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On-Screen Children's Stories:

the Good, the Bad and the Ugly

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On-Screen Children's Stories: the Good, the Bad and the Ugly

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Chapter 1

General Introduction

Narrative stories like picture storybooks have an important role in the lives of young children, they are a source of cognitive, social and emotional development. Stories support language development by exposing children to sophisticated words and expressions in addition to teaching literacy skills like print and letter knowledge (Bus, van IJzendoorn, & Pellegrini, 1995; Mol & Bus, 2011). According to the book reading paradigm young children are read print storybooks by an adult. However, with the rapid spread of technology, children's stories are going digital.

Technology is massively present in the lives of young children in Western societies. According to a representative survey in the United States (Common Sense Media, 2013), children up to 8 years of age spend almost two hours a day with screen media. While children, although decreasingly, still use older screen technology like television, DVDs, computers and video games, mobile media devices such as smartphones and tablets grow in popularity. In fact, it was found that 75% of American children in the age of 8 or under had access to a mobile media device in the fall of 2013 (Common Sense Media, 2013). Additionally, 58% of the parents reported downloading apps specifically for their child in the same study. Similarly, 86% of Dutch children up to age 7 watch television regularly and 70% use tablets often, as found in an online survey in 2014 (Iene Miene Media, 2014).

Narrative stories for young children are also widely available on different platforms and devices like television (e.g., *Mijn Mooiste Prentenboek, KRO*), CD-ROMs (e.g., *Hennie de Heks* by Bombilla) and DVDs (e.g., *Hoe Tem Je een Draak* movie by DreamWorks Animation), educational websites (e.g., www.kenny.nl/koekoeksklok or www.bereslim.nl), but more recently also on mobile media devices (e.g., *Mama Kwijt* app by Gottmer Uitgevers Groep B.V.), and video game consoles (e.g., *Freddi Fish en het Verhaal van de Verdwenen Zeewierzaadjes* for the Wii by Majesco). This transformation to digital stories fundamentally changes the experience of sharing a storybook with an adult and results in a wide variety of electronic storybooks. For example, many print children's storybooks that have been adapted to DVDs and apps include animated illustrations, music and sound effects. To illustrate, in the multimedia app *Roodkapje* by Chocolapps SAS the illustrations are animated featuring movements like the Little Red Riding Hood skipping away in addition to zooming in on specific parts of the illustration such as the wolf knocking on grandma's door, sound effects as Little Red Riding Hood screaming and a background music demonstrating the story like when grandma is surprised and afraid when the wolf comes to her house. Similarly, children's educational television programs like *Dora* by Nickelodeon present narrative stories with the addition of such film effects. However, educational television programs like *Dora* can be quite different from multimedia storybooks because they often include dialogues instead of narrations, making the language of the story more colloquial.

On the other hand, some electronic stories utilizing the possibilities of interactive devices like mobiles, tablets and video game consoles aim to involve the child actively in the story. They include interactive features that do not play automatically but children need to activate them. The app *Noa's Sterren* by Hanneke van der Meer, for example, includes 'hotspots', areas in the illustrations that can be activated upon touching them. For instance, Noa starts humming, the frog jumps and the plants rock when touched. In the same app, and in many storybook apps, children need to swipe the screen in order to "turn the page" giving them control over the pace of the story and allowing them to spend time with the hotspots on each page. Similarly, in the app *Finn's Hoedje van Papier* by Tizio B.V. children can activate sound effects on each page by touching details in the illustration like the sound of a seal. The app *De Drie Kleine Biggetjes* by Johnny Balassis includes hotspots; after touching the 'sun' or the 'flowers' the narrator names those. As this function is also available during the oral narration there may be some verbal overlap. The English-spoken app *Oh, the Things You Can Do That Are Good For You!* by Oceanhouse Media includes a vocabulary function in the form of highlights: upon touching a bolded word in the written text like 'exercise' a written definition of the word appears in addition to the narrator reading the definition.

Many storybook apps include small games all along the story. On several pages in *Noa's Sterren* children need to solve a problem (e.g., collect stars in Noa's lantern) before they can turn the page. In the app *De 5 Hoofden* by Barbara de Wolf children can make the peas fly away from the illustration. In the famous English-spoken app *Alice for the iPad* by Atomic Antelope there are many hotspots with small games like a bottle that can be moved around the screen. The English-spoken "storybook adventure" video game *Sesame Street: Once Upon a Monster* for the Xbox 360 by Double Fine Productions features a plethora of mini-games focusing on dancing and movements utilizing the motion detector of the device. Likewise, in the award-winning English app *Little Red Riding Hood* by Nosy Crow children play a game like collecting flowers or pouring honey in Little Red Riding Hood's basket on every page. Interestingly, the same app allows children to choose from eight possible endings for the story. The story *Robot in Space* in the app *Speakaboos Stories* by Speakaboos also offers choices regarding different elements in the story like the vehicle in which the robot travels. Another feature to involve the children personalizes the story for them, for example, in the English-speaking app *I Imagine* by Bizzibrains users can upload photos and design the characters of the story looking like themselves. The app *Timo* *en het Toverstokje* by Books2download allows parents to record their own narration of the stories.

In sum, electronic storybooks for children vary hugely in terms of the mix of features they offer. On one end of the spectrum electronic storybooks are very similar to print storybooks. Exemplary are the app *Dikkie Dik* by Gottmer Uitgevers Groep B.V. or the *VerhaaltjesApp* by De Onderwijsstudio. Both present the static illustrations and the written text on the screen while a narrator reads the story without any technological additions. On the other end of the spectrum, there are storybook apps like *De Geweldige Vliegende Boeken van Meneer Morris Lessmore* by Moonbot Studios LA that include automatic animations, music and sound effects in addition to numerous hotspots and games on every page. In between there are electronic stories with mostly multimedia features and no interactive options. The app *Roodkapje*, for instance, plays the story automatically with animated illustrations and background music and there is very little interaction in between. There are also digital stories with many interactive functions but without automatic dynamic visualizations. Exemplary is the app *Woeste Muis* by Tizio B.V. with hotspots in the illustration that, upon touching, result in sound effects and brief animations. Which features are present in an electronic story depends on the device for which they are made. For example, interactive features are very popular in mobile media story apps and such apps are preferred by distributors in order to utilize the possibilities of the device. However, instead of considering the different devices, the present thesis focuses on features that electronic stories have in common: multimedia and interactive features.

Multimedia Features

Animations including motion and zooming, sound effects and background music are the characteristic multimedia features in electronic storybooks. In a recent content analysis about half of English-spoken storybook apps were found to include animation, while 60% featured music or sound effects (Guernsey, Levine, Chiong, & Severns, 2012).

These additions may serve story comprehension when they are well matched to the story language. However, multimedia features can also be purely decorational or incidental. In the app *Nijntje op School* by Sanoma Media Netherlands B.V. the only animation on most of the pages is the bunny blinking, which has nothing to do with the story. In the app *Verhaaltjes Verteller, Deel 2* by Fisher-Price the clouds in the background are moving all along the story which is irrelevant for understanding the story. In the English-spoken app *Elmer and Rose* by Oceanhouse Media there are

sound effects of monkeys and lions while the main theme is a conversation between three elephants about a fourth elephant missing. In these cases the motion and sound effects do not match the oral language of the story and are purely for decoration.

Interactive Features

Older generations of electronic stories included many interactive features (de Jong & Bus, 2003). With the introduction of mobile media devices like smart phones and tablets variation in interactive features increased. For example, they may include tilting, shaking or turning the device and utilize the gyroscope in the iPad. By tilting the iPad in the English-spoken app *PopOut! The Tale of Peter Rabbit* by Loud Crow Interactive Inc. flowers of the Chinese lantern slide up and down on the bottom of the screen. Scanning the most popular children's apps and their descriptions, it seems that interactivity is a large selling point. In fact, it was found in 2012 that 75% of story apps that were on the market in that year contained hotspots, while 65% included games and activities like coloring (Guernsey et al., 2012).

Interactive features may be more supportive for story understanding if they are related to the narration. For example, most of the effects in the app *Noa's Sterren* elicited by touching details in the illustration are not mentioned in the narration. Similarly, the English-spoken apps of *PopOut!, The Tale of Peter Rabbit* or *Alice for the iPad,* include small details in the illustration like blackberries that children can enlarge and smash or a clock they can spin. None of those have a relation to the story. Actually 90% of the hotspots were found irrelevant to the story in older CD-ROM stories in the Netherlands (de Jong & Bus, 2003). In the same vein, Guernsey and colleagues (2012) found that only 25% of story apps that were available in 2012 included games that foster reading skills. Hotspots including labels for visual elements in the illustration, small animations, sound effects or dictionary functions might be more congruent with and relevant for the story.

With electronic stories that are filled with hotspots and games, one might wonder where storybook reading ends and playing begins. It is questionable whether young children are able to play with the hotspots and games and simultaneously understand the story and learn story language. Actually doing both at the same time requires multitasking, which may put young children at risk of cognitive overload.

Cognitive Resources

Humans have limited working memory capacities, that is, the amount of information that we can hold for a short term is restricted (Baddeley, 2003; Sweller, 2005). If games and hotspots are part of the storybook children need to switch between playing with the interactive features and listening to the narration. Thus, interactive features might distract children from the story due to their limited working memory capacities. This is especially likely when games and hotspots are available at the same time as the story is read to them.

On the other hand, the multimedia may be helpful in selecting the relevant information from the illustrations that match the story text, and form integrated mental representations. That is, the animated pictures might guide children in making a connection between images and story language by attracting their attention to specific parts of the illustration via motion and zooming. Paivio's dual coding theory (Paivio, 2007) and Baddeley's working memory model (Baddeley, 2003) propose that verbal and nonverbal information are processed by two independent but integrated channels. This suggests that processing nonverbal information at the same time as verbal stimuli does not result in cognitive overload especially when there is a strong match between the non-verbal and verbal information.

Building on these premises instructional theories like the cognitive theory of multimedia learning (Mayer, 2003) assume that pictures in addition to words, as long as they are congruent, may result in deeper learning than words alone. This might apply to storybook reading as well and preschool-aged children may benefit from a multimedia presentation of a narration.

In sum, the story language can be visualized and concretized by means of animated illustrations and thus facilitate story comprehension. This is only possible when there is a strong connection between the verbal and nonverbal information. On the other hand, according to the coherence principle of the multimedia learning theory, extraneous additions might interfere with learning (Mayer, 2003). Information that is not tightly connected to the story might distract children and reduce comprehension of and learning from the story. Incidental motions in the illustrations or small games not closely related to the story can cause overload of children's working memory resources. Multimedia and interactive additions in electronic stories may enhance learning but only as long as they are tightly connected to the content of the story.

Overview of the Thesis

The present thesis reports the results of research that was part of the PROO project 'Creating and Implementing Technology for Early Literacy'. The thesis focuses on the effects of electronic stories on children's cognitive development. The main issue was whether, and if so why, technology-enhanced stories are more facilitative of children's learning of language and literacy skills than the more traditional print storybooks with static pictures. In case digital stories are found more beneficial, it is important to identify features that contribute to this effect.

Chapter 2 reviews the empirical evidence for effects of digital stories, making a distinction between multimedia and interactive features. Research findings are explained by referring to cognitive information processing theories including dual coding and cognitive overload.

Based on the conclusions of the narrative review, **Chapter 3** presents a quantitative research synthesis that addresses the hypotheses raised in Chapter 2 regarding the distinct effects of multimedia and interactive features on children's story comprehension and vocabulary development. Additionally, the impact of technological enhancements for children raised in disadvantaged environments is discussed.

Taking the issue one step further, **Chapter 4** reports another meta-analysis comparing the benefits of multimedia elements in digital stories on children's story comprehension and word learning to the benefits of support from an adult when children encounter traditional print stories.

Chapter 5 zooms in on the advantage of animations in multimedia stories for children's story comprehension. Furthermore, the underlying mechanisms are discussed based on eye-tracking data of children's attention to and processing of animated and static storybook illustrations.

Finally, **Chapter 6** discusses the conclusions of the results presented in the present thesis and formulates guidelines for designing and selecting high-quality electronic stories that support young children's language and literacy development.

