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Review Article

A systematic review on the effectiveness of children's interactive reading applications for promoting their emergent literacy in the multimedia context

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ABSTRACT

Emergent literacy is the term used to describe the reading and writing experiences of young children before they learn to write and read conventionally, and it is important for the construction of children's early reading skills and the enhancement of their later reading performance. The systematic review was conducted to examine the effectiveness of children's interactive reading apps in promoting emergent literacy for children between the ages of three and eight over the last decade (2013-2022). A total of 50 studies were included in this review, and it can be concluded that multimedia features (e.g., a dictionary, background music, and animated pictures) in children's interactive reading apps are effective for enhancing emergent literacy. Conversely, interactive functions (such as games and hotspots) may distract children's attention, leading to poor reading performances. This review also demonstrated the positive effects of children's interactive reading apps on improving their learning outcomes and behavior. In addition, the results indicated that well-designed apps could promote children's emerging literacy skills. However, more in-depth studies will be required in the future to provide designers with a well-defined guideline for designing reading apps for children.

Keywords: emergent literacy, interactive, application, systematic review

INTRODUCTION

There is no doubt that reading is an important part of a child's literacy development. Reading stories to children enhances both their reading ability and their ability to acquire complex vocabulary. In the dyad model of parent and child reading processes, storytelling through parents leads to better story comprehension and retention (Dore et al., 2018; Scarborough & Dobrich, 1994). Rosen and Randell (2016) define the synergy mechanism of parents in developing children's reading skills as cognitive scaffolding (e.g., guided reading, vocabulary interpretation, story content interpretation, meaning-making) and affective scaffolding (e.g., praise, encouragement, and behavior control). Children are increasingly exposed to on-screen reading activities as technology advances and smart devices (computers, smartphones, and tablets) become more popular (Christ et al., 2019; Smeets & Bus, 2015). Based on the National Literacy Trust's 2014 annual literacy survey (Picton, 2014), between 2012 and 2013, the percentage of children responding to the annual literacy survey who owned an e-reader increased from 20% to 30%, while tablet ownership increased from 38% to 65%, and smartphone ownership increased from 38% to 70%. Additionally, the number and availability of interactive reading apps for children have increased dramatically, from the first computerized storybooks available through CD-ROM to today's touchscreen interactive reading systems (Elizabeth & Mark, 2014). This shift from traditional paper books as the primary resource for children's reading to screen-based e-books

changes the reading environment and experience for young children. Along with this trend, media, schools, and parents are increasingly concerned about the educational value of children's interactive reading apps, particularly how these apps can support children's emergent literacy (e.g., vocabulary acquisition and story comprehension) in a multimedia context (Korat & Falk, 2019). There is an urgent need for a deeper understanding of the effectiveness of interactive reading apps for young children's emergent literacy development, given that the majority of children have not yet entered elementary school for systematic reading instruction (Furenes et al., 2021).

A variety of e-book terms are used in the current research, including animated storybooks, digital books, interactive e-books, and app books. This category of screen-based e-books is referred to as "interactive reading apps" in this review. Through technological advancements, the Interactive Reading App can not only replicate the reading experiences of children but also supply them with reading materials that are distinct from those found in traditional paper books. Interactive reading apps often have multimedia features like voice-over, animation, animated graphics, background music, online dictionaries, and text that is read out loud. As technology advances, interactive hypermedia elements that allow children to activate animated effects or game content by touching hotspots on an electronic touch screen are becoming more common in e-books. Interactive reading apps can integrate a wide range of digital features, which greatly enhance the reading experience for children. According to previous studies, interactive reading apps can improve motivation, confidence, satisfaction, engagement, and ultimately comprehension (Bus et al., 2019; Korat & Falk, 2019; Smeets & Bus, 2015).

A huge number of studies have assessed the effectiveness of interactive reading apps, with mixed results. Furenes et al. (2021) quantitatively reviewed 39 studies reported in 30 articles (n=1,812 children) in order to compare how children's story comprehension and vocabulary learning differ in different media formats. They found that books with enhancements that target story content, such as prompting children to provide background knowledge and/or providing additional explanations, outperformed digital books without enhancements (Furenes et al., 2021). In contrast, a number of studies have suggested that interactive reading apps with a high level of interactive elements, such as hotspots, games, and online dictionaries, decrease retelling and inference critical thinking scores. In particular, games activated by hotspots can impair children's story comprehension because they divert their focus away from the story (Christ et al., 2019; Piotrowski & Krcmar, 2017; Takacs et al., 2015). Meanwhile, experimental research has shown that interactive reading apps with animations and interactive elements are neither good nor bad for children's reading comprehension, despite the fact that children show strong treatment effects on target word and vocabulary learning while reading a story (Smeets & Bus, 2015; Kelley & Kinney, 2017). Roberts and Barber (2013) conducted a small-scale (n=30) experimental investigation to see whether the e-book format affects children's reading comprehension. They reached the conclusion that there were no statistically significant changes in understanding based on book format for readers with higher levels of proficiency. Based on diverse theories and research contexts, previous investigations have achieved exceptional success (Bus et al., 2019; Fuernes et al., 2021; Korat & Falk, 2019; Smetts et al., 2014). However, such inconsistent results make it challenging to apply them to children's learning.

Parents and educators are faced with the challenge of selecting appropriate interactive reading apps for children to facilitate teaching and learning. App designers should consider what makes a well-designed interactive reading app. As well as technological improvements, multimedia technology has also improved dramatically compared to a decade ago. Technology-enhanced e-books will also demonstrate some new features, considering the time since the first wave of e-book evaluations (Korat & Falk, 2019). So, in this review, relevant topics from the last decade (2013-2022) were examined, and 22 studies were found from different databases. The purpose of this review is to examine the effectiveness of children's interactive reading apps in promoting emergent literacy skills. It will also discuss the advantages, limitations, trends, and challenges of children's reading apps in the context of multimedia.

