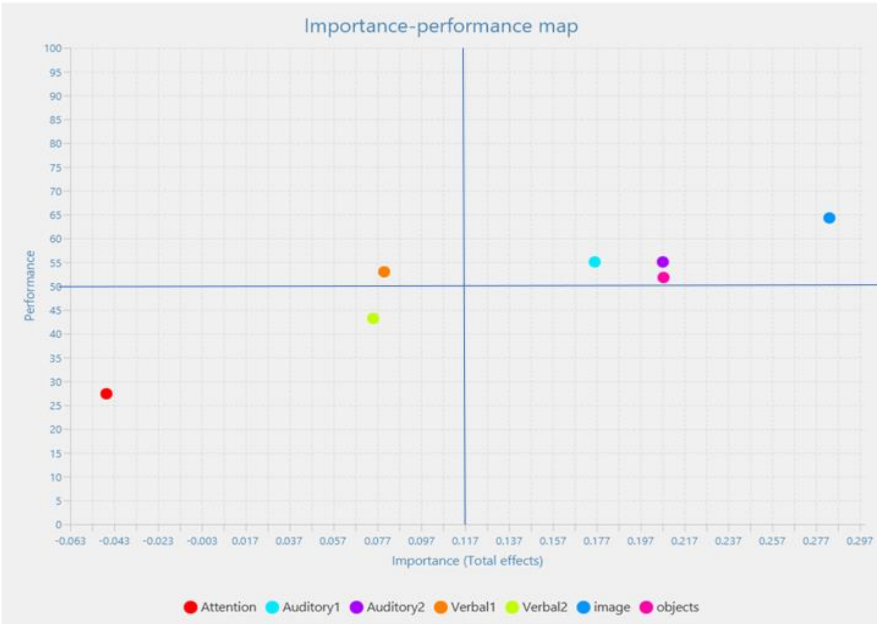
Importance-Performance Map Analysis (IPMA) Results for Storytelling

Construct	Total Effect (Importance)	Index Value (Performance)
Fixation duration	0.441	59.391
Auditory attention	0.310	55.060
Verbal fluency	0.126	48.442
Visual attention	–0.047	27.381

Note. Constructs are ranked by their total effect on storytelling performance. Higher values indicate greater impact or performance.

Figure 4.

Importance-Performance Map for Predictors of Storytelling Performance (STP)



Note. The x-axis represents importance (total effects), and the y-axis represents performance (index values). Constructs in the upper-right quadrant show high importance and performance.

Discussion

This study investigated the effects of cognitive skills such as visual attention, auditory attention, and verbal fluency, and duration of fixation on the performance of prereaders in retelling a story. Eye-tracking was used to assess the duration of fixation when the prereaders listened to a story being read aloud with congruent pictures and text displayed on a computer display. The findings can make important contributions to the overall knowledge about the cognitive processes that support the practice of multimedia storytelling by prereaders.

The findings indicated that the fixation time was significantly influenced by visual attention according to path analysis, which proves H4. Prereaders with greater visual attention took longer to fix on particular Areas of Interest (AOIs), e.g., images and objects. The present discovery is a continuation of the past study, which has highlighted visual attention as an enabler of reading accuracy and narrative comprehension (Arslan-Ari & Ari, 2021; Evans & Saint-Aubin, 2013; Justice et al., 2005; Kaefer et al., 2017). The most significant predictor of cognitive engagement is the fixation duration because it characterises a greater degree of mental activity and processing of information when the prereaders are performing storytelling tasks (Henderson et al., 2015; Liu et al., 2020; Negi & Mitra, 2020).