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Chapter 2

Affordances and Limitations of Electronic Storybooks for Young Children's Emergent Literacy

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Abstract

Stories presented on phones, tablets and e-readers now offer an alternative to print books. The fundamental challenge has become to specify when and for whom the manner in which children retain information from stories has been changed by electronic storybooks, for better and for worse. We review the effects of digitized presentations of narratives that include oral text as well as multimedia information sources (e.g., animations and other visual and sound effects, background music, hotspots, games, dictionaries) on children's emergent literacy. Research on preschool and kindergarten children has revealed both positive and negative effects of electronic stories conditional upon whether materials are consistent with the way that the human information processing system works. Adding certain information to electronic storybooks can facilitate *multimedia learning,* especially in children at-risk of language or reading difficulty. Animated pictures, sometimes enriched with music and sound, that match the simultaneously presented story text, can help integrate nonverbal information and language and thus promote storage of those in memory. On the other hand, stories enhanced with hypermedia interactive features like games and "hotspots" may lead to poor performance on tests of vocabulary and story comprehension. Using those features necessitates task switching, and like multitasking in general, seems to cause *cognitive overload*. However, in accordance with *differential susceptibility* theory, well-designed technology-enhanced books may be particularly suited to improve learning conditions for vulnerable children and turn putative risk groups into successful learners. This new line of research may have far-reaching consequences for the use of technology-enhanced materials in education.

Nowadays on-screen activities (i.e., watching television, playing games on computers, tablets and other devices) have come to dominate children's daily lives (Rideout, 2011; Zeijl, Crone, Wiefferink, Keuzenkamp, & Reijneveld, 2005) and they become familiarized with technology at increasingly early ages. An online questionnaire among 1532 Dutch parents in 2012 (Iene Miene Media, 2012) showed that computers and tablets are growing in importance among 3- to 3½-year-olds, but not yet among 1- and 2-year-olds (see Rideout, 2011 for similar results in the U.S.). At the same time, the number and availability of electronic storybooks has increased dramatically. The first picture storybook on CD-ROM, *Just Grandma and Me*, appeared in the mid-'90s (Ito, 2009), but this new format has only recently become a widespread alternative to traditional paper book reading for children. According to the Association of American Publishers (Publishers Weekly, 2012), sales of children's electronic books presented on phones, tablets and e-readers went from seven million dollars in March 2011 to 19.3 million in March 2012. This transition from traditional paper books as the primary source of storybook reading for 3- to 6-year-old children to electronic sources (Burnett, 2010) marks a change in the 'textual landscape' in which young children are growing up. As there has been concern expressed in the media and by parents about the potential negative effects of technological devices on young children (e.g., Spitzer, 2013), there is an urgent need to deepen our understanding of how interacting with digital stories can either support or hinder literacy development in the age range of 3 to 6 years when most children are not yet conventional readers (Miller & Warschauer, 2013).

We find electronic storybooks to be particularly interesting because these books not only simulate the experience of reading or listening to a story but also provide technological enhancements that make the reading experience qualitatively different from that with traditional paper books. Electronic books usually contain a combination of features, such as animated pictures and background sounds and music that dramatize the text. Most books also include interactive hypermedia elements such as animations that can be activated by the child with a mouse click or screen touch. These "hotspots" may be primarily for entertainment but certain features such as a dictionary function with word definitions can also provide useful on-demand help. Electronic picture storybooks can incorporate a diverse variety of such digital features and there is surprisingly little homogeneity in format across currently available storybook apps (de Jong & Bus, 2003; Guernsey, Levine, Chiong, & Severns, 2012; Korat & Shamir, 2004; Zucker, Moody, & McKenna, 2009).

The overarching theme of the current review is to evaluate whether, and under what conditions technology-enhanced storybooks can be a viable option for the development of emergent literacy. In making explicit when and for whom these books change the manner in which children retain information from stories, we will not discuss the role of co-reading in spite of the importance attributed to adults' participation in the traditional book reading paradigm (Mol, Bus, de Jong, & Smeets, 2008). When electronic books include a limited number of digital enhancements, parental involvement is, just as in print book sharing, an important predictor of children's story understanding (Robb, 2010). However, a recent study by the Joan Ganz Cooney Center (Chiong, Ree, Takeuchi, & Erickson, 2012) indicated that co-reading could be at odds with enhanced electronic books that contain highly interactive features. They found that both parents and children became frustrated when parents attempted to read enhanced stories, thereby interfering in children's interactions with the program. The observations of Chiong et al. demonstrate that the role of the adult in the new era of digital storybooks seems to be a highly complicated issue that needs to be targeted in further reviews.

We will summarize (quasi-) experimental studies in which a wide variety of technology-enhanced books designed for young children are compared and contrasted to more traditional print-like presentations. Although our main focus is on 3- to 6-year-old children, for comparative purposes, we will occasionally refer to research targeting somewhat older pupils. Our minimum definition of an electronic storybook for preschool and kindergarten children requires that it has oral narration instead of, or in addition to written text, and some form of multimedia (e.g., animations and visual effects, sound effects, background music) and/or hypermedia interactive features such as embedded images or activities (Zucker et al., 2009). We evaluate the effects of features that are most typical for technology-enhanced stories - multimedia and hypermedia - and do not consider effects of looking, touching, moving and gesturing behaviors typical for particular devices while interacting with electronic books (Roskos & Burstein, 2013). Although we are aware that several genres of electronic books are available – like concept or information books – we concentrate in this review primarily on narratives and storybooks (Yokota & Teale, 2014). We focus on the effects on *foundational* literacy skills like text comprehension and the understanding of complex grammar and vocabulary; all skills that are strongly related to later reading comprehension and academic performance in school (e.g., Whitehurst & Lonigan, 1998). We do not consider the development of what is sometimes referred to as *new literacies* or *multiliteracies*, that is, a set of skills and strategies related to modes of representation much broader than language alone (e.g., blogging, social media, photo sharing) (e.g., Lankshear & Knobel, 2011; Leu & Kinzer, 2000).

The fundamental challenge is to make explicit when and for whom interaction with technology-enhanced picture storybooks changes the manner in which children retain information from narrative text and when and for whom they strengthen or weaken story understanding and language growth. This is a particularly important question now that educators, parents and teachers are faced with the challenge of designing and selecting appropriate software for young children as avenues for teaching and learning literacy skills. The current review is different from previous research syntheses (Miller & Warschauer, 2013; Salmon, 2014; van Daal & Sandvik, 2012; Zucker et al., 2009) in that we were careful to only include studies that represent the typical multimedia and hypermedia features of digital stories. We have also taken the synthesis one step further by making connections between these typical features of technology-enhanced narratives and cognitive information processing theories that include relevant constructs such as dual-coding (Baddeley, 1986; Paivio, 1986), multimedia learning (Mayer, 2005), cognitive load (Sweller, 2005), and differential susceptibility to environmental input (Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2007).

- In the first section of this review we provide rationales for the effects of multimedia storybooks and for whom in particular they may strengthen learning. A fundamental and guiding hypothesis is that instructional materials that are designed to be consistent with the way that the human information processing system works are more likely to foster learning than those that are not.
- In the second section we discuss the potential advantages for children's learning from nonverbal multimedia features such as motion pictures, background sounds, and music to electronic storybooks that match the story text.
- In the third section of this review we focus on the potential effects of common interactive hypermedia features. Apart from games and "hotspots" irrelevant to the text, we discuss on-demand interactive assistance in understanding story content like a dictionary function or a tutor who asks questions and provides feedback to children's responses.
- In the concluding section we will review what we have learned from research about designing digitized storybooks that are developmentally appropriate in form and function for young children. We aim to provide design suggestions for maximizing the potential of electronic storybooks for learning and for minimizing potential negative effects on the development of foundational literacy skills.

Rationales for Learning with Multimedia Storybooks

In interpreting findings of the research on young children's learning from digital storybooks, we made connections between the typical features of technology-enhanced narratives and several key principles from established theories of human learning and information processing. An evidence-based theoretical framework for multimedia learning was used to make predictions about the way that instructional multimedia messages will be received and interpreted by users of various ages (Mayer, 2005). One prediction is that when stories that are read or heard are accompanied by visual illustrations or other non-verbal information (background sounds and music) that enhance the content of the text, and these information sources are simultaneously available, the text will be understood and retained better than if conveyed by words alone. According to Paivio's (1986) dual-coding theory and Baddeley's (1986) model of working memory, humans process visual and auditory information in separate channels. When incoming sensory information is such that it can be processed in both channels at once, it is learned and retained more effectively than if it is processed in a single channel. One implication of this for multimedia books is that information that targets separate channels should be well integrated and consistent with the core message to be acquired and presented at the same time.

On the other hand, technology-enhanced books may include multimedia features that can interfere with learning. When they are not directly related to the story text and children have to switch from processing one kind of information to another without being able to integrate them, these features can exceed capacity and children may experience cognitive overload (Sweller, 2005). Both children and adults have a limited capacity to process information at any one point in time (Kahneman, 1973). When we try to both comprehend the story text and the content of animations that are only indirectly related to the story content there is a threshold for how much information we can successfully attend to and manage. The constraints on processing capacity require a "central executive" (Baddeley, 1986) to deploy metacognitive strategies to select what we should focus on and how the selected information should be processed. Without such a mechanism, children may fail to select the relevant information that is needed to understand the story in the presence of distractors. Research has shown that task switching is especially difficult for young children whose executive functions are immature and who might predictably retain less from an electronic than a paper book format (e.g., Garon, Bryson, & Smith, 2008). One implication of this for hypermedia books may be that if multimedia additions are inconsistent with the core message to be acquired they may interfere with children's story understanding. When children switch their attention among the text and such interactive features of electronic storybooks while trying to retain the details of the story, they are engaging in an approximation to "everyday" multitasking, which may cause cognitive overload.

In testing the effects of multimedia in technology-enhanced storybooks we also used the concept of differential susceptibility to predict individual variation in responses to multimedia books (Belsky et al., 2007). In the developmental psychopathology literature there is growing evidence for the hypothesis that not all children are uniformly susceptible to the quality of educational input. The basic idea rests on the evolutionary-inspired proposition that depending on certain neurobiological, temperamental or genetic characteristics, some children seem to suffer more from poor guidance but also appear to benefit more from individualized scaffolding than others do. Building on this proposition, it is expected that not all children will be equally susceptible to the qualities of technology-enhanced materials. Intensive, closely monitored, and individualized scaffolding as can be offered by multimedia features, more so than is available in traditional learning settings These features direct putatively vulnerable children's attention and motivation toward the tasks at hand while solving problems. As a result, children who lag behind when they do not have a chance to practice with optimally designed technology-enhanced materials might outperform their peers when receiving such materials. Books with built-in multimedia features that match the story text may thus offer a better starting point for the development of language and literacy skills and turn a "risk" group into a successful group. We expect that technology, given that particular conditions are fulfilled, may thus open up new learning opportunities for vulnerable children.

The Potential of Animation, Background Sounds and Music in Storybooks to Support Emergent Literacy

We expected from previous research that multimedia learning might play an important role in emergent literacy and that electronic books equipped with motion pictures, background sounds and music might be especially supportive of this development (e.g., Verhallen, Bus, & de Jong, 2006). Within the multimedia learning framework (Mayer, 2005), there is reason to expect that young children will learn more effectively from presentations that include words combined with pictures than from words alone (Schnotz, 2005). For example, there is evidence that children are more successful in understanding and retaining unfamiliar words (Paivio, 1986; Sadoski & Paivio, 1994) and the story meaning (Guttman, Levin, & Pressley, 1977; Sharp, Bransford, Goldman, Risko, Kinzer, & Vye, 1995), when the story is processed through both the visual and verbal channels rather than through a single channel. These findings are consistent with Paivio's dual-process theory, in which a verbal system specialized in dealing directly with language and a nonverbal system specialized for dealing with nonlinguistic information are integral. Drawing on both channels simultaneously, nonverbal information can help young children to comprehend language including unfamiliar words and complex grammar. Vice versa, verbal information may help children to comprehend difficult or unfamiliar images. In addition to the effect of dual-channel processing per se, when there is close temporal proximity of words and images, integration of verbal and nonverbal information is facilitated thus enhancing memory traces that connect details of pictures with phrases in the narrative (Paivio, 2008; Wickens, Kramer, Vanasse, & Donchin, 1983).