The Mechanism of Interactive Reading Apps from a Theoretical Perspective

According to Paivio's (1991) dual-coding theory, when processing information, visual and auditory information are two independent and mutually inclusive channels. When stories that are read or heard are accompanied by visual illustrations or other non-verbal information, the stories will be better understood and

retained than when they are told or read solely based on a single channel. Since the interactive reading app contains multimedia and interactive elements, it encourages children to read through visual, auditory, and tactile means (Korat, 2010). The empirical studies based on this theory tend to report positive results, including improvements in children's reading ability, recall and retention, story comprehension, and vocabulary (e.g., Broemmel et al., 2015; Korat & Falk, 2019). In line with the dual-coding theory, a multimedia learning theory (Mayer, 2005; Mayer & Moreno, 2003) believes that deep learning occurs when information is presented in both verbal and non-verbal formats, especially when narration and pictures are presented concurrently. When this occurs, children are able to learn stories promptly, and their ability to recall them is enhanced. Under such circumstances, learning is more effective. According to Baddeley's (1986) working memory model, people process information through various channels (visual and auditory). When input sensory information can be retrieved simultaneously through visual and aural channels, a highly effective memory effect will emerge. These results indicate that interactive reading apps provide multimedia elements and interactive functions for children's reading, that these functions are geared toward multiple retrieval channels, and that these channels should be properly incorporated with the main content. (Kozminsky & Asher-Sadon, 2013).

The interactive reading apps, on the other hand, have multimedia features and interactive functions that can be distracting for children and interfere with their reading performance (Piotrowski & Krcmar, 2017). Whenever these functions are unrelated or occasionally connected to the content of the story, children have to switch between multiple channels of information, which can cause cognitive overload (Sweller, 2005). Fish (2000) proposed that children have a limited cognitive capability in terms of processing information, so switching their attention between different types of information (e.g., text and interactive features; narrative and text) depletes their cognition and leads to cognitive overload (Richter & Courage, 2017). When overloaded, processing and subsequent comprehension are expected to suffer. This means that the closer the story and multimedia additions are, the smaller the cognitive cost of switching between them.

Interactive Reading Apps in the Multimedia Context

As multimedia has evolved, the traditional paper book, which included only text and images, has given way to multimedia, which combines audio, images, animations, and videos into a single interactive presentation for children. In his book Multimedia: Making it work, Tay (1993) mentions that multimedia enters the interactive multimedia phase when users have control over when and how media elements appear, and interactive multimedia becomes hypermedia when there is a structure of linked elements that can be navigated by users. Since the first generation of e-books just digitized paper books (such as Amazon's kindle) and added basic interactive features, such as clicking the arrow or swiping the screen to simulate the page turn of a paper book, e-books have been developed for more than two decades. As information technology has advanced, smart phones, platform computers, and other intelligent terminals have greatly improved their ability to process information, and children's interactive reading apps have entered the era of interactive media and hypermedia, which allows children to read at their own pace and allows enhanced levels of interactivity through combining multiple forms of media content. When a child activates a hotspot on a tablet, he or she can activate sounds and animations and control the progress of reading according to their needs. (Korat & Or, 2010). Research conducted so far has provided us with several pieces of evidence about the features of children's interactive reading apps in the context of multimedia:

(a) **Significant interactivity:** Many recent e-books and apps contain interactive features. The Joan Ganz Cooney Center analyzed the 137 most popular children's e-books in 2012 and found that 75% of the e-books contained hotspots (Guernsey et al., 2012).

(b) **Entertainment:** Popular children's interactive reading apps cater to children's entertainment psychology by incorporating a lot of entertaining content to increase exposure. For example, a very popular reading app in China, "Little accompaniment dragon," has more entertainment elements than reading content.

(c) **Gamification:** Children's interactive reading apps have recently added the ability to activate games through hotspots. In some cases, the games are related to the story; for example, word hotspots, word puzzles, picture selection, etc.; while in other cases, the games might not be related to the story and are designed purely to capture children's attention.

Purpose of the Study

The literature indicates a gap concerning an intensive review of children's interactive reading apps in a multimedia context. It is not possible to provide a guideline for educators, designers, and parents on how to design content and make choices for children's emergent literacy, while the development of multimedia has also brought new features to interactive reading apps (Korat & Falk, 2019). As a result, this study conducted a systematic literature review to determine the effectiveness of children's interactive reading apps in a multimedia environment.

The present study also analyzed categories of functions (multimedia and interactive) and emerging literacy (learning outcomes and behavior) in interactive reading apps. Overall, based on the available literature, this systematic literature review is guided by three research questions:

1. Do the multimedia features and interactive functions in children's reading apps enhance their emergent literacy?
2. What is the effect of children's interactive reading apps on learning outcomes and behavior to enhance their emergent literacy?
3. What are the trends, advantages, limitations, and challenges of children's interactive reading apps?

METHOD

The purpose of this review was to assess the effectiveness of interactive reading apps for children in a multimedia setting. Children's interactive reading apps were defined as any reading medium specifically designed for children's use that contains oral narration instead of or in addition to text, as well as multimedia elements (e.g., animated pictures, sound effects, background music) and interactive functions (e.g., questions, games) (Takacs et al., 2015). In keeping with this definition, this review excludes forms of reading in which paper books are simply digitized and displayed on a screen (kindle). In addition, animations that simulate the page-turn action of a book are not considered interactive (you can't tap the arrows or swipe the screens). Furthermore, we evaluated the effects that are most typical for children's interactive reading apps–multimedia and interaction–not the appearance of specific devices, children's gestural behavior, or the impact on children's vision (Roskos & Burstein, 2013). We did not require the story to have a text similar to a printed book.