It has been proven that the capacity of working memory is limited. In that case, the adequate distribution of attention to the new information processing needs to take place (Cognitive load theory, Sweller, 1988). This theory suggests that prereaders with the most visual attention have longer fixation periods and, therefore, group and encode narrative information more effectively. This could be attributed to the fact that in a multimedia learning setting, visual stimuli can be used to develop critical thinking (Eng et al., 2020). The significant correlation between fixation time and storytelling performance, which supports H6, confirms the importance of visual attention as a critical predictor to enhance the ability to narrate stories. Prereaders who were oriented to congruent illustration during the listening to narration showed better storytelling performance. It concurs with the conclusions reached by Takacs and Bus (2018) and Verhallen and Bus (2011) that highlight the importance of congruent visuals in the process of scaffolding the understanding and memory of young children. The findings also support previous research that suggests that visual concentration when reading stories to children has a positive relationship with their capacity to tell stories (Montak et al., 2015; Liao et al., 2020).

The PLS-SEM model showed a clear cognitive pathway: visual attention → fixation duration → storytelling performance. This pathway illustrates the mediating effect of fixation period in the translation of visual attention to storytelling expertise. The results indicate that visual attention alone is not the type of effect that positively influences storytelling performance (H1 rejected), but the effect is mediated by the long-lasting exposure to visual stimuli. It also coincides with the Dual Coding Theory developed by Paivio (1986) that suggests that the verbal and the visual channels are interactive in nature and therefore, encourages memory retention and recall. Likewise, the Cognitive Theory of Multimedia Learning (2005), developed by Mayer, supports the significance of visual and auditory information integration to process a narrative.

However, unlike anticipated, the auditory attention did not correlate significantly with the storytelling performance or the fixation duration, and H2, H3, and H5 were rejected. Although auditory processing has long been thought to have a key role in narrative processing (Justice et al., 2008; Kuperman and Van Dyke, 2011), the results of the current study suggest that visual attention can assume a more central role in leading prereaders to interact with digital storytelling content. The prevalence of visual attention is also consistent with studies that have indicated that children in the early literacy phase usually give priority to visual content over auditory information during multimedia content consumption (Takacs and Bus, 2018; Montag et al., 2015). In addition, this difference may be enhanced by the competition between visual and auditory modalities over cognitive resources. Sweller, in his Cognitive Load Theory (1988), posits that the working memory has a limited capacity and therefore prereaders find it difficult to process and combine multimodal input at the same time; visual information tends to dominate over auditory information. Moreover, the non-significant influence of verbal fluency could be due to the developmental constraints in the language skills of prereaders. Early language proficiency, such as the size of vocabulary and ability to construct sentences, has been reported to have an effect on storytelling performance (Isbell et al., 2004; Reich et al., 2019).

The Importance-Performance Map Analysis (IPMA) results show that fixation duration is the most significant variable that affects the performance of storytelling, and that the duration of time the prereaders spend concentrating on the pictures and particular Areas of Interest (AOIs) is a very important variable. The outcome confirms the critical importance of visual attention in processing story content, and the longer fixation period leads to a stronger encoding of the narrative information, which eventually leads to an improvement in the ability to tell the story. Furthermore, auditory attention became the second most significant construct, which highlights the significance of the attentiveness of prereaders when listening to a story. An active listening of the story by prereaders results in the comprehension and memorization of the story, which once again depicts that storytelling comprehension is multimodal.

Moreover, the analysis of these phenomena within the frames of the cognitive theories, e.g., the Dual Coding Theory by Paivio, or the Cognitive Theory of Multimedia Learning (CTML), allows understanding the way in which children react to the content in the multimedia much better. The theory of Paivio places great emphasis on the use of both audio and visual channels in learning. When children read storybooks, their focus on both verbal narration and visual cues works simultaneously and encourages parallel processing and encoding of information. This bilateral process activation probably helps explain longer fixation times, because children focus on the inputs of both modalities, resulting in more complete encoding of story content.

The Cognitive Theory of Multimedia Learning (CTML) also emphasizes the combination of auditory and visual information as a condition of successful understanding. CTML states that when children face multimedia information, sensory information is initially processed in sensory memory, where it is organised in working memory, and then stored in long-term memory. The increased duration of fixation in prereaders is a sign of greater attention to visual and auditory stimuli, which helps to better comprehend the story and to perform storytelling. However, even though those results can be quite useful to comprehend the cognitive processes that result in the engagement of children in multimedia storytelling, several considerations have to be made. One of these is that, even though longer fixation periods are an indication of more cognitive processing, they must be interpreted in terms of individual differences. Age, stage of development, and previous interactions with literacy materials are likely to impact the way children learn about visual and auditory stimuli, and their future performance in telling stories (Goswami and Bryant, 2012; Reich et al., 2019).