These multimedia learning principles can explain why young children's recall of the story line and story details improve when a narration is lavishly illustrated, as is typical of most paper and electronic storybooks for young children (Hayes, Kelly, & Mandel, 1986; Greenfield & Beagles-Roos, 1988). According to the dual-channel assumption, the advantage of books that include images in addition to text is that children thus have a chance to match verbal information with corresponding images because they are presented at the same time. This match with non-verbal information may result in more understanding of story text due to better comprehension of story events and stronger encoding of the verbal material. There is some research (Verhallen & Bus, 2011) showing that young children naturally try to match verbal information with images. Their looking behavior while listening to the story text seems to promote close temporal contiguity of word and image. Using a remote eye-tracking system to register which details in a still illustration were fixated while listening to the story text (Verhallen & Bus, 2011), we found that the text limited where in the illustration children fixated. They looked more often and for a longer time inside the areas in the illustrations that the text highlighted, than outside these areas. As a matter of fact, children's visual attention seemed to be directed by the content of the oral text. To further test the importance of close temporal contiguity of word and image in picture storybooks, we also carried out an experimental study in which we compared the effects of simultaneous with successive presentation of oral text and illustration. We found evidence for the hypothesis that, especially when the text is complex, simultaneous presentation is more effective for learning story information than is the sequential presentation of oral text followed by the corresponding illustration, such as children often experience at story time in school (Takacs & Bus, 2013).

The special effects generated by technology-enhanced storybooks can reinforce multimedia learning and promote comprehension. The new formats allow simultaneous presentation of images and text in ways that are not possible in print books (Ito, 2009). Consistent with the cognitive theory of multimedia learning, we expected that electronic book features could bolster story and text comprehension in ways that listening to a typical read-aloud of a picture storybook does not. In listening to the words read from printed picture storybooks, children may not readily connect the visual images in the storybooks to the (oral) text, even when both are presented simultaneously (Verhallen & Bus, 2011). This may be especially likely when the child is at risk of language delay (e.g., low SES; second language learning) or the material is complex. Moreover, as the amount of information that can be processed in each channel at one time is limited, children can hold only portions of an image in a picture storybook in working memory (Baddeley, 1986). Likewise, they can only hold a few words from the narration to which they are simultaneously listening. We hypothesized therefore that children might often fail to match the narration with the illustration (Verhallen et al., 2006). However, electronic books that include animated pictures can provide guidance to the learner, more so than printed books, in integrating images and language and cementing these associations firmly in memory. In animated pictures, visual elements that are normally presented as a single very detailed static illustration can be split into several smaller portions that are highlighted or zoomed in on, each representing one element of the narration. By thus synchronizing phrases in the narration with portions of the relevant picture there is a higher probability that connections will be made between words and images and that children can 'concretize' the narration without much effort (see exemplary pictures from print books as compared to screen shots from the digitized versions of the same scenes in Smeets & Bus, 2012, 2014). The material thus assists the learner in constructing a coherent mental representation of visual and verbal input.

To illustrate this issue, it is not easy to connect an image in *Winnie the Witch* (Thomas & Gorky, 1996) that depicts the witch with her wand and her green cat with the events in the narration that successively explains how the black cat was turned to a green cat by waving the magic wand and reciting a magic spell. The electronic version of this picture storybook with animated pictures, by contrast, may facilitate the association between text and image. This version of the book is more informative about the event by showing, in this order, how Winnie picks up her wand, waves it, uses the spell, and turns the cat from black to green, thereby exactly matching the images with events in the narration. Improving temporal proximity of text and images by zooming in on details in pictures or adding motion that attracts children's attention to a particular element may help the child to understand the story events and may strengthen recall and retention of unfamiliar words. Motion in particular seems to direct children's attention to important details of animated illustrations thereby facilitating integration of the verbal and non-verbal information (Takacs & Bus, under review). We expected that, in this way, animated electronic books might facilitate the learner's understanding of the scene and of complex expressions like "wand" or "wave" (Smeets & Bus, 2012, 2014).

Recent storybook apps often include, along with animated visual images, auditory information (background sound and nonverbal music), which may be an additional advantage for multimedia learning. According to Schnotz's (2005) integrative model of text and picture comprehension, pictorial information is not necessarily associated with the visual modality alone, but can also be conveyed by other sensory modalities such as sound images. Background sound - the sound of knocking on a door, birds whistling, or an engine running – are also processed in the visual/pictorial channel. This may enrich nonverbal coding and thus help concretize scenes and words' meanings just as images. When background sounds are contingent with the oral text, this may also enable simultaneous processing of verbal and nonverbal material, thereby facilitating language comprehension. Moreover, storybook apps often include nonverbal music that may lend support to text comprehension by illustrating the characters' moods (e.g., fear, sadness or happiness). For instance, when Winnie the Witch is furious because she stumbled again over her black cat in her black house and turns the cat into a colorful cat to make him visible, the happy tune stops and turns into atonal sounds. Although images and sounds are functionally independent, both information sources may facilitate the learner's understanding of the scene and of the grammar and abstract expressions by concretizing the narration (Thompson & Paivio, 1994), especially when phrases in the narration are synchronized with non-verbal information in storybook apps (Schnotz & Rasch, 2005).

Evidence for the Efficacy of Multimedia Storybooks Enriched with Animated Pictures, Music and Sounds

In early studies conducted into television as a medium for young children, the potential negative effects of animated stories were often emphasized. For instance, it was concluded that students invest less mental effort when activities are perceived as entertaining (Salomon, 1984). In line with this argument, watching animated stories on various devices may be less effective for learning than listening to an oral text while looking simultaneously at illustrations in print books. It was also hypothesized that children might pay greatest attention to the visual aspects of animated pictures, thereby ignoring language features. Only a few early studies on television viewing in the early 1980s (Hayes & Birnbaum, 1980; Hayes, Chemelski, & Birnbaum, 1981) found higher retention of visual information than of audio information, a phenomenon denoted as the *visual superiority effect*. However, based on the dual channel assumption of multimedia learning (Mayer, 2005), we might expect that books that optimally enable dual-coding by including congruent animated pictures and nonverbal sounds and music with the text would offer more comprehensive support than print books that only contain still pictures. So previous results that supported the visual superiority effect may be an artifact of a set of stimulus materials that were not closely matched and thus did not support dual coding.

For a critical test of multimedia effects we selected (quasi-) experiments from the literature in which additional non-verbal information was included in electronic stories. We assessed whether these features actually improved the manner in which children learned and retained information from storybooks and for whom those additions were most effective. The seminal study by Sharp et al. (1995) was among the first to test whether what they called 'dynamic video information' aided children's understanding of short stories. The study showed that, in a group of 5- and 6-year-olds, a learning context with silent video that illustrated the entire story accelerated story comprehension more than did a silent video in which only one video event from the story was shown. More recent studies have also revealed positive effects of animated books that included animated pictures, background sound, and nonverbal music when compared with the same or similar books that included static images. Most experiments focused on children aged 5 and 6 years with a limited Dutch or English background for whom the scenes were complex and the narrations included difficult language (Kamil, Intrator, & Kim, 2000). From these randomized controlled trials it appeared that electronic multimedia books were more appropriately tailored to meet the needs of these children than still versions of the same books that contained only static images (Smeets & Bus, 2014; Verhallen & Bus, 2010; Verhallen et al., 2006). For instance, after 20 minutes, the time it takes to hear the computer voice read the story about *Winnie the Witch* four times, second language learners' vocabulary gained six out of the 42 words selected from the focal story (Verhallen et al., 2006). Children's word knowledge also improved as a result of spending the same amount of time reading a still version of the same book – a condition that seems analogous to a print-book reading sessions – but growth was less substantial. Stories with animated pictures were also more beneficial for story understanding (Verhallen et al., 2006). After hearing the oral narration four times while looking at static pictures on the screen children understood only part of the story. Their retellings were far from complete and included on average slightly less than 40% of the story elements. In the multimedia condition, children's retellings covered on average 55% of all story elements. Effects were most pronounced for understanding the goals, intentions, motivations, and feelings of story characters. Children in the static condition understood that *Winnie the Witch* kept stumbling over the cat (action) and that she changed the cat into a green cat (action) but they did not mention the fact that *Winnie the Witch* got angry when she had fallen once again and decided to do something about it (implied). Retellings of a story after being exposed to the multimedia book, on the contrary, did not just contain actions but implied elements as well. These children also named states of minds of main characters ("sees," "is furious," or "decides").

The results of these studies were consistent with the hypothesis that nonverbal information does not necessarily "use up" the capacity for storing language in working memory but rather enables children to figure out the meaning of unknown words and store those in long-term memory (Paivio, 2008; Wickens et al., 1983). None of the experiments with animated storybooks that included motion pictures, sound and music supported the visual superiority hypothesis that these books were so overwhelming that children failed to listen to the story text and just focused on the animations. The multimedia effect may not, however, be the only explanation for the finding that children learned more from such books compared with print books. Alternatively, animated storybooks may be more effective in attracting children's attention than static books, especially when children repeatedly listen to the same story. Evidence for this comes from a study in which we found that children's level of arousal as indicated by skin conductance while listening to a story was higher during the animated version than while listening to the static version, especially when the book was repeated for the third or fourth time (Verhallen & Bus, 2009). A balanced set of motion pictures enriched with music and sound may help young children to stay attentive while listening to the story, thereby enjoying books more and becoming more motivated to reread stories more than once.

Not All Multimedia Features Facilitate Children's Emergent Literacy

Not all experimental results supported the positive effect of animated stories on learning in young and language-delayed groups of children. Unlike the above-mentioned studies, Korat and Shamir (2007) and Silverman (2013) did not find positive effects of animated stories on story comprehension and vocabulary learning. However, the materials in these studies may not have been designed in a way that non-verbal information provided guidance to the learner for understanding the narration. For instance, Korat and Shamir (2007) used scanned illustrations that included automatic dynamic visuals to dramatize the story, but the animations were not created to attract attention to the particular details that matched the story text. Motion was added to make the scene more realistic (e.g., trees moving in the wind), but not to attract children's attention to relevant story elements in the illustrations and thus optimize temporal congruity of text and illustrations, and dual coding. Where the visualization is not intended to focus attention on particular details, but rather includes purely 'decorative' or incidental animations, electronic books may not benefit literacy skills. Silverman (2013) used children's television programs as a medium for vocabulary instruction and contrasted those with print versions that were made by selecting screenshots from the videos, "chosen to be optimally representative of the theme". The text was created by incorporating dialogue from the script verbatim into the books. The videos showed the whole scene but were not created to make complex narrative story language understandable by zooming in on or turning critical details (e.g., bear's red face due to being shy) or typical behaviors (e.g., a fluttering butterfly) in motion.

We predict, therefore, that positive effects for multimedia additions to stories will be observed only if images that attract the most attention are semantically related to the words and if they are presented closely together in space or in time (Kamil et al., 2000; Moody, Justice, & Cabell, 2010). The "crowdedness" of animated presentations may become problematic if the result requires children to process information simultaneously through multiple modalities that do not match. This might cause overload of children's working memory and reduce learning about the story language, rather than making the most efficient use of limited cognitive resources. Likewise, the integration of commercial movie footage with written text, as in so-called 'vooks' (an amalgamation of video and books), may not fulfill the minimum requirement of temporal contiguity and therefore not support language development. Given the discrepancies in the extant research base on how static and animated media compare as contexts for vocabulary learning and text comprehension, more research is required. We need to specify the ways that different media should be harnessed to improve learning; that is, under what conditions does information presented through multiple versus single modalities bootstrap the development of literacy skills.

Differential Effects of Additional Information Resources

Even though detailed pictures make storybooks particularly suitable for extracting meaning and deriving unknown words from the book context (Hayes et al., 1986; Greenfield & Beagles-Roos, 1988; Carney & Levin, 2002), they may not always be needed or helpful because some readers are able to create mental images of story events from the words alone (Guttman et al., 1977). With age, easy-to-follow texts that are highly concrete and engaging (e.g., interesting narrative passages) may readily elicit visual imagery (Carney & Levin, 2002). We therefore expected that not all children would benefit from multimedia stories that use a broader range of symbolic elements to carry meaning. The inclusion of additional information sources - images, music and sounds - in addition to text may be primarily helpful for children who experience problems in understanding story events and learning new words (Reinking, 2005). Nonverbal support for story and text comprehension may be important because these children have fewer words with which to comprehend new words through verbal communication alone (Silverman & Hines, 2009). Consistent with this reasoning, Kamil et al. (2000) predicted that the strongest effects of the extension and application of multimedia features for children who find it hard to understand narration based on language alone: second-language learners, other groups at risk of language delay (e.g., low SES), and very young children.