Based on the National Literacy Foundation's 2014 literacy study (Picton, 2014), the proportion of children with tablets and smartphones has reached 70%, and for the first time, children are reading more on screens than paper books, which demonstrates screen reading's popularity among children, so a time frame of 2013 to 2022 makes sense for this study. In addition, this review is focused on children aged three-eight years old because, according to Piaget and Inhelder's (1969) theory of cognitive developmental stages, children under the age of three are hardly able to interact while using interactive reading apps, whereas previous studies have found that children aged eight and older have already begun systematic reading instruction when they enter primary school and may have mastered reading comprehension, so neither interactive reading apps nor paper books have any effect on their reading ability (Roberts & Barber, 2013).

For a study to be included as experimental, no matter if it was a between- or within-subjects experiment, there had to be a comparison condition between children's interactive reading apps and paper books or basic e-books (no dynamic effects). The children were narrated by their parents when reading the paper books, whereas during the experiment, the adults acted as guides when using an interactive reading app, minimizing the interaction with the children (e.g., Bus et al., 2019; Korat et al., 2019), imitating a natural reading session. We focus on the effects of the app on children's emergent literacy (learning outcomes and behaviors) such as story comprehension, recall and retention, vocabulary, motivation, attention, engagement, and so forth–all skills that are directly related to later learning outcomes in school (e.g., Whitehurst & Lonigan, 1998), as well as the effectiveness of the multimedia features and interactive functions placed in the app. We do not include skills that are usually referred to as "broad modes of representation" (such as writing on social media, ins, etc.) (Lankshear & Knobel, 2011).

Article Search Strategy

Initially, we searched the Scopus and Science Direct databases, Google Scholar, Cambridge Press, and Springer Publishing for journal articles, conference articles, and book chapters, using various combinations of the following search terms: ebook* OR e-book* OR "electronic book*" OR "story app*" OR "Animated eBooks*" OR "digital book*" OR "digital stories*" OR "Technology-Enhanced Storybooks*" OR "children's interactive reading apps*" OR "multimedia reading stories*" OR "interactive stories*" OR "interactive-e-books*" OR "App books*" AND "pre-schoolers*" OR "preschoolers*" OR "kindergarten*" OR "early-child*." OR "Young-Children*" OR "Preschoolers*" AND "word-learning*" OR "vocabulary*" OR "story comprehension*" OR "Reading comprehension*" OR "emergent literacy*."

Secondary search involved inspection of the reference lists of review articles and the research papers published by leading authors (e.g., Bus, Korat, and Kucirkova). All searches and screening were done independently by the first and second authors. The inconsistent search results were discussed by the two authors, and eventually agreement was reached.

Inclusion Criteria

We used the following inclusion criteria based on our operational definitions:

1. In an experimental design, no matter whether it was a between- or within-subjects experiment, there had to be a comparison condition between children's interactive reading apps and paper books or basic e-books (no dynamic effects).
2. A technology-enhanced story may include an oral narration as well as multimedia (e.g., background music, a dictionary, and animated pictures) and interactive functions (e.g., hotspots, questions, and games) in one case.
3. The adults were only involved in the experiment as guides (in other words, actions taken to ensure a smooth transition) when the children used the interactive reading apps and kept their interaction with the children to a minimum.
4. The participants were children aged three-eight (inclusive). The articles needed to be published between 2013 and 2022, and they needed to be written in English, but the study could have been conducted anywhere.
5. There were at least one or more outcome measures including
   (a) children's emergent literacy (e.g., story comprehension, cognitive ability, vocabulary, recall, and retention),
   (b) children's behavior while listening to stories (e.g., their motivation, attention, and engagement), or
   (c) functions (multimedia and interactive) in children's reading apps.

Exclusion Criteria

We excluded relevant studies showing that no experiments comparing children's interactive reading apps with paper books or basic e-books (e.g., Djonov et al., 2021; Kucirkova, 2019) or adults (either parents or experimenters) did not maintain a minimum level of interaction when children were reading with interactive reading apps during the experiment (e.g., Ross et al., 2016). We also excluded studies that did not employ technologically enhanced books as the medium (e.g., Azfar & Rambli, 2013; Jeong, 2013). In addition, we excluded studies focusing on participants older than eight years old (e.g., Bursali & Yilmaz, 2019; Chen et al., 2013; Ghalebandi et al., 2019; Kong et al., 2018) or diagnosed with autism or another intellectual disability (e.g., Munir et al., 2018; Wainwright et al., 2020).

Table 1 lists the inclusion and exclusion criteria.

Finally, there were 50 articles included in the literature search as reported in Preferred reporting items for systematic reviews (PRISMA) flow diagram for systematic reviews and meta-analyses (**Figure 1**).

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. There had to be a comparison condition between children's interactive reading apps & paper books or basic e-books.	1. No experiments comparing children's interactive reading apps with paper books or basic e-books.
2. A technology-enhanced story includes an oral narration, as well as multimedia features and interactive functions.	2. Studies that did not employ technologically enhanced books as medium.
3. The adults were only involved in the experiment as a guide kept their interaction with the children to a minimum.	3. Adults did not maintain a minimum level of interaction when children were reading with interactive reading apps during experiment.
4. The participants were health children aged three-eight (inclusive). Articles needed to be published between 2013 and 2022 & written in English.	4. Studies focusing on participants older than eight years old or diagnosed with autism or another intellectual disability & not published between 2013 & 2022 & written in English.
5. There were at least one or more outcome measure.	