Implication

This study's findings provide critical insights into how cognitive abilities and eye movements influence prereaders' storytelling proficiency in digital storytelling. Identifying fixation duration as a key determinant emphasises the importance of visual attention in enabling children to process and articulate narratives effectively. The results indicate that teachers and curriculum experts should develop interventions that can be adopted to facilitate long-term adherence to visuals like interactive picture books and multimedia storytelling devices. The development of literacy can be supported by encouraging these skills at a young age, when a child can understand, synthesise, and retell stories and acquire a solid foundation.

In addition, the findings point out the complementary effect of auditory attention in facilitating the meaning and memorisation of story content. Cognitive models such as the Dual Channel Model of Paivio and the Cognitive Theory of Multimedia Learning can incorporate digital narratives and the use of auditory stimuli and visual stimuli (Mayer, 2005). They use these methods to take advantage of the synergistic benefits of working with more than one of the sensory modalities, facilitating more in-depth thought processes and greater storytelling skills. Thus, visual and auditory methods, when used together like narrated digital storybooks, can be of great benefit to young learners. In theoretical terms, the study contributes to the knowledge of the mediating effect of duration of fixation in the relationship between visual attention and storytelling performance. These findings confirm the hypothesis that although visual and auditory attention are vital elements of narrative understanding, the length and concentration of cognitive processes (as measured using fixation measures) are vital in converting these skills to storytelling skills. It emphasises the necessity of possessing educational means and structure that enables the capacity to concentrate on visual and auditory content.

Future Research

The future study could investigate the mediation of fixation time on influencing storytelling abilities. One can speculate on hypothetical confounding factors (e.g., working memory capacity or narrative comprehension ability) to provide some indication of the relationship between length of fixation and storytelling results. Second, studies concerning the efficacy of multimedia learning mediums (interactive storybooks or audio-visual presentations) would also provide meaningful information on the most effective methods to facilitate the process of literacy acquisition in young children. The most recent results contribute to the topic of multimedia storytelling reactions in prereaders, but more research is required to assist in illuminating some of the enigmas in the mechanisms. This project will deliver evidence-based solutions that will help to develop impactful literacy programs addressing the cognitive and developmental needs of young children.

Conclusion

In conclusion, the current study contributes to the recently growing body of knowledge on the topic of cognitive skills and digital narration by answering the question of what processes contribute to the acquisition of narrative skills among prereaders. The researcher, teacher, and policy implications of the research work are put in a practical setting as the correlation between visual attention, fixation time, and storytelling performance has been determined. Their practical applications include developing visual and auditory alertness through special exercises and applying interactive multimedia tools to facilitate the acquisition of literacy. The relationship during the storytelling performance, the length of fixation, the working memory, and narrative comprehension should be examined in future research to understand more about the mental processes during the storytelling performance. Research into the possibilities of higher multimedia forms, including immersive or augmented reality storybooks, may provide new approaches to optimising digital storytelling experiences. Based on these findings, stakeholders may establish evidence-based practices that would foster literacy in prereaders to enable them to succeed in learning processes in a technology-based environment.

Acknowledgments

This study is funded by the Ministry of Education, Malaysia, through the Fundamental Research Grant Scheme FRGS/1/2019/SSI09/HELP/01/1.

Conflict of Interest

The authors of this publication declare there is no conflict of interest.

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Appendix A

I. AUDITORY ATTENTION TASK

Task A: Instructions for the child

1. You will hear some words.
2. When you hear the word red, put a red square into the box lid as so (demonstrate).
3. When you hear any other words--do not do it. You are going to hear many words, so make sure you listen to the end.