Smeets and Bus (2014) did not find effects of multimedia compared to static storybooks on story comprehension in a normative sample of 4- and 5-year-olds who were first language learners with average scores on language proficiency. Yet Smeets and Bus (2014) found that animated electronic storybooks provided more opportunities for vocabulary growth and resulted in an additional 6% increase in word learning in this group compared to stories presented on the computer with static pictures alone. Other studies that included children from elementary schools indicated that for these older students with normal language skills (Beagles-Roos & Gat, 1983; Gazella & Stockman, 2003; Neuman, 1989, 1992), providing animated pictures was not as helpful in promoting story comprehension as it was for younger groups. This was probably because hearing the text content directly elicited useful images in older and more advanced students but not in younger students. In so far as these findings concern students in higher grades of education, they are consistent with the "expertise reversal effect", in which instructional techniques that are effective for less experienced learners might not be useful for more experienced learners because the redundant additional information can distract the experienced learner and increase cognitive load (Kalyuga, Ayres, Chandler, & Sweller, 2003; Kalyuga, 2007).

A study targeting kindergarten children diagnosed with Severe Language Impairment (SLI) showed that symbolic elements used to carry meaning such as background sounds and nonverbal music are not always helpful for young children who experience problems in understanding and retaining the story language. In those cases, music and sound added to electronic stories contributed negatively to learning new language (Smeets, van Dijken, & Bus, 2014), just as adding music and sounds to general learning tasks seemed to do in young toddlers (Barr, Shuck, Salerno, Atkinson, & Linebarger, 2010). According to Schnotz's (2005) integrative model of text and picture comprehension, information enters working memory from the outside world through sensory channels. During the first step in processing information that enters through the ears, the learner makes exact auditory images of words for a very brief time period in an auditory sensory memory. Children with SLI may experience problems with creating these exact images because of the presence of background sounds and music. The SLI children in the Smeets et al. study also failed to repeat novel non-words when background noise was present (c.f., Robertson, Joanisse, Deroches, & Ng, 2009; Vance & Martindale, 2012; Vandewalle, Boets, Chesquière, & Zink, 2012), which may indicate that they had problems creating auditory images of words in the sensory registers. As a result, they may have failed to create, in the next step of processing verbal information, a verbal representation of selected words or phrases in the verbal working memory thus interfering with learning unfamiliar words (Schnotz, 2005). It is also possible that children with SLI experience problems in identifying basic emotions from music (Spackman, Fujiki, Brinton, Nelson, & Allen, 2006). This might interfere with processes that take place when non-verbal information is integrated in working memory in order to create a mental model of non-verbal information. Even though music and sounds are present only in the background and provided to supplement images, they attract attention (Barr et al., 2010) and might have caused cognitive overload for these children when they were organizing visual and auditory information into a mental representation.

Whatever the exact nature of the interference of music and sounds may be, an important message of the Smeets et al. (2014) study is that adding these to stories might diminish rather than enhance the learning potential of multimedia storybooks for children who have problems with verbal processing (Courage, Bakhtiar, Fitzpatrick, Kenny, & Brandeau, in press). In those cases, it might often be best to present oral text alone, without any music or sound effects. The finding that music and sounds can be detrimental for learning has far-reaching implications in a world that is dominated by storybook apps that mostly include background sounds and music (Smeets & Bus, 2013). In many apps, the volume of the soundtrack is loud and not adjustable. In examining the current offerings in app stores, we found many that typically are too loud. For example in Disney's *Cars 2*, the narration can barely be heard over the exciting background music and sound effects of racecars driving by. The storybook app *Magic Gold Fish* by Yasmin Studios includes hotspots with sound effects (e.g., a fish splashing in the water) that are very loud in comparison with the narration. Interestingly, for example, the apps *Pansjo Tummy* developed by ThenQ, *PopOut! The Tale of Peter Rabbit* (Loud Crow Interactive) or *The Fantastic Flying Books of Mr. Morris Lessmore* (Moonbot Studios) include an option for turning off background music and narration separately; such a feature makes an animated multimedia book more adaptive to support learning in different target groups.

Effects of Interactive Features in Hypermedia Storybooks

Most first generation electronic storybooks included interactive features, as was evident from content analyses of Dutch (de Jong & Bus, 2003) and Israeli e-books (Korat & Shamir, 2004). Since the first books on CD-ROM appeared, researchers have studied the effectiveness of hotspots in these stories. One of the first interactive electronic storybook that came out in the Netherlands in the late '90s was based on the stories by German author-illustrator Janosch. A scene from one of the stories shows Dr Cornelis Frog examining Tiger because he did not feel well. After the events were dramatized, the screen was frozen and it was possible to click on about five details in the illustration such as the light bulb, the little duck on the floor, or Tiger, whereupon visual and/or sound effects were activated. Doctor Frog may, for instance, take a bite from the light bulb hanging above his head. Hotspots in the early electronic storybooks were rarely supplemental and intended to help to understand story events. A content analysis carried out in the Netherlands (de Jong & Bus, 2003) and replicated in Israel (Korat & Shamir, 2004) indicated that in most first generation digitized books, almost all interactive hotspots were incidental (more than 90%). As a result of the increased popularity of touch screen devices, hypermedia stories for the youngest children usually include a large number of increasingly fancy but incidental hotspots. For example, in the app *PopOut! The Tale of Peter Rabbit* (Loud Crow Interactive) children have small games on every screen utilizing the advanced features of the device. By touching and moving leaves, berries and other objects pop up and fall down the screen; at the bottom they can be moved to and fro by physically moving the device as marbles in a box can be moved. All of the games are surprising and amusing but irrelevant to the story. In another app *The Three Little Pigs* (Game Collage), in addition to the option to make parts of the illustrations pop up, there is a feature included on every page that allows children to put on an x-ray view showing the mechanics of those pop-ups. Such incidental features that do not enhance the story line are typical for many books developed for the youngest children. In electronic stories for 9- and 10-year-olds, the 'menu' may allow the child to visit the different planets, listen to the characters, play a game, keep a diary, and find out about the life of the author (Grimshaw, Dungworth, McKnight, & Morris, 2007).

However amusing those interactive features might be, there is concern for the educational quality of these electronic storybooks (e.g., de Jong & Bus, 2003; Korat & Shamir, 2004; Roskos, Brueck, & Widman, 2009; Zucker et al., 2009). Kamil et al. (2000) described electronic books that are loaded with extraneous information as more like a game than a book reading experience. Although playful additions are designed to be interactive, motivating, and self-paced (e.g., Ricci & Beal, 2002), adding 'bells-and-whistles' to a multimedia presentation may distract children from the main activity - story comprehension – or interfere with extracting meaning from the main message (Mayer, 2001). As the human information processing system has a limited capacity (Sweller, 2005; Baddeley, 1986), sharing resources among various tasks (e.g., memorizing and integrating story events in between playing games) may come at a cost for performance (Kahneman, 1973). In his review of the educational potential of electronic story texts, McKenna (1998) noted that interactivity in electronic texts for literacy learning makes great intuitive sense but that interactivity can also take forms that interfere with story comprehension. Preschool children's learning may suffer especially from task switching between game-like features and story understanding, as their executive functions are immature (Garon et al., 2008). We shall now review the available research that examines common forms of interactivity in storybook apps for preschool age children.

Effects of Games or "Hotspots" that are Incidental to Story Content

Clicks on hotspots that activate links to animation, sound, or music - mostly incidental to the narration - may attract the viewers' attention and increase arousal, motivation, and engagement (Smith, 2012). Moody et al. (2010), for instance, reported higher levels of persistence during the adult-led storybook with hotspots compared to the adult-led print book reading. That is, the children were more problem-oriented and more able to complete and maintain participation with hotspot-enriched storybooks (cf. James, 1999). However, there are more studies indicating that switching among divergent tasks within a window places the younger user at risk of cognitive overload. Rather than enhancing learning outcomes as intended, carrying out game-like activities during the story reading session interrupts the processing of the story line and results in interference, distraction, and ultimately errors and diminished performance (Courage et al., in press).

Although the twenty 8-year-old children in a seminal study (Okolo & Hayes, 1996) enjoyed the animations (clicks on an element of the picture revealed a written label, spoken out loud and sometimes accompanied by sound effects), the extensive animation sequences often misled children into drawing wrong conclusions about the text and diminished their ability to make sense of a story. Similar results were reported for 10-year-old students (Trushell, Maitlend, & Burrell, 2003). Children in the *Let me play* group condition that contained visual distractions that lured attention away from text, scored lower on story recall measures than students in the *Read to me* group without distractions. When incidental hotspots were included, children's recollections of the story were lacking in detail and also contained distortions.

In a case study, Labbo and Kuhn (2000) compared retellings of two books, one with incidental interactive features incongruent with the text and the other with congruent, supplemental features. The study involved a Spanish-speaking child practicing with books written in English in the classroom. Their observations indicated that storybooks on CD-ROM with supplemental interactive features supported this child's understanding and retelling of the story. However, CD-ROM stories with many incidental effects resulted in the child's inability to retell the story in a cohesive way. In other words, when given two tasks to perform concurrently - understanding the story while resisting distraction from interactive features – it was difficult for this child to construct a coherent mental representation of the story. The authors concluded that kindergarten children could fail to understand stories especially when special effects in the storybook apps were frequent and inconsistent with the story.

De Jong and Bus (2004) replicated the negative result of incidental interactive features in a larger group of kindergarten children. The children in their experiment were native speakers and therefore not as delayed in language as was the Spanish-speaking boy. The CD-ROMs used in this experiment included many incidental interactive features. On average each screen included 5 animations that could be activated after listening to the story text read to them by a computer voice. More than 90% of the animations were incongruent with the story. All children were attracted to the embedded effects and activated about 20 animations in each 15-minute session. After listening to the story, children were able to retell it but did so in much less detail than without having had access to the embedded animations. This suggested that children were unsuccessful in coordinating simultaneous task demands and, perhaps due to a higher cognitive load involved in multitasking, their comprehension was diminished (Mayer & Moreno, 2003).

A likely explanation for the negative effects of incidental interactive features inconsistent with the story is that task switching (or multitasking) is particularly difficult for young children. They are typically unsuccessful in carrying out simultaneous activities that require different cognitive processes at the same time or alternating between activities that consume processing resources. According to the research, preschool and kindergarten children fail to attend to all of the relevant information that is needed to understand the story while resisting distraction from animations that are interesting but less relevant. These negative outcomes - distortions and less detailed retellings - may be the result of immature executive functions such as working memory, attention shifting, and inhibition (Kegel & Bus, 2014). They may also reflect a "switch cost" (Courage et al., in press): When attention is divided or switched among two or more tasks, some degree of dual-task inference or switch cost may result in poorer performance. However, not all studies show negative effects of children's access to irrelevant interactive hotspots and games on story memory (Homer et al., 2014; Ricci & Beal, 2002; Robb, 2010). The kinds of interactivity offered by the device in those studies may have been limited enough that children were able to focus on the story line. In other words, the success of hypermedia electronic storybooks may depend critically on a variety of pedagogical and design factors as well as on the maturity of executive functions and comprehension skills that the child possesses.

Nowadays apps are available that, more than the first generation of electronic stories, include playful interactive features that must be activated by the reader in order to advance the story. The programs that we examined, however, showed that this type of design can be effective but mostly at the expense of the story's complexity and language. In the app *The Birthday* by Sylvia van Ommen, for instance, a mouse brings written invitations for his birthday to all his friends. By dragging the letter to a friend or the letterbox of a friend the child continues the story. The activities may not place the young user at risk of cognitive overload but the result is, unavoidably, an extremely simple story told in colloquial language with phrases like: "hi", "did you read it?", "cool", which is rather limited even for 2- and 3-year-olds. The activities might be entertaining because they are game-like, but the medium may develop children's visual and motor capabilities at the expense of story understanding and language processing (Greenfield, 2009).

Efficacy of On-Demand and Automatic Support for Story Comprehension

In one of the first prize-winning digitized picture storybooks released on CD-ROM in the Netherlands, *P. B. Bear's Birthday Party* (Davis, 1994), several different activities took place across the windows but, unlike the storybooks described above, the on-demand sources within a window were not only meant to be amusing but to provide support in understanding the story text. As the story text was read aloud by clicking on an icon at the beginning of the text, children could, for instance, activate the illustration to dramatize the story text or use a dictionary. Clicking on pictures replacing words in the story text revealed animations or sounds to explain the words' meaning. Furthermore, they could listen for a second or a third time to the oral text read by the computer voice or return to a previous screen for a repeated reading of the story text. One study tested whether such on-demand sources for understanding the story were used effectively by young children to support story comprehension. A randomized controlled trial (de Jong & Bus, 2002) revealed that 4- and 5-year-old participants did not recall the story line as well as children who listened to an adult read the same story to them. It seemed that young children who explored the electronic story were unsuccessful in dividing their attention across reading and using the on-demand resources in all six 15-minute sessions. Most children completely ignored the oral text and just played games and activated the animations. In so far as they listened to the story text, they did not listen to the pages in order. They spent more than half of the available time (about 2 hours in total) on the attractive animations and games, and the rest of the time was alternated between animations and a film about the story that was presented without (oral) text. They rarely listened to the story text and if this occurred they focused on text fragments after clicking on a sentence probably because they liked the motorial activity. As a result, most children heard the story text in a seemingly random order that was disconnected from the visualizations.