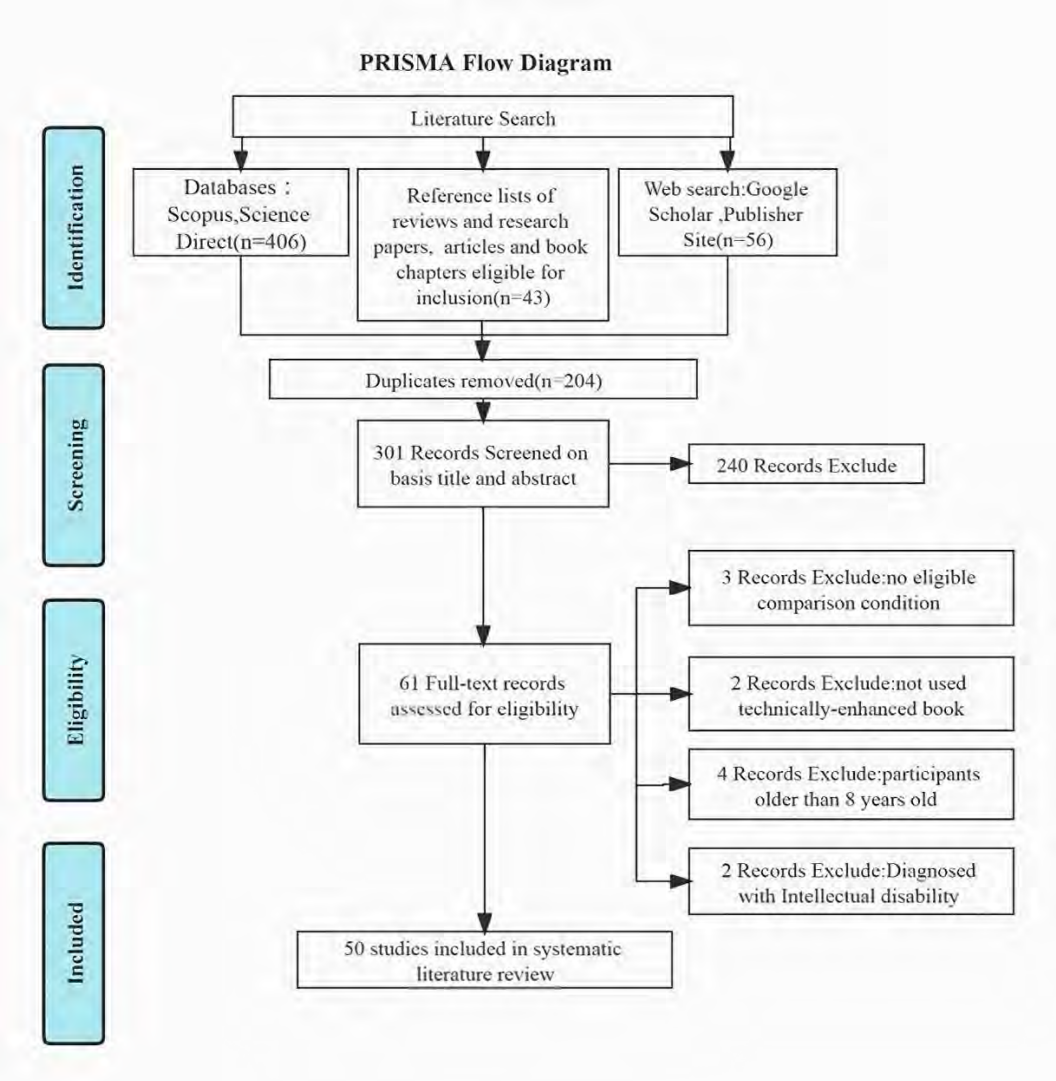

Figure 1. PRISMA flow diagram of study selection (Source: https://prisma-statement.org/)

RESULTS AND DISCUSSION

Results

For the first question of the purpose of the study, we studied multimedia and interactive functions in children's reading apps. Results obtained from the data encoding process are presented in **Table 2** in which data was coded for both multimedia and interactive functions.

Table 2. Effectiveness of functions in children's interactive reading apps

Authors	Multimedia features			Interactive functions	
	Dictionary	Background sound/music	Animated pictures	Hotspots	Games
Abrami et al. (2016)		+	+		
Altun et al. (2018)		+	+		
Barnyak et al. (2016)		+	+		
Bickel (2017)		+	+		
Broemme et al. (2015)			+		
Bus et al. (2015)	+	+	+	-	-
Bus et al. (2019)		-	+		
Bus et al. (2020)		+		-	-
Bus et al. (2021)		+	+		
Christ et al. (2019a)	+	+	+	+	
Christ et al. (2019b)		+	+	-	
Danaei et al. (2020)		+	+	-	
Dore et al. (2018)		+	+		
Drigas et al. (2015)		-			
Furenes et al. (2021)	+	+			
Ghalebandi et al. (2019)		+	+		
Ihmeideh (2014)		+	+	+	
Johnson et al. (2017			+		-
Kao et al. (2016)		+	+		
Kelley et al. (2015)		+	+		
Kelley et al. (2017)	+	+	+	-	
Kocaman-Karoglu (2015)		+			
Korat et al. (2014)	+				
Korat et al. (2019)	+		+	-	-
Korat et al. (2022)		+	+		
Kozminsky et al. (2013)			+		
Longa et al. (2013)				-	
Miller et al. (2014)	+	+			
Mohammed et al. (2017)			+		
Picton (2014)	+				
Piotrowski et al. (2017)		+		-	
Reich et al. (2016)		-	+	-	-
Reich et al. (2019)		+			
Reid et al. (2016)	+		+		
Richter et al. (2017)			+	-	-
Rowe et al. (2016)			+		
Rvachew et al. (2017)			+	-	
Sari et al. (2019)		-	+		
Smeets et al. (2015)	+		+	+	
Strouse et al. (2016)		+			-
Strouse et al. (2017)		+	+		
Sun et al. (2019)		+	+		
Sung et al. (2019)			+	+	
Takacs et al. (2015)	+	+	+	-	-
Takacs et al. (2016)			+		
Wang et al. (2019)		+	+		
Willoughby et al. (2015)		+	+	-	
Wong et al. (2019)		+	+		
Zhou et al. (2017)			+	+	
Zipke et al. (2017)		+	+	+	

Note: +: Positive; -: Negative; & Blank: Not mentioned

The coding of the multimedia function revealed 11 studies that assessed the dictionary function, all of which reported positive results. 34 studies on background sounds and music have been conducted, with 30 showing that background sounds and music are effective and four showing negative results. All 39 of the studies that included animated pictures reported positive results. As well as coding for the hotspots function, there were six studies that reported positive results, whereas the other 13 studies showed the opposite. It surprised us that all of the studies (n=8) on the function of the game turned out to be negative. The systematic review indicated that multimedia features contributed to children's enhanced reading skills, but interactive functions have been ineffective or even detrimental.