E.g. of list of words-- now, peg, that, red, there, yellow, blue, take, red, thing, now (read aloud one word per sec. 180 words total)

Task B: Instructions for the child:

1. This is a slightly different game. You will hear some more words.
2. As you hear the word red, put a yellow square in the box like this (demonstrate).
3. You will find that when you hear the word yellow, you may put a red square in the box like this (demonstrate).
4. You can have a blue square in the box when you hear the word blue (demonstrate).
5. When you hear any other word--do not do anything. You are going to hear many words, so make sure you listen to the end.

Figure 5. Illustration of the auditory attention task setup. Image shown for demonstration purposes only.

II. VISUAL ATTENTION

Task A: Instructions for the teacher

1. Put the response sheet in front of the child. The child is not given the option to move the response sheet. Give the child a coloured pen.
2. On the page at the very top of the page, point to the cat and say:

Here is a cat, and down here (point to the array) are more cats. See if you can find more cats. You see a cat, you make a mark on it, such as this (demonstrate on the middle cat).

Check off all the cats that you can. Ask me when you are done. Are you ready? Go.

3. Start timing. Stop when 180 seconds elapse or when the child drops the pencil, or when the child says that he/she is done. Record the elapsed time.

Figure 6. Sample response sheet for the visual attention task.

Task B: Instructions for the teacher

1. Point at the target faces in the first line and say:
2. There are two faces here, and more faces down here. Now, attempt to find faces that look like the ones on the top. When you see the same face, mark it in this way (demonstrate on the face in the first line). The two faces need not be next to one another.
3. Put the colour pen in the middle of the child and say:
4. Attempt to locate the faces as fast as possible. Move forward (point to the left to the right of the child) without leaving out any faces. You have finished this row (gesture), now proceed to the next. When you are done, tell me. Are you ready? Go".
5. Start timing. Stop timing at 180 seconds or stop timing when the child lays the pencil down or says he/she is finished. Record the elapsed time.

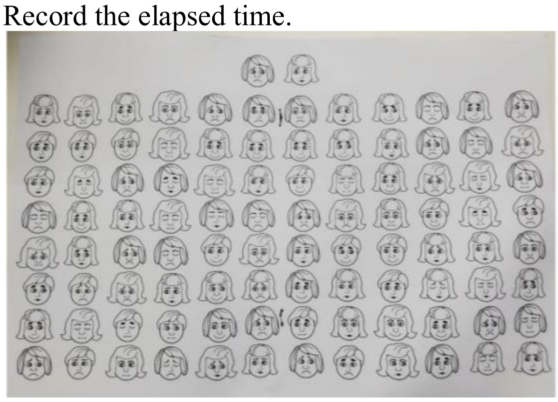

Figure 7. Sample response sheet for the visual attention task involving face identification.

III. VERBAL FLUENCY

Part A: Instructions for the child

1. Can you name as many different animals as you can, such as a cat or a dog? Say them as quickly as you can. Are you ready? Go.

1. Start timing. In case the child fails to utter any word in 15 seconds, say:

Then say: Tell me some (more) animals.

2. At 60 seconds, say "stop".

2.	*Part B: Instructions for the child* 1. Now, can you call some things you can drink or eat? Eat as many different ones as you can, like milk or pizza. Do it quickly. Are you ready? Go. 2. Start timing. In case the child fails to utter any word in 15 seconds, say: Name some (more) of the things you can eat or drink.
3.	3. At 60 seconds, say "stop".

Biodata

Dr. Loo Fung Lan, Programme Director at Open University Malaysia, has over 20 years of teaching experience in early childhood education. Based in Malaysia, her research interests include early literacy, child psychology, pedagogy, and curriculum development. She holds an M.Ed. and a PhD in Early Childhood Education from leading Malaysian universities.

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Dr Wong Hoo Keat, as a cognitive psychologist, focuses his research on cross-cultural face perception. With the use of eye trackers, he investigates how interracial contact, cultural factors, and media exposure may interact to influence the underlying mechanisms of human face processing. He has adopted combined techniques – eye-tracking, encephalography (EEG), and heart rate variability (HRV) to study the attentional bias and emotional face processing in depressive individuals and to examine the psychophysiological effects of mindfulness breathing meditation.

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