In general, the basic goal of this first generation electronic storybook, to provide additional information sources (e.g., explaining words, visualizing the story events, rereading the story text) to promote (oral) text comprehension, was not effective for young children. Both playing and reading can occur in parallel but the children preferred playing with animations and games to listening to the story text, maybe because distributing limited mental resources differentially among them was too taxing. Resources were redistributed in a graded fashion (e.g., mainly ignoring the most complex task - understanding the story text) to maximally enjoy the games. Probably because of the group's limited text comprehension skills, children gave priority to animations and games at the expense of oral text, and the animations and the visualization of story events were used on their own and not as tools to improve story understanding. The extra material in this interactive storybook seemed to distract young children from the story, even though most additions were relevant for story comprehension. Although the story was designed to be interactive, motivating, and self-paced, it placed the young user at risk of cognitive overload rather than enhanced learning outcomes. We hypothesized that due to young children's inability to divide and deploy attentional resources effectively across the various subtasks, this interactive story supported a game-playing approach rather than engagement in the story.

On the other hand, there is evidence indicating that young children can benefit from explanations of difficult words when those are automatically presented during story reading and interruptions are limited to a few times per book. For instance, in *Bear Is in Love With Butterfly* (van Haeringen, 2004), a definition of words that are often unknown to 4- and 5-year-old children (heartbroken, shy, wharf, imitate) were audio-recorded and linked to a hotspot in the illustration. After the screen freezes a green circle appears around one element, for instance Bear's red face, and the voiceover explains Bear's mindset: "Bear is shy, his cheeks have turned red." When word meanings were thus defined children gained, after four encounters with the same story, an extra 8% of word meanings beyond encounters with words in the text alone (Smeets & Bus, 2014). Similar results were reported for other studies with a 'dictionary option' that automatically defined words (e.g., Korat, Levin, Atishkin, & Turgeman, 2013; Korat & Shamir, 2008; Shamir & Korat, 2009; Shamir, Korat, & Shlafer, 2011) or presented word definitions as games (e.g., asking a child to click on a target object in the picture; Segers & Verhoeven, 2002, 2003). These hypermedia features may be effective because children are safeguarded from having to coordinate simultaneous task demands and also receive help in dividing attention across reading and on-demand sources.

Somewhat older, conventional readers seem more able to use on-demand help in understanding the story events and language probably because they have more mature executive functions and can multitask more effectively. For instance, the online dictionary providing on-demand word definitions and synonyms was accessed by 18 of the 26 9- and 10-year-olds while only one child accessed a printed copy of the Oxford Primary Dictionary once while reading from the printed version of the same text (Grimshaw et al., 2007). However, there was no strong evidence for the effects of a dictionary or other supplement information on story comprehension in this young age group. Although students utilized additional reading resources when engaged with digital text, Wright, Fugett, and Caputo (2013) reported similar comprehension scores for print and electronic storybooks.

Questions and Comments Modeled on Co-reading with Adults Can Stimulate Learning

In accordance with engagement theory, the hypothesis that students must be meaningfully engaged in learning activities through interaction with others for optimal learning to occur (Kearsley & Schneiderman, 1999), developers have begun to model questions and feedback about complex words or important story points on adult supports that occur during book reading sessions. Children who read an interactive book with a parent get tailored support from the parent, as well as access to desirable interactive features. Comparable verbal support from a computer tutor might encourage children's continued, positive engagement in the task just as it does in co-reading sessions. When adults prompt children with questions pertaining to the text, label object, and encourage them to discuss the book content in terms of their experiences and interests, this elicits increased motivation and verbalization by the child and can improve literacy development (e.g., Biemiller & Boote, 2006; Blewitt, Rump, Shealy, & Cook, 2009; Brabham & Lynch-Brown, 2002; Collins, 2010). The promptness and contingency of responsiveness might help ensure that the child remains focused on the computer task. In this line of argument, we expect that a tutor modeled after an adult would facilitate children's understanding of complex word explanations. In fact, there is evidence that a story incorporating an on-screen dialogic questioner modeled on parent-led questioning enhanced children's story comprehension at age 3 (Strouse, O'Doherty, & Troseth, 2013). The storybook pages included very light animation and there was a voiceover of an adult reading the story. Each page also included a small picture-in-picture in the corner of the main story image. An actress on the pre-taped video asked dialogic questions but could not respond contingently to the viewing child. Consistent with this, the results of a randomized controlled trial study (Smeets & Bus, 2012) indicated that children who learned by answering multiple-choice questions outperformed those who received identical information in a non-interactive message. When Bear in the story *Bear Is in Love With Butterfly* (van Haeringen, 2004) is fanning the fire, the story is interrupted for a question by the computer assistant: "Bear is fanning the fire. In which picture can you see that?" To answer questions about difficult words or important story points, children can click on one of three pictures that appear on screen (the correct image among two distractors). The tutor gives feedback regarding the correctness of the response and provides clues in the cases of incorrect responses that become more specific as children continue to make errors (van der Kooy-Hofland, Kegel, & Bus, 2011).

The pattern of results suggests that the inclusion of a tutor using dialogic questioning within electronic stories modeled on co-reading with adults, although probably not as effective as true social contingency, might be useful in increasing what young children can learn from electronic books. We have therefore begun testing the hypothesis that, for susceptible children (i.e., whose performance depends more strongly on the quality of educational input than for others; Belsky et al., 2007), multimedia books that provide intensive, closely monitored, and individualized scaffolding may be especially effective in turning a putative "risk" group into a successful group. The experiment (Plak, Kegel, & Bus, 2015) was carried out at 82 Dutch schools. All 5-year-olds who belonged to the lowest quartile of a national standard literacy test were eligible to participate in this experiment. The experimental group used the books twice a week for three months while a control group played games not related to literacy during the same time. By analogy with findings in developmental psychopathology, we assumed that some children would be more susceptible to environmental input than others (van IJzendoorn & Bakermans-Kranenburg, 2012). In this study we focused on children's genetic make-up as marker for differential susceptibility and tested whether carriers of the long variant of the DRD4 genotype may also be a susceptible group in the cognitive domain. It is assumed that transmission of electric signals, especially in the prefrontal cortex monitoring impulses from the limbic system, is less efficient in this group. Consequently, these children may be easily distracted by irrelevant elements in the learning environment and experience more problems in canalizing stress elicited by school tasks, with poor achievement as a result. An engaging learning environment, on the other hand, might influence these children more positively than it affects their peers. The first experimental results indicated that only carriers of the long variant of the DRD4 genotype benefited from an intervention in which they read multimedia books on their own. In this susceptible group (about one-third of all participants), the electronic books program caused a moderately strong effect on a national standard literacy test (effect size d = 0.56), whereas the program did not affect the other children (d = -0.09). Further studies are required to test why carriers of the long variant of the DRD4 genotype in particular lag behind without multimedia book reading but outperform their peers with such experiences in addition to the common core curriculum in kindergarten. Guidance and feedback provided by the tutor may make the multimedia books especially effective in susceptible groups. It is also possible that attractive multimedia including motion pictures, sound and music help young vulnerable children to stay engaged and control stress while reading books (Kegel & Bus, 2012).

Conclusions: What we have Learned about Designing Digitized Storybooks that are Developmentally Appropriate in Form and Function

Digital storybooks, including those designed for recent devices like phones and tablets, contain a combination of enhancements (Horney & Anderson-Inman, 1999) that will change children's early experiences with books. The research synthesis provided here indicates that additional enhancements can improve the manner in which children as young as 3 years of age comprehend and retain information from stories. As one '*working' principle* for app developers, it seems important to promote dual-coding by facilitating the matching of nonverbal information sources with the oral text. When there is close congruency and temporal proximity between narration and non-verbal information, electronic storybooks can offer new opportunities to promote story and text comprehension. Research findings indicate that animated pictures can reduce the amount of effort that is required for matching nonverbal information with story language, which can then facilitate word learning and story comprehension (Schnotz & Rasch, 2005). Animated pictures may be especially promising for very young children and language-delayed learners. We found evidence for the importance of strong congruency between the verbal and nonverbal modalities for those children. However, additional irrelevant visualizations may hamper learning when they deplete information processing resources. For instance, where the visualization is not designed and intended to focus attention on particular details, but is simply frivolous live action video that does not match the story text, the storybook app may hamper instead of stimulate story and language comprehension. Such visualizations may attract children's attention to details of the illustration that are irrelevant to the text. There is also evidence that music and sounds can easily lead to interference and diminished performance when these nonverbal additions compete for limited auditory or visual resources, especially in children with language impairments. By offering more options in electronic storybooks, software could be designed to enable adults to tailor electronic stories to the needs of children. For example, the option of turning the sound effects and background music off could be helpful for children experiencing problems with verbal processing.

Hypermedia Features Easily Interfere with Optimal Learning Conditions

Hypermedia features are a popular addition to storybook apps because of their potential to enhance the effect of book exposure by creating electronic storybooks with automatic or on-demand interactive features. Similar to first generation CD-ROMs, apps that are now available for new devices include an extensive number of embedded features that are increasingly novel. Retailers prefer to offer apps that include a maximum number of embedded features. However, these may lure children's attention away from the narration and turn the activity into a game instead of a reading experience. The evidence presented in this review suggests that app developers should consider, as a second vital *working principle*, that the youngest children cannot distribute their limited mental resources differentially between story comprehension and on-demand forms of assistance such as dictionary or word pronunciation features. Several studies showed unambiguously that the presence of games and hotspots, incidental to the story line, diminish children's performance in story and language comprehension. If they have a choice, children prefer playing with animations and games to listening to the story. Moreover, we found that young children will likely not develop language and literacy skills when stories include task switching between the story text and embedded features, whether supportive or frivolous. Task switching, or multitasking, requires executive functions and most young children are not yet able to control and deploy their attentional resources effectively. Consequently, they enjoy playing with the programs but the activities may no longer support and expand literacy skills and experiences. The studies that were discussed here underscore the problems that can arise when children lack a purpose or focus for reading, rendering them easy prey to "eye-candy" (Trushell et al., 2003). The book reading experience will only support literacy development when the program safeguards children from having to coordinate simultaneous task demands and they receive support in dividing attention across reading and embedded features. Suggestions for improvements of electronic storybooks generally call for greater balance between making use of the exceptional capabilities of technology and the careful selection of features that support literacy and language development in order not to overwhelm the child.

Technology currently provides one of the most important sources of literacy development for children of all ages but without a balanced set of hypermedia, there is a serious risk of a downward reading spiral in the long-term. Considering the numerous distractors in popular apps, we suspect that the many hours spent with screen media cannot replace the time spent sharing print books with parents and teachers. As a result, children may develop lags in a whole range of literacy skills (Mol & Bus, 2011). Already at 15 months, rarely-read-to infants lag behind regularly-read-to peers in vocabulary and thereby in their ability to understand and enjoy books (van den Berg & Bus, 2014). We urge therefore the development of optimally designed and evidence-based story apps that will foster young children's foundational literacy skills.

Engineering and Assessing New Electronic Stories: New Roads for the Future

The multimedia and interactive stories for children targeted in research projects are rather heterogeneous making it difficult to disentangle the effects of the many different design features on children's learning. Moreover, the electronic stories available on the market are changing rapidly, including new features, new platforms and eventually quite novel reading experiences (e.g., movement-based devices like the Microsoft Kinect in Homer et al., 2014). Additional well-controlled studies on the effectiveness of the new wave of available apps that ostensibly present stories to toddlers and preschoolers are urgently needed to test the effects of these formats and their content on emerging literacy skills.

Furthermore, research to date supports the hypothesis that technology-enhanced books can be particularly helpful for children with a high susceptibility to environmental input and help them to make optimal use of their learning abilities. We reported some preliminary findings demonstrating that multimedia storybooks that also provide positive feedback in response to children's answers to embedded questions about complex words or the story content can boost learning for susceptible children. An explanation for these findings may be that technology-enhanced materials can help easily distracted children to stay engaged while solving tasks and may enable them to control stress elicited by the task. As a further test of technology-enhanced materials, and in particular digitized books for young susceptible children, we need to identify the key components that make these enriched multimedia books most effective. To achieve this, we also need more variety in digitized book formats than is now available. Dutch publishers are aware of the shift that is taking place towards digitized reading in kindergarten and primary education and are looking for ways of making optimal use of the digitized format. On the other hand, they are unlikely to invest in new book designs without data to support their economic viability. As researchers, it is incumbent upon us to provide that data as technology may open up new opportunities for vulnerable children and turn putative "risk" groups into successful groups.