Table 3. Effect of children's interactive reading apps on children's learning outcomes & behavior

Authors	Learning outcomes				Behavior		
	SC	Cognitive ability	Vocabulary	R&R	Motivation	Attention	Engagement
Abrami et al. (2016)	+		NE				
Altun et al. (2018)	+	+		+			
Barnyak et al. (2016)			+	+	+		
Bickel (2017)	NE		+		+		+
Broemme et al. (2015)	+	+	+		+	+	+
Bus et al. (2015)	+		+	+			+
Bus et al. (2019)	+		+			+	+
Bus et al. (2020)	+			+	+		
Bus et al. (2021)	+						
Christ et al. (2019a)	+	+					
Christ et al. (2019b)	+			+		+	
Danaei et al. (2020)	+	+		+	+	+	+
Dore et al. (2018)	+			+			
Drigas et al. (2015)	-	+	+	+	+		+
Furenes et al. (2021)	+	+	+		+		
Ghalebandi et al. (2019)					+		+
Ihmeideh (2014)	+	+	+		+	+	
Johnson et al. (2017)			+		+	+	
Kao et al. (2016)	+	+			+		
Kelley et al. (2015)	+		+				
Kelley et al. (2017)	NE		+	NE	+	+	+
Kocaman-Karoglu (2015)	+	+					
Korat et al. (2014)			+	+			
Korat et al. (2019)	+	+	+	+	+	+	
Korat et al. (2022)	+		+			+	
Kozminsky et al. (2013)	+		+			+	
Longa et al. (2013)	-			-			
Miller et al. (2014)	+				+	+	
Mohammed et al. (2017)		+	+		+	+	+
Picton (2014)	NE				+	NE	NE
Piotrowski et al. (2017)	NE			NE		-	
Reich et al. (2016)	+		+				+
Reich et al. (2019)	+			NE		NE	NE
Reid et al. (2016)	+			+	+		+
Richter et al. (2017)				NE	+	+	NE
Rowe et al. (2016)			+				
Rvachew et al. (2017)	NE		+	NE		+	
Sari et al. (2019)	+		NE	+	+	+	
Smeets et al. (2015)	NE		+	+	+		+
Strouse et al. (2016)	+	+	+				+
Strouse et al. (2017)			+				+
Sun et al. (2019)	+	+	+	+	+	+	+
Sung et al. (2019)		+	+		+	+	
Takacs et al. (2015)	+	+	+	+			+
Takacs et al. (2016)	+	+	-	+	+	+	+
Wang et al. (2019)	+		+		+	+	+
Willoughby et al. (2015)		+	+				
Wong et al. (2019)	+				+		
Zhou et al. (2017)	+		+		+		+
Zipke et al. (2017)	+		+	+	+	+	

Note: +: Positive; -: Negative; NE: No effect; Blank: Not mentioned; SC: Story comprehension; & R&R: Recall & retention

For the second question, the data coding process yielded the results shown in **Table 3**, which summarizes four learning outcomes and three behaviors. The most significant finding of the analysis of learning outcomes was that the majority of the studies (n=40) addressed the impact of children's interactive reading apps on children's study comprehension, with 32 studies finding a positive impact and two studies finding the opposite, while six studies found no impact. After story comprehension, vocabulary was the second most studied goal. There were 32 studies exploring the impact of the intervention on children's vocabulary acquisition and 29 studies claimed a positive impact, while one reported a negative impact. There were 17 studies reporting positive effects on recall and retention, while five showed no effect.

Finally, nearly half of the studies (n=17) indicated that children's interactive reading apps have a positive effect on their cognitive abilities. The review also examined children's learning behaviors. The majority of studies (n=27) demonstrated that children showed higher levels of motivation when using the reading interactive app and that reading motivation affects reading attention, which improves reading engagement and thus enhances children's ability to read. According to the study data, children's interactive reading apps had a positive effect on enhancing children's reading attention (n=20) and engagement (n=19). Therefore, this systematic review can conclude that children's interactive reading apps are beneficial to children's emergent literacy (learning outcomes and behavior).

As for the third question, what are the trends, advantages, limitations and challenges of children's interactive reading apps in the multimedia context? Based on the data in **Table 2** and **Table 3**, it is easy to see that interactive reading apps have a positive impact on children's emergent literacy (learning outcomes and behavior). Advantageous, for instance, are the behaviors. From the data coded for learning behavior in **Table 3**, we can see that many of the studies (n=27) demonstrated that children showed high motivation when using interactive reading apps. An increased motivation to read affects children's attention to reading; if a child is attentive when reading, then he or she is more engaged in the reading process. Children's engagement in reading is an effective indicator of their reading skills, and data shows positive correlations between motivation, attention, and engagement. Moreover, children's interactive reading apps can enhance multimedia learning, promote story comprehension, and offer a media environment that maximizes the temporal congruence of text and illustrations. The updated format can simultaneously display images, text, and background music. This may result in stronger encoding, which is not possible with traditional paper books. While children may not combine text content with static illustrations when reading paper books, with an interactive reading app, enhanced by technology, highlighted text and animated images are displayed simultaneously and can encourage recall and retention. Then, the learner is guided to combine text and images and encode this content into associations firmly engraved in memory. Meanwhile, background music can help young readers understand the story's emotions. For example, the music is more upbeat when the characters are happy and subdued when they are sad. The sound effects and actions of the characters (e.g., the breaking of cups; characters making sounds that represent emotions) can enhance children's comprehension of the story, which results in increased recall and retention as well as enhanced emergent literacy. Moreover, we found that interactive reading apps have a significant impact on children's vocabulary development (**Table 3**). Multimedia features such as a dictionary, highlighted text, and narratives provide children with the means to combine the contents to form long-term memories, and the added vocabulary enhances their cognitive and expressive skills, thus enhancing their reading ability and emergent literacy.

Moving on to the limitations of children's interactive reading apps, along with technological development and the popularity of smart devices (e.g., iPad, smartphones, etc.), as a result of the influx of children's interactive reading apps onto the market, they are now including more hotspots and games. The data in **Table 2** indicates that the majority of studies (n=13) reported negative effects of the hotspot features, while all of the studies on games showed negative effects (e.g., Bus et al., 2020; Korat et al., 2019; Richter & Courage, 2017). Many empirical research studies in which children read with hotspots in comparison to those without indicate that the task switching between hotspots and story reading affects their comprehension of the story (Bus et al., 2019; Takacs et al., 2015). This makes sense considering that children's ability to process information is limited and switching between tasks may affect their reading performance (Fisch, 2000; Kahneman, 1973).

The capacity theory suggests that children's ability to process information simultaneously depends on how much capacity they need for different types of information. This is risky for children's developing brains. When demand exceeds capacity, some story content is ignored, resulting in distorted comprehension or partial recall. Games are entertainment activities that are not directly related to teaching children to read. Games can be related to story readings or appear on different channels. According to **Table 2**, games have a significant negative impact on children's reading performance. This is in line with findings in previous studies that children playing games while reading could disrupt their reading process and result in cognitive overload, resulting in decreased reading comprehension and vocabulary acquisition (Christ et al., 2019; Korat et al., 2019; Takacs et al., 2015).

Story content design is a central challenge for children's interactive reading apps. The impact of interactivity and multimedia features on children's emergent literacy was studied in this systematic review. It is critical to recognize that it is the combination of these functions, rather than any one of them, that achieves the goal of improving children's emergent literacy skills. Ideally, the story's content design should make reasonable use of multimedia and interactive features. In particular, the interactivity should be designed to relate to the story content and serve as an organic interactive reading mechanism (Wang et al., 2019). Gamification and entertainment are also challenges. Some commercial apps on the market try to attract children's attention by incorporating a lot of games, videos, animations, and other features that have little or no relevance to the story content, which defeats the purpose of children's interactive reading apps to enhance their emergent literacy skills. This is also a major concern for parents, educators, and researchers.

Furthermore, Bus et al. (2020) and Korat et al. (2019) highlight the additional challenges when using interactive reading apps, namely the fact that children have to constantly switch between multiple tasks while reading and their limited cognitive capacity, which is an objective physiological issue. How can we balance the conflict between children's cognitive abilities and the functionality of the app to its maximum advantage without overloading children's cognitive abilities? This is an important question that we need to examine.

Discussion

The current systematic review compiled a decade's worth of empirical evidence (2013-2022) on the effectiveness of interactive reading apps for children in promoting emergent literacy. In twenty-two studies conducted across eleven countries, we found that multimedia features had a significant positive effect on children's emergent literacy skills, while interactive functions had the opposite result.

Multimedia features and Interactive functions

Data from **Table 2** demonstrated that multimedia features in children's interactive reading apps play an important role and have a positive influence on children's emergent literacy. Interactive reading apps with animated pictures and background music will especially support this developmental role and have a positive influence on children's emergent literacy. Interactive reading apps with animated pictures and background music will especially support this development. Based on multimedia learning theory (Mayer & Moreno, 2003), it is reasonable to assume that children are taught more effectively by presenting words and pictures simultaneously than by using words alone. In contrast to the single channel of paper books, children are more likely to be successful in story comprehension, word acquisition, and cognitive ability when stories are processed simultaneously through both visual and auditory language channels. These findings agree with Paivio's (1991) dual-coding theory. In conjunction with verbal information, visual information can help children better understand verbal information, including the transmission of story emotions and the development of story lines. Vice versa, verbal information can assist children in interpreting visual information and help them overcome cognitive challenges. Along with the impact of dual-coding, multimedia features present animated pictures and text, complemented by simultaneous story development, which helps facilitate the effective integration of verbal and non-verbal information. Animated pictures can emphasize certain details in the story by using methods such as highlighting, zooming, and motion as a way to draw children's attention to specific details, which can boost the children's ability to integrate information and comprehend the story. By coding words with pictures, it is easier for children to make associations between the words and images, which allows them to visualize the story more clearly. Therefore, multimedia elements contribute to a child's ability to think coherently and create mental representations.

The advent of new technology has led to the development of children's interactive reading apps that often include visual images and auditory elements (i.e., background sound and music), providing an additional advantage of multimedia learning. Schottz's (2005) integrated model of text and picture comprehension suggests that learners can utilize multiple sensory modalities. It includes reading comprehension, listening comprehension, visual picture comprehension, and sound comprehension. Background sounds–such as wind, rain, or animal sounds–are also integrated into the visual and auditory channels to contextualize the meaning of story scenes and words. Meanwhile, children can also benefit from the non-verbal music included in the children's interactive reading apps, as it enriches scenes and conveys the characters' emotions (e.g., fear, crying, or happiness). We summarized the experimental studies included within our systematic review

to illustrate this issue, and it was interesting that studies that reported positive effects on multimedia features also showed positive effects on children's story comprehension, cognitive enhancement, and word acquisition (e.g., Furenes et al., 2021; Korat & Falk, 2019; Sung et al., 2019).

The experimental results do not always support the view that children's interactive reading apps have a positive impact on their literacy development. As opposed to the studies mentioned above, Drigas et al. (2015) and Sar et al. (2019) concluded that background sounds and music had a negative effect. However, in these studies, the background sounds and music were not related to the stories themselves. Children can suffer from cognitive overload due to inconsistent images, sounds, and text. Similarly, digital books may not improve literacy skills when visual information (e.g., animated pictures and illustrations) is purely decorative or irrelevant (Furenes et al., 2021). Therefore, we predict that the best effects of multimedia features can be achieved only if the most attractive animated images are close enough to the text or are simultaneously present in space and time with it. In contrast, too many features, decorative pictures, and mismatched information processing can lead to cognitive overload and poor reading performance (Mayer, 2005; Mayer & Moreno, 2003). The recommendation for children's interactive reading apps is to strike a greater balance between taking advantage of the particular strengths of multimedia and choosing how to support children's emergent literacy.