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CHAPTER 3

BENEFITS AND PITFALLS OF MULTIMEDIA AND INTERACTIVE FEATURES IN TECHNOLOGY-ENHANCED STORYBOOKS: A META-ANALYSIS

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Abstract

A meta-analysis was conducted on the effects of technology-enhanced stories for young children's literacy development when compared to listening to stories in more traditional settings like storybook reading. A small but significant additional benefit of technology was found for story comprehension ($g+ = 0.17$) and expressive vocabulary ($g+ = 0.20$), based on data from 2,147 children in 43 studies. When investigating the different characteristics of technology-enhanced stories, multimedia features like animated pictures, music and sound effects were found beneficial. In contrast, interactive elements like hotspots, games and dictionaries were found to be distracting. Especially for children disadvantaged because of less stimulating family environments multimedia features were helpful and interactive features were detrimental. Findings are discussed from the perspective of cognitive processing theories.

There is no doubt that reading stories to young children are one of the most important sources of literacy development (Bus, van IJzendoorn, & Pellegrini, 1995; Mol & Bus, 2011). Listening to stories children expand their story comprehension skills and acquire sophisticated language in addition to code-related skills such as phonological awareness or concepts of print. With the emergence of technology in homes and school settings, children can watch a narrative on television, on the computer using a CD-ROM or DVD, or on the Internet, and more recently, they can use a tablet or a smartphone (e.g., apps on the iPad or the iPhone) to access stories. Television only allows for multimedia features (like animated illustrations in addition to music and sound effects); in contrast, it is possible for stories on the computer or tablets to involve the child in the story through interactive features such as questions, dictionaries, games, and animations, or sounds to be activated by clicking on or touching a spot in an illustration (often indicated as hotspots).
The Joan Ganz Cooney Center analyzed the 137 most popular American electronic books (e-books) for young children in 2012 (Guernsey, Levine, Chiong, & Severns, 2012) and found that 75% of the e-books included hotspots and 65% included game-like activities. Only about 20% of hotspots and a quarter of the games were related to the story. From the perspective of information processing, this shift from listening to a story to playing during listening might require the child to continuously switch between listening and playing, which could have serious consequences for story comprehension and learning as a result of cognitive overload (Bus, Takacs, & Kegel, 2014).

At the same time, it has been suggested that technology-enhanced stories will enhance children's comprehension of stories (Salmon, 2014; Zucker, Moody, & McKenna, 2009). Multimedia additions provide nonverbal information that might help story comprehension by visualizing story events congruent with the narration (Sharp et al., 1995; Verhallen, Bus, & de Jong, 2006). Similarly, interactive features that are relevant to the story (e.g., a hotspot with a question that is tightly connected to the story) or aimed at developing literacy skills (e.g., an alphabet game) might enhance the effects of listening to a story (Segers, Nooijen, & de Moor, 2006; Shamir, Korat, & Fellah, 2012; Smeets & Bus, 2014). Additionally, technology-enhanced stories may be more engaging for children in comparison to print storybooks (Adam & Wild, 1997; Chiong, Ree, Takeuchi, & Erickson, 2012; Moody, Justice, & Cabell, 2010; Okolo & Hayes, 1996), especially during repeated readings (Verhallen & Bus, 2009a).

For the purposes of the present meta-analysis of technology-enhanced stories, the effects of different devices and platforms were ignored (see Roskos & Burnstein, 2013, for a study on the role of devices). Instead, the effects of multimedia and interactive elements were examined. Furthermore, the effect of technology was investigated as a function of children's risk status, because it has been suggested that multimedia may be especially beneficial in risk groups (Kamil, Intractor, & Kim, 2000).

Multimedia Features

The visual superiority hypothesis assumes that salient visual information presented in television programs distracts children from the verbal stimuli (e.g., narration or conversation). This hypothesis, however, has not been confirmed. Research has shown that children pay attention to the verbal information when it is congruent with the visual information (for reviews see Bus et al., 2014; Rolandelli, 1989). However, we still do not know if a presentation of stories that include nonverbal information is better for comprehension than a verbal-only source of information.

The cognitive theory of multimedia learning (Mayer, 2003) proposes that deeper learning occurs when information is presented both verbally and nonverbally. According to the dual coding theory (Paivio, 2007), verbal and nonverbal information are processed in two separate but interconnected channels. Thus, processing the two kinds of stimuli simultaneously does not result in cognitive overload but, on the contrary, it facilitates learning. Because illustrations and narration mostly complement each other in picture storybooks, the nonverbal information may support comprehension of verbal information and, vice versa, verbal information may support the interpretation of illustrations and other nonverbal information (Sipe, 1998).

Technology-enhanced books may, even more than traditional print books, enhance children's story comprehension and word learning from the story due to a closer match between nonverbal and verbal information. When pictures include movements and zooming, each frame might illustrate the oral narration more closely in time than static pictures, resulting in a higher temporal contiguity between the verbal and visual information. In fact, the temporal contiguity principle of the multimedia learning theory predicts deeper learning when the verbal and nonverbal information are presented close to each other in time rather than further apart (Mayer, 2005). The hypothesis is that in the case of high temporal contiguity, children do not need to hold the oral narration and the illustration in working memory in order to integrate them, thus reducing the cognitive load children face when listening to a story. Additionally, it is plausible that sound effects and background music that are often part of technology-enhanced books might, if congruent to the narration, illustrate feelings and mood, thereby facilitating story comprehension and learning abstract words from the narration.

The literature comparing children's comprehension and memory of the details of animated (television) to audio-only (radio) stories show some evidence that dynamic visualizations enhance story comprehension (Beagles-Roos & Gat, 1983; Gibbons, Anderson, Smith, Field, & Fischer, 1986; Hayes, Kelly, & Mandel, 1986; Pezdek, Lehrer, & Simon, 1984; Sharp et al., 1995). A more recent line of research that compares (a) electronic stories with animated pictures, background sounds, and music to (b) print or print-like presentations that include static illustrations found an advantage for technology-enhanced books on story comprehension and word learning (Smeets & Bus, 2014; Verhallen et al., 2006; Verhallen & Bus, 2010) with some exceptions. For children having difficulties with verbal processing, sound effects might disrupt perception of speech (Smeets, van Dijken, & Bus, 2014).

In sum, as long as they are congruent to the story, animated pictures, sound, and music do not seem to distract children from the story text. On the contrary, meaningful nonverbal additions to stories have been shown to boost story comprehension and word learning. In the present study, the effect of multimedia features was compared to those of oral narration of stories including some or no static illustrations.

Interactive Features

Most technology-enhanced stories are loaded with interactive features such as puzzles, memory tasks, amusing visual or sound effects, dictionary function, or word or picture labels appearing when activating the hotspot (de Jong & Bus, 2003; Guernsey et al., 2012; Korat & Shamir, 2004). As these features are often available not only after but also during the oral narration (de Jong & Bus, 2003) they might interrupt the flow of the story or draw children's attention away from listening to the oral narration. In fact, de Jong and Bus (2002) found that when a lot of visual and sound effects are available and children can make a choice between listening to the narration and playing with visual and sound effects, they hardly spend any time listening to the oral narration.

According to the cognitive load theory (Sweller, 2005), working memory capacity is very limited. Instructional designs that do not take this limited capacity into consideration can result in a large cognitive load and disrupt learning. The coherence effect of the cognitive theory of multimedia learning (Mayer, 2003) predicts deeper learning when extraneous materials that are not directly related to the learning material are excluded from the multimedia message. Interactive features, especially the ones that are not tightly connected to the story line like games or hotspots on irrelevant details, might function as seductive, extraneous materials that can distract children from the story.

In fact, incongruent interactive features have been found to result in the child's failure to retell the story (Labbo & Kuhn, 2000; Okolo & Hayes, 1996). Ricci and Beal (2002), on the other hand, found that children's recall of a highly interactive story including unrelated interactive features was better than their recall of a recorded audio-only presentation. Interactive features that support story content may have a potential advantage. Segers et al. (2006) found that an electronic book with games to explain story vocabulary was more beneficial for special needs children's word learning than a teacher reading a story to them. Korat and Shamir (2008) showed that children reading electronic books with dictionaries improved more in vocabulary than children reading electronic books without interactive features. Smeets and Bus (2014) found that children in the condition including explanations of difficult words from the narration in the form of hotspots outperformed the children in the electronic story condition without interactive features to support word learning.

In sum, interactive elements that are not supportive of story comprehension might function as extraneous material resulting in incidental processing and cognitive overload that disrupts processing of the essential material of the story and learning (Mayer & Moreno, 2003). Constant switching between two different tasks, understanding the story on the one hand and exploring games and hotpots on the other, might place too much extraneous load on the working memory of young children and decrease their performance on both tasks. Specifically, it may result in decreased story comprehension and word learning from the story. Even interactive features that are relevant to the story may disturb story comprehension and language learning. Story comprehension and playing with hotspots or games are two fundamentally different tasks, even when their content is related, and carrying out both requires task switching. On the other hand, the more closely related the story and the interactive additions are, the smaller the cognitive cost of switching between the two tasks is.

Disadvantaged Children

It is plausible that for children who do not fully understand the narration because they lack the language and comprehension skills necessary, nonverbal information from animations and sound effects can fill in the gaps. Similarly, games related to literacy skills in interactive stories can offer an appealing environment to practice and develop literacy skills, which might be especially important for children who are behind or who are having difficulties with these skills. Thus, in the present meta-analysis, special attention was given to the effects of technological enhancements on stories for the different groups of disadvantaged children by testing every effect separately for disadvantaged and non-disadvantaged children.

As we found samples with a wide range of characteristics that might put children at risk of lagging behind in language and literacy development in the primary literature, we used the umbrella term, *disadvantaged*, for groups of children from low socioeconomic status (SES) families (e.g., Korat & Shamir, 2007) or immigrant, bilingual families (e.g., Segers et al., 2004), and children with learning problems, such as struggling readers (e.g., Karemaker et al., 2010a), children with special needs (Segers et al., 2006), children with developmental delays (Shamir et al., 2012), or children with severe language impairments (Smeets et al., 2014).

Research Questions

In the present meta-analysis, we were specifically interested in the additional effects of technology as compared to more traditional presentations of stories, like telling a story or reading a print storybook. Thus, only studies contrasting technology-enhanced story presentations to more traditional presentations of the same or a similar story were included in the meta-analysis. In both the technology-enhanced and the comparison conditions, an oral narration of the story had to be included. We considered independent reading of a story as fundamentally different from listening to stories because children need to pay attention to decoding the written text when reading themselves instead of just focusing on comprehending the story.

There were four research questions. The first question asked whether technology-enhanced stories foster learning more compared with traditional print-like story presentations. Based on the primary literature we expected a general advantage of technology-enhanced stories over more traditional presentations on children's literacy outcomes. The second question asked if multimedia-enhanced stories were more beneficial for children's literacy than traditional story presentations. Based on the theory of multimedia learning, it was hypothesized that multimedia features, congruent to the narration, such as animated pictures, music and sound may be beneficial.

Question 3 asked whether interactive features in technology-enhanced stories were distracting at the expense of children's literacy learning. In contrast to multimedia elements, interactive features, especially the ones that are irrelevant to the story, may be distracting and harmful for story comprehension (Bus et al., 2014). Finally, Question 4 asked if technological additions to stories were more important for disadvantaged groups of children than for non-disadvantaged students. We expected that the addition of multimedia features to stories would be especially important for children who are at risk of getting behind or are already behind in language development. That is, because of these children's limited understanding of the story language, they are the ones who might benefit the most from extra nonverbal information. In fact, it is plausible that older and typically developing children with average or above average vocabularies and language skills might not need much, or even any, nonverbal addition to understand a story.

Method

Operational Definitions

The goal of the present study was to compare the effects of technology-enhanced narrative stories to more traditional presentations on young children's language and literacy development. Technology-enhanced stories were defined as any orally narrated story presented with some digital addition, like multimedia (animated and/or video illustrations, zooming, sound effects, background music) or interactive features (hotspots, questions, games). Our broad definition of technology-enhanced stories included a wide range of electronic stories and television shows and very different devices on which the story was presented, like television sets (e.g., Pezdek & Stevens, 1984), computers (e.g., de Jong & Bus, 2002, 2004; Ricci & Beal, 2002), tablets (Chiong et al., 2012; Noel, 2013), or other platforms like the Microsoft Kinect (Homer et al., 2014). Unlike other reviews (e.g., Zucker et al., 2009), we did not require the technology-enhanced stories to include the print text on the screen similar to print books.