Due to the importance of vocabulary acquisition to children's developing literacy skills, the designers also tried to improve children's vocabulary through the use of dictionaries. There are both text and audio explanations provided for children to learn the meanings, pronunciations, and spellings of story-related vocabulary. Korat et al. (2010), for instance, found that different types of vocabulary support modalities had varying degrees of impact on children's vocabulary acquisition, with the dynamic dictionary in technology-enhanced books proving to be particularly effective. In this study, however, vocabulary acquisition was the only objective, and whether dictionary features interfered with story processing was not explored. A meta-analysis by Furenes et al. (2021) examined ten digital books with dictionaries and found they had a positive effect on vocabulary learning but noted that such results could be obtained only when the digital book only had a dictionary function. This effect disappeared when the digital book had other enhancements related to the story content. Meanwhile, the study points out that the dictionary can interfere with storyline processing. While vocabulary acquisition is important, it is preferred to enhance reading skills as well as story comprehension.

Many interactive reading apps for children are loaded with interactive functions. Additional content appears by activating hotspots and, of course, games. The purpose of analyzing games separately in this systematic review is that more and more reading apps are including games in an effort to increase book exposure and attract children. It is surprising that seven studies in this paper that involve interactive functions reported that the hotspots and games had a negative effects games. The purpose of analyzing games separately in this systematic review is that more and more reading apps are including games in an effort to increase book exposure and attract children. It is surprising that seven studies in this paper that involve interactive functions reported that the hotspots and games had a negative effect. Our analysis revealed that these interactive functions appear both outside and inside the storytelling channel. It can interrupt the story and distract the children's attention away from the stories, resulting in fragmented story content that impairs story recall and retention (Bus et al., 2015). Meanwhile, we analyzed two studies that reported the positive impacts of hotspots. For instance, a study indicates that students' reasoning and critical thinking scores were on average 3% higher when reading app books that had word hotspots, which were specifically designed to aid children's comprehension and cognitive skills (Christ et al., 2019). Smeets and Bus (2015) conducted an empirical study that demonstrated that children learned an additional 8% of word meanings (four words) when animated e-books contained hotspots that explained word meanings. Thus, word definition hotspots appear to be an effective tool for stimulating children's word learning. Games, on the other hand, can lead to cognitive overload for children and have a negative impact on their story comprehension and learning (Bus & Neuman, 2014).

In summary, multimedia and interactive functions that fail to support story comprehension can lead to cognitive overload in children, which interferes with their ability to comprehend stories (Mayer, 2001). Constant switching between tasks poses a challenge to children's immature cognitive abilities and reduces their reading performance. It is critical for app developers to design their apps based on theories such as

multimedia learning theory, dual-coding theory, cognitive overload theory, etc. Furthermore, multimedia and interactive functions that are designed around story content have been shown to be effective. The closer the relationship between story content and functions, the lower the cognitive cost of switching between them. Games, which are not an inherent part of the story content and have independent operating mechanisms, are features that we believe are not beneficial for the development of children's literacy and should therefore not be included in children's interactive reading apps (Korat & Falk, 2019).

Learning outcomes and behavior

Table 3 shows that most studies have demonstrated a significant positive impact of interactive reading apps on children's story comprehension. There may be an explanation for this in the fact that multimedia and interactive functions enhance children's story comprehension when they are strongly connected to the story content. Story comprehension can be impaired by functions that are irrelevant to the story content or only intended to be decorative, entertaining, or game-like. We analyzed studies that did not report any effect on story comprehension, such as Kelley and Kinney (2017), who conducted a meta-analysis of word learning and story comprehension for young children after experience with interactive and non-interactive versions of digital storybooks; there were no differences between the two groups for story comprehension and recall. Instead, the study demonstrated significant advantages in language learning and vocabulary acquisition. A possible explanation is that story recall was used as a measure of story comprehension in the Kelley et al.'s (2017) study, and the interactive element was separated out. It is worth considering whether this is a reasonable measure. Meanwhile, Kelly and Kinney (2017) used commercially available digital storybooks rather than custom-designed materials, and the results of their study may be biased.

Meanwhile, Piotrowski and Krcmar (2017) compared reading apps with and without interactive features, revealing that there was no difference between the two in terms of story comprehension and recall. However, children's attention decreased significantly in the interactive condition. Interestingly, the data in **Table 3** reported that while the interactive reading app had no effect on story comprehension, it also had no effect on recall and retention. We observed the same results when children's reading behaviors such as engagement and attention were reported to have no effect or a negative effect. It is consistent with previous research (e.g., Korat et al., 2022; Takacs et al., 2015; Wang et al., 2019) that the motivation, attention, and engagement of children directly affect their comprehension, vocabulary acquisition, cognitive enhancement, recall, and retention of stories.

There have been numerous studies evaluating the impact of interactive reading apps on children's cognitive development, and they have found that well-designed apps enhance children's abstract thinking, reflective thinking, ability to analyze information, and coordination skills. Through the use of multimedia features, children are able to process multiple pieces of information in their brains while integrating textual and verbal information; to feel the atmosphere of the story through background music; and to access real-world information through the use of sound effects such as glass breaking or a knock on the door. This series of activities requires children to process knowledge in their brains and might be integrated with prior knowledge to create a new understanding. This is consistent with Kahneman's (1973) theory of cognitive load.

Through analysis, one expected result emerged: there have been 29 studies reporting a positive effect on vocabulary acquisition. A number of reasons were identified:

(a) Interactive reading apps hold children's attention better than static e-books or paper books (Korat et al., 2022; Sun et al., 2019).

(b) In addition to dictionaries, children can rely on them for instant interpretation of the meaning of words (e.g., Bus et al., 2015; Miller et al., 2014; Takacs et al., 2015).