For a study to be included there had to be a comparison condition in which the same or a similar story was presented in a way that resembled the more traditional circumstances of children listening to stories, that is, listening to someone either tell a story or read one from a picture storybook. For this criterion, a comparison condition with either only orally presented stories or oral text in addition to static illustrations sufficed. Earlier studies assessed the differences between stories presented through television and radio formats, that is, an audiovisual and an audio presentation (e.g., Beagles-Roos & Gat, 1983; Gibbons et al., 1986). Later studies compared technology-enhanced stories to an adult reading the story from a print picture storybook to the child, thus presenting static illustrations during the story. In these studies, the adults were either instructed to keep their interaction with the children to a minimum (e.g., Critelli, 2011) or were encouraged to interact with the child during the reading, imitating a natural interactive shared reading session (e.g., de Jong & Bus, 2004; Homer et al., 2014; Korat & Shamir, 2007). Another alternative was to have the computer read the story while presenting the static pictures on screen without any other technological advancements (e.g., Gong & Levy, 2009; Smeets & Bus, 2014). These comparison conditions were all considered imitations of traditional story sharing activities with young children, even when children listened to a story on the computer but with no other information that is commonly available in a more traditional story sharing session.

Search Strategy

We searched three databases—PsychInfo, ERIC, and the Web of Science—for journal articles, reports, and book chapters with a detailed search string including different terminology for literacy outcomes, technology-enhanced narrative stories, and young children (see Appendix A). Secondary searches involved inspection of the reference lists of review articles and the included articles for other suitable studies, in addition to checking handbooks on technology and children's literacy development (see Appendix B for the list). We also searched for dissertations and theses reporting data that might be suitable for the present meta-analysis.

When we could not find a full text, authors were contacted. When we could not contact the authors of the original manuscript, we contacted authors who referenced the study to see if they had a copy. Four studies (two conference papers and two reports) were not included in the meta-analysis because we could not locate copies of the manuscripts (George & Schaer, 1986; Hudson, 1982; Meringoff, 1982; Montouri, 1986).

Inclusion Criteria

According to our operational definitions described, intervention studies were included based on the following criteria:

1. The study was experimental or (quasi-)experimental, either a between- or a within-subject design, and contrasted a technology-enhanced condition with a comparison condition;
2. In one condition, stories were technology-enhanced, including an orally presented narration, multimedia features such as animations, music, and sound effects, and/or interactive features (e.g., questions, hotspots, games);
3. The comparison condition involved an orally presented narration with or without static illustrations;
4. Participants were preschool- and/or elementary school-aged children;
5. The study included at least one outcome measure such as (a) the child's literacy skills (including story comprehension and vocabulary, and code-related literacy skills such as phonological awareness, letter knowledge, concepts of print, word

reading, or general reading skills), or (b) the child's behavior while listening to the stories (including not only the child's engagement and attention but also communication initiated by the child).

Parental interaction, as already discussed, was beyond the scope of the present study so measures of those were not included (e.g., in Chiong et al., 2012). There were no restrictions regarding the publication status of the manuscripts or the participants' country of origin as long as the article was written in English.

Exclusion Criteria

We excluded correlational studies not comparing a technology-enhanced with a comparison story (Kendeou, Bohn-Gettler, White, & Van den Broek, 2008; Kim, Kendeou, Van den Broek, White, & Kremer, 2008), studies targeting foreign language learning (Jakobsdottir & Hooper, 1995; Tsou, Wang, & Tzeng, 2006), and studies without an eligible comparison condition (Hayes & Birnbaum, 1980; Matthew, 1996; Trushell, Maitland, & Burrell, 2003). We also excluded technology-enhanced interventions focusing on expository texts (Peracchio, 1992; Silverman & Hines, 2009), programs that targeted explicit literacy training (Penuel et al., 2012), or stories with only written text (Doty, Popplewell, & Byers, 2001; Lewin, 2000; Miller, Blackstone, & Miller, 1994; Neuman, 1992) or sign language (Gentry, Chinn, & Moulton, 2004; Wang & Paul, 2011). Additionally, we excluded studies that overlapped with other studies (Choat & Griffin, 1986; Greenfield & Beagles-Roos, 1988; Reissner, 1996; Vibbert & Meringoff, 1981), presented data already included in another study (Korat, Segal-Drori, & Klein, 2009), or presented data for children and adults together (Pratt & MacKenzie-Keaing, 1985).

In some instances, no data were available on the measure, even after contacting the authors (e.g., the measures of word shape concept and word element concept in Gong & Levy, 2009; the measure of justifications of inferences in Beagles-Roos & Gat, 1983; the measure of picture ordering in Meringoff, 1980; or the measure of child initiated communication in Chiong et al., 2012). We also could not include results when the measure assessed memory for information that was not presented in the comparison condition (e.g., nonverbal information when having an only audio comparison in Pezdek and Stevens, 1984; identification of the tutor when the tutor was not included in the comparison condition in Homer et al., 2014), or measures that were outside the scope of this meta-analysis (e.g., creativity in Valkenburg and Beentjes, 1997; characteristics of parent-child interaction in Chiong et al., 2012; or attitude towards computers in Karemaker et al., 2010a and towards reading in Stine, 1993). See Appendix C for a prisma diagram of the literature search.

Coding

We coded the following information: (a) bibliographic information (e.g., authors, year, and title of study, published or not, kind of publication and the country in which the study was conducted); (b) any possible disadvantage factors (e.g., basic information such as the number of participants, gender distribution, and mean age in addition to characteristics of the sample (e.g., socioeconomic status, intelligence, first or second language learners, language skills, and disabilities or developmental delays); (c) the design of the study (experimental or quasi-experimental and between- or within-subject); (d) materials used in the technology-enhanced condition, including the kind of software used (multimedia story, television program or interactive books), multimedia features (animation, music and sound effects), interactive features (hotspots, games and questions), and whether those were relevant or irrelevant to story comprehension or other literacy skills, and any other technological features (e.g., highlighting print); (e) the number of repeated interactions with the stories; (f) whether static illustrations were presented in addition to the oral narration in the comparison condition; and (g) outcome measures, including story comprehension (retelling of the story or comprehension questions), vocabulary (expressive or receptive vocabulary, and whether assessing book-based or general vocabulary), code-related literacy skills (alphabet knowledge, concepts of print, name writing, phonological awareness, word writing, word reading and recognition, or reading skills), and child's engagement during the intervention (e.g., visual attention, skin conductance as indicator of arousal or communication initiated by the child).

To obtain information that was not available in the studies regarding the details of the technology-enhanced stories, we looked the software up on the Internet, for example, checking videos and demos on Youtube.com or other studies reporting on the same software (e.g., Talley, Lancy, & Lee, 1997, for the Stories and More software used in the dissertation of Stine, 1993). When more information was needed, the authors of the study were contacted via e-mail, if possible.

As shown in Table 1, whenever results were reported separately for subgroups of children, based on age (e.g., Pezdek et al., 1984; Williamson & Silvern, 1983), disadvantage status (e.g., Segers, Takke, & Verhoeven, 2004) or ability level (e.g., Verhallen & Bus, 2009b), effect sizes were calculated for each subgroup in order to test differences among different groups of children. When studies included two technology-enhanced conditions (e.g., Korat & Or, 2010; Okolo & Hayes, 1996; Robb, 2010), both groups were contrasted with the control group so we could test differences among different features of technology-enhanced stories. In such cases we divided the number of participants in the comparison group by two in order not to include control group children twice in the analyses (for a similar procedure see Bakermans-Kranenburg, van IJzendoorn, and Juffer, 2003; Mol, Bus, de Jong, and Smeets, 2008). When there were more than one non-technology comparison condition in a study, the condition most similar to a traditional print book reading activity was chosen (e.g., the adult reading condition in Terrell and Daniloff, 1996 and the text and accompanying illustrations condition in Williamson and Silvern, 1983).

One technology-enhanced condition was chosen instead of including both when the control condition included fewer than 10 children (e.g., de Jong & Bus, 2002). In these cases, we chose the most technology-enhanced condition (e.g., the video with music and sound condition in Experiment 2 in Smeets et al., 2014; the Kinect with activities condition in Homer et al., 2014; the interactive condition in Ricci and Beal, 2002; the helpful video condition in Sharp et al., 1995, or the technology condition including an adult such as the adult-led e-book condition in Moody et al., 2010). However, in the study by de Jong and Bus (2002) the restricted/no-game electronic book condition was chosen because when children had the option to play with the games, they hardly spent time listening to the story. Another exception was the study described in Caplovitz (2005); we merged two technology-enhanced story conditions in this study as the difference between the two, instruction for the parents on how to use the talking book, was not considered a potential moderator in the present meta-analysis. In the Gong and Levy (2009) study, the bouncing ball condition was chosen for the technology-enhanced condition because the bouncing ball jumping from word to word while they are read aloud was regarded as highlighting the text. The other conditions in this study, including violations in the written text on screen, were considered fundamentally different from the technology-enhanced story conditions and therefore not included.

All studies were coded by two independent coders to assess inter-rater reliability. Full agreement was reached for study eligibility. For further coding, agreement was on average $\kappa = .77$, ranging from $\kappa = .65$ for the materials used in the technology condition to $\kappa = .99$ for bibliographic information. Disagreements were settled in discussion.

Meta-Analytic Procedures

The dependent variable in the present meta-analysis was the difference in mean score between the technology-enhanced condition and the condition similar to a traditional print book reading activity. As different outcome measures were included with different scales, the standardized mean difference, Hedges' *g*, was calculated

for each contrast between the two conditions. To calculate Hedges' *g*, raw post-test means and standard deviations were favored over other statistics, but in some cases, only frequency distributions, *F, t*, chi-square statistics (e.g., Segers et al., 2006), or gain scores in the two conditions (e.g., Critelli, 2011) were available. In the case of gain scores, we calculated the difference between the average gains in the technology-enhanced and comparison condition (Morris & DeShon, 2002). We entered the available statistics in the Comprehensive Meta-Analysis software, Version 2.0 (Borenstein, Hedges, Higgins, & Rothstein, 2005), which calculated Hedges' *g* for each contrast for each outcome variable, as presented in Table 1. We preferred Hedges' *g* to alternatives because Ns were rather small. If two or more outcome measures were available in one study, the effect sizes for the different measures were averaged to compute an overall effect for the study. Interpretation of Hedges' *g* statistics is similar to that of Cohen's *d*. In previous meta-analyses of print exposure, effect sizes averaged around $d = .50$ (Bus et al., 1995; Mol & Bus, 2011). We expected a small advantage of technology-enhanced compared to more traditional print book reading.

A positive effect size indicated an advantage for the technology-enhanced condition to a condition more similar to traditional print book reading. The effect sizes for all separate outcome measures were inspected for outliers, which resulted in eight outlying values (with a standardized residual exceeding ± 3.29; Tabachnick & Fidell, 2007). The most extreme value, the effect size for looking time at the screen or the book in the study of Homer et al. (2014; i.e., Hedges' $g = 22.00$) was excluded from further analysis. The outlying effect size resulted from the small standard deviation of this variable. All other outliers were winsorized into values of .01 higher, or lower in the case of the one negative effect size, than the highest or the lowest non-outlying effect size. Results were averaged for four sets of outcome measures: story comprehension, vocabulary, code-related literacy skills, and children's behavior during reading session. We also differentiated expressive and receptive vocabulary measures because there is some evidence that these two measures reflect different levels of word knowledge (Verhallen & Bus, 2010).

Overall effect sizes and 95% confidence intervals were computed based on the random effects model (Lipsey & Wilson, 2001; Raudenbush, 2009). This model takes into account the variation between studies as a result of differences in participants, study design, and intervention characteristics, in addition to within-study variance (Borenstein, Hedges, Higgins, & Rothstein, 2009). Heterogeneity of the effect sizes was estimated using the *Q*-statistic, with a significant *Q* indicating a heterogeneous effect, which means that more variability is found within the included studies than may be expected from sampling error on a subject level only (Lipsey &

Wilson, 2001). Studies were weighted by the inverse of their variance, so that studies with larger sample sizes and more accurate estimates of population parameters had a greater weight on the mean effect size (Lipsey & Wilson, 2001; Shadish & Haddock, 2009).