(c) All study materials had a clear educational purpose, either for reading or vocabulary, or a combination of both.

This is also consistent with the multimedia learning theory (Mayer, 2005; Mayer & Moreno, 2003) as well as the dual channel theory (Paivio, 1991). Children's impressions of vocabulary are deepened when pictures, text, and sound are associated with the story content and presented simultaneously. As for learning behaviors, the majority of studies report that interactive reading apps help children become more motivated

(n=27), pay attention (n=20), and be more engaged (n=19). The systematic review examined these studies and summarized the reasons for them:

(a) Multimedia features such as animation, animated pictures, videos, background music, and sound effects, as well as interactive functions such as hotspots and games, are inherently appealing to children.

(b) Animated pictures emphasize the details of illustrations through magnification, highlighting, and other technological enhancements that capture children's attention. Children remained focused on the screen for a longer period of time when the illustrations were animated (Takacs et al., 2015).

(c) Engagement refers to children's concentration on the story, their ability to keep their attention during reading, their interest in the storybook, and their spontaneous discussion of its content (Kaderavek et al., 2014). There is a direct relationship between engagement in reading and learning outcomes.

There is an important question, however, about whether the increase in children's motivation and attention is due to the story content, the multimedia features, the novelty of the device, or the hotspots and games. A study conducted by Richter and Courage (2017) found that children tended to talk about the device when using e-books in preschool. When reading on an iPad, children showed equal emotional and behavioral engagement. Mohamed et al. (2017), Richter and Courage (2017), and Wang et al. (2019) showed in their studies that children in hotspot conditions showed less attention and that high interactivity caused children to be more concerned with the device and its functions while ignoring the story content in associated books. Based on these studies, we can infer that interactive functions boost children's motivation to some extent at the expense of their attention and engagement. It has been demonstrated that children's interactive reading apps promote positive learning outcomes and behavior, especially in story comprehension, cognitive ability, and vocabulary acquisition; this is related to the multimedia function. For learning behavior, it is necessary to distinguish whether children are motivated by the story content or other technological enhancements.

Trends, advantages, and challenges

Children's interactive reading apps are changing in a multimedia context, and researchers, designers, and educators are exploring their educational value within this context. Based on the above analysis, the advantages and limitations of children's interactive reading apps can be seen to be interconnected. In order to enhance children's literacy development, the designers integrated multimedia features and interactive features, adhering to the theory of multimedia learning and the dual channel theory (Mayer, 2005; Mayer & Moreno, 2003; Paivio, 1991), and multimedia features and interactive functions also became the most significant advantages of the reading apps.

The cognitive capacity theory suggests, however, that processing multiple pieces of information at once is hazardous to a child's immature cognitive abilities and that when cognitive overload occurs, some information is not processed and may result in distortions of story content and less detailed recall (Bus et al., 2020). Furthermore, we should examine whether interaction, entertainment, and gamification impact children's literacy development. Additional research is needed to answer these questions. What is the best way to balance technology enhancement with children's emergent literacy? According to Fisch (2000), there is sufficient working memory for story comprehension when the distance between story content and multimedia features is small enough that they complement rather than compete. In other words, complementary functional support may facilitate story comprehension. As a design principle for application developers, it is important to promote dual coding by facilitating the matching of nonverbal information (e.g., animated images, background music, and sounds) with verbal text. Children's interactive reading apps can facilitate story comprehension when there is close congruency and temporal proximity between narrative information and verbal text. Conversely, additional irrelevant functions (e.g., hotspots and games) may exhaust children's limited cognitive abilities and hamper learning. The most reasonable suggestion for addressing these challenges is to use multimedia learning theory (Mayer, 2005; Mayer & Moreno, 2003), dual channel theory (Paivio, 1991), and cognitive load theory (Sweller, 1988), and call for increasing the balance between taking advantage of the particular advantages of children's interactive reading apps and carefully selecting support to assist children in their emergent literacy development. It is also important to maximize the design purpose of the app–all functions should be centered around the story.

Limitations and recommendations

There are a number of limitations to this study that need to be considered. Firstly, the number of studies included in this study is limited, which compromises the generalizability of the results. It is imperative that future research include more studies to achieve generalizability of the findings. Furthermore, each empirical study in this study had its own experimental context and analysis method. We can only use three criteria–positive, negative, and no effect–to describe the effectiveness of the children's interactive reading app because it is difficult to use a single standard. Future research could gather more comprehensive data to provide more precise outcomes, such as high, medium, and low levels. Further, while we evaluated the features (multimedia and interactive) of the children's interactive reading apps and analyzed the learning outcomes and behaviors of the children, we suggested that well-designed apps can promote children's emergent literacy skills, but more detailed and specific research is needed in order for designers to have a well-defined guideline. Finally, some studies randomly selected commercially available apps for effectiveness analysis, while others used apps specifically designed to enhance children's emergent literacy, and the results were quite different. It is therefore imperative that interactive reading apps be developed that are based on multimedia theory, tested for their effectiveness, and provide well-designed, high-quality reading support for children.

CONCLUSION

In this systematic review, we summarized research findings on the effectiveness of interactive reading apps in promoting children's emergent literacy in a multimedia context. Based on these findings, the majority of studies support the positive impact of the functions (multimedia and interactive), particularly in improving young children's emergent literacy. The findings showed that children's interactive reading apps improve their learning outcomes and behavior, particularly in terms of story comprehension, cognitive enhancement, vocabulary acquisition, and motivation, attention, and engagement in reading. It can be concluded that children's interactive reading apps are effective tools for improving their emergent literacy skills. It is also important to note that only well-designed apps can enhance children's literacy skills. We suggest that designers, policymakers, educators of young children, and parents consider the above principles of good educational reading apps for young children. Further research should explore reading apps that include advanced digital narrative features and consider incorporating new features (i.e., high interaction, entertainment, and gamification) into future research.

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