It is called publication bias when studies with significant and/or large findings are overrepresented because those are more likely to get published (Borenstein et al., 2009). Publication bias can be observed by visual examination of the funnel plot. In case of asymmetry around the mean effect size, Duval and Tweedie's (2000) Trim and Fill procedure was used to adjust the overall effect size for publication bias. Additionally, the classic fail-safe *N* was calculated to have an indication of the confidence of the effect. The fail-safe *N* shows how many studies showing null effects would be needed to turn a significant effect size into a non-significant one. A fail-safe number of $5k + 10$ is considered robust, where *k* is the number of studies in the meta-analysis (Rosenthal, 1979).

Moderator analyses were performed using a random effects model to contrast subsamples based on different categorical study variables. Only moderator variables that had at least four contrasts in one cell were used (cf. Bakermans-Kranenburg et al., 2003). For continuous study variables, as for example, publication year, a meta-regression analysis was performed. Moderators were significant in cases of categorical variables, if $Q_{between,}$ or, for continuous variables, the regression model was significant.

Results

Preliminary Analyses

The search resulted in 43 studies, including 57 effects, published between 1980 and 2014. All contrasts are shown in Table 1. Eight contrasts came from dissertations, two from a research report, and 47 from journal articles. One of the studies used a quasi-experimental design (Stine, 1993); all other studies had an experimental design. Twenty-four studies were conducted in the United States and three in the United Kingdom, all including interventions in English. Eleven studies were conducted in the Netherlands with interventions in Dutch, and five studies originated from Israel with interventions in Hebrew. In total, 2,147 children between 3 and 10 years of age were included in the meta-analysis. The average sample size of the primary studies was 38.34 children ($SD = 21.52$). The mean number of repeated readings of the same story during the interventions was 2.30 ($SD = 1.65$).

To test for publication bias, all effect sizes were transformed into Fisher's *Z*. Inspection of the funnel plot showed an even distribution of the effect sizes and no studies were imputed. The number of missing studies that would turn an overall effect for all contrasts non-significant was $N_{fs} = 344$, which is a robust effect according to Rosenthal's (1979) criterion. Publication status (i.e., journal article vs. non-refereed publications such as dissertations) was not a significant moderator, $Q_{between}(1) = 0.26$, $p = .61$, indicating no evidence of publication bias. To test for other biases, moderator analyses were performed for subject design (within vs. between) and country, and meta-regression analyses were performed for publication date, number of repeated readings, and sample size. No significant regression models or moderators were found, except for design. On average, studies with a between-subject design yielded an average effect of 0.33, $k = 40$, SE = 0.08, 95% CI = [0.17, 0.48], $p < .01$, which was significantly higher than studies incorporating a within-subject design, $g+ = -0.02$ $k = 17$, $SE = 0.11$, 95% CI = [-0.24, 0.21], $p = .89$), $Q_{between}(2) = 6.25$, $p = .01$. A likely explanation for this design effect is the role of interactive features as will be shown hereafter: two-thirds of the within-subject design experiments included interactive features, in contrast, less than half of the between-subject design studies featured interactive elements.

Table 1
Overview of the Studies in the Meta-Analysis Including the Moderators and the Effect Sizes

First author	Year	Disadvantaged	Technology-enhanced condition	Material	Multimedia features (animation and/or music and sound)	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Outcome measures	Average effect size (Hedges' g)
Beagles-Roos	1983	No	'Television' (*n* = 24)	*A Story, a Story, Strega Nona* Animated by Weston Woods Studios	Yes	No	'Radio' (*n* = 24)	No	Story comprehension (3 measures)	0.34
Caplovitz (dissertation)	2005	No	'Talking book' (*n* = 48 + 44)	*The Story of Clifford, Elmo's Noisy Day* Talking book with plastic case for a paper book	No	Yes, relevant and irrelevant	'Books only' (*n* = 47)	Yes	Story comprehension (2 measures) Code-related skills (15 measures)	-0.24 0.03
Chiong	2012 Contr 1	No	'Basic e-book' (*n* = 16)	iPad application	No	Yes, relevant	'Print book' (*n* = 16)	Yes	Story comprehension (1 measure)	0.17
Chiong	2012 Contr 2	No	'Enhanced e-book' (*n* = 16)	iPad application	Yes	Yes, relevant and irrelevant	'Print book' (*n* = 16)	Yes	Story comprehension (1 measure)	-0.81
Critelli (thesis)	2011	No	'E-book' (*n* = 5)	*Bubbles* CD-ROM story	Yes	No	'Print book' (*n* = 5)	Yes	Story comprehension (1 measure) Code-related skills (2 measures)	0.00 -0.10
De Jong	2002	Yes (low SES)	'Computer book – restricted' (*n* =12)	*P.B. Bear's Birthday Party* Bombilla	Yes	Yes, relevant and irrelevant	'Regular book' (*n* = 12)	Yes	Story comprehension (2 measures) Code-related skills (6 measures)	-0.27 -0.25
De Jong	2004	Yes (low SES)	'Electronic book' (*n* = 18)	*I'll Make You Well Again Said the Bear, Big Party for Tiger, Tiger and Bear in Traffic* Het Spectrum Electronic Publishing	Yes	Yes, relevant and irrelevant	'Printed book' (*n* = 18)	Yes	Story comprehension (1 measure)	-0.53
Gazella	2003	No	'Audiovisual' (*n* = 15)	Researcher-constructed story with videotaped puppets	Yes	No	'Audio-only' (*n* = 14)	No	Story comprehension (2 measures)	-0.11
Gibbons	1986	No	'Audiovisual' (*n* = 48)	Researcher-constructed stories with animated puppets	Yes	No	'Audio' (*n* = 48)	No	Story comprehension (1 measure)	0.52
Gong	2009	No	'Bouncing ball' (*n* = 24)	Talking books with a bouncing ball above the text being read aloud	No	Yes, only highlighting the text as it is read	'Story control' (*n* = 24)	Yes	Code-related skills (1 measure)	0.60
Hayes	1986	No	'Television' (*n* = 22)	*How the Whale Got Its Throat* Television segment	Yes	No	'Radio' (*n* = 22)	No	Story comprehension (2 measures)	-0.45
Homer	2014	No	'Kinect with activities' (*n* = 12)	*Children Make Terrible Pets* by Microsoft Games Studio for the Kinect	Yes	Yes, relevant and irrelevant	'Book reading' (*n* = 14)	Yes	Story comprehension (3 measures) Vocabulary – expressive (1 measure) Code-related skills (2 measures) Engagement (1 measure)	0.26 0.37 -0.22 -0.57
Karemaker	2008	No	'ORT for Clicker' (*n* = 27)	Talking books from the Oxford Reading Tree for Clicker series by Crick Software	No	Yes, relevant	'ORT Big Book' (*n* = 27)	Yes	Code-related skills (5 measures)	-0.04
Karemaker	2010a	Yes (struggling readers)	'ORT for Clicker' (*n* = 17)	*Strawberry Jam, Kipper the Clown* Oxford Reading Tree for Clicker series by Crick Software	No	Yes, relevant	'ORT Big Book' (*n* = 17)	Yes	Code-related skills (9 measures)	0.07

First author	Year	Disadvantaged	Technology-enhanced condition	Material	Multimedia features (animation and/or music and sound)	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Outcome measures	Average effect size (Hedges' g)
Karemaker	2010b	No	'ORT for Clicker' (*n* = 61)	*Strawberry Jam, Kipper the Clown* Oxford Reading Tree for Clicker series by Crick Software	No	Yes, relevant	'ORT Big Book' (*n* = 61)	Yes	Code-related skills (5 measures)	0.20
Korat	2010 Contr 1	No	'Educational electronic book - Tractor' (*n* = 12)	*The Tractor in the Sandbox* Researcher-constructed CD-ROM story	Yes	Yes, relevant	'Print book' (*n* = 12)	Yes	Communication by the child (1 measure)	2.06*
Korat	2010 Contr 2	No	'Commercial electronic book - Grandma' (*n* = 12)	*Just Grandma and Me* Living Books series	Yes	Yes, relevant and irrelevant	'Print book' (*n* = 12)	Yes	Communication by the child (1 measure)	2.06
Korat	2007 Contr 1	Yes (low SES)	'E-book' (*n* = 25)	*The Tractor in the Sandbox* Researcher-constructed CD-ROM story	Yes	Yes, relevant	'Adult book reading' (*n* = 25)	Yes	Vocabulary – receptive (1 measure) Code-related skills (2 measures)	0.06 0.29
Korat	2007 Contr 2	No	'E-book' (*n* = 25)	*The Tractor in the Sandbox* Researcher-constructed CD-ROM story	Yes	Yes, relevant	'Adult book reading' (*n* = 25)	Yes	Vocabulary – receptive (1 measure) Code-related skills (2 measures)	-0.03 -0.18
Korat	2007 Contr 1 & 2	No	'E-book' (*n* = 50)	*The Tractor in the Sandbox* Researcher-constructed CD-ROM story	Yes	Yes, relevant	'Adult book reading' (*n* = 50)	Yes	Story comprehension (1 measure)	-0.13
Korat	2013	Yes (low SES)	'Electronic book' (*n* = 30)	*Confused Yuval* Researcher-constructed CD-ROM story	Yes	Yes, relevant	'Print book' (*n* = 30)	Yes	Vocabulary – receptive (1 measure) Code-related skills (2 measures)	-0.17 0.11

First author	Year	Disadvantaged	Technology-enhanced condition	Material	Multimedia features (animation and/or music and sound)	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Outcome measures	Average effect size (Hedges' g)
Meringoff	1980	No	'Television' (*n* = 24)	*A Story, a Story* Animated by Weston Woods Studios	Yes	No	'Book' (*n* = 24)	Yes	Story comprehension (3 measures) Communication by child (1 measure)	-0.21 -1.08
Moody	2010	Yes (low SES)	'Adult-led e-book' (*n* = 25)	*Little Monster at School* Living Books series	Yes	Yes, relevant and irrelevant	'Adult-led traditional storybook' (*n* = 25)	Yes	Engagement (3 measures) Communication by child (5 measures)	0.24 0.04
Neuman	1989	No	'Televised version' (*n* = 17)	*Simon's Book*	Yes	No	'Storybook' (*n* = 10)	Yes	Story comprehension (3 measures)	0.32
Noel (thesis)	2013	Yes (low SES)	'Electronic book' (*n* = 3)	*How Rocket Learned to Read, Tacky the Penguin, Elmer's Special Day, Elmer and Rose, The Bremen Town Musicians, Curious George, Jumanji* Applications on the iPad	Mix	Mix	'Print book' (*n* = 3)	Yes	Vocabulary – expressive (1 measure) Engagement (1 measure)	0.15 0.56
Okolo	1996 Contr 1	Yes (learning disabled students or poor readers)	'High-animation condition' (*n* = 20)	*Harry and the Haunted House* Living Book series	Yes	Yes, relevant and irrelevant	'Adult-reader' (*n* = 20)	Yes	Story comprehension (2 measures) Communication by child (1 measure)	-1.19 0.64
Okolo	1996 Contr 2	Yes (learning disabled students or poor readers)	'Low-animation condition' (*n* = 20)	*Thomas's Snowsuit* DISCIS book series	No	Yes, relevant	'Adult-reader' (*n* = 20)	Yes	Story comprehension (2 measures) Communication by child (1 measure)	-0.28 0.53

First author	Year	Disadvantaged	Technology-enhanced condition	Material	Multimedia features (animation and/or music and sound)	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Outcome measures	Average effect size (Hedges' g)
Parish-Morris	2013 Study 2	No	'Electronic console books' (*n* = 20)	*The Berenstain Bears, Dora the Explorer* by Fisher-Price Power-Touch Learning System	No	Yes, relevant and irrelevant	'Traditional book' (*n* = 20)	Yes	Story comprehension (2 measures)	0.65
Pezdek, Lehrer, & Simon	1984 Contr 1	No (3rd grade)	'Television' (*n* = 24)	*A Story, a Story, Strega Nona* Animated by Weston Woods Studios	Yes	No	'Radio' (*n* = 24)	No	Story comprehension (3 measures)	1.02
Pezdek, Lehrer, & Simon	1984 Contr 2	No (6th grade)	'Television' (*n* = 24)	*A Story, a Story, Strega Nona* Animated by Weston Woods Studios	Yes	No	'Radio' (*n* = 24)	No	Story comprehension (3 measures)	0.55
Pezdek & Stevens	1984	No	'Audiovisual match' (*n* = 24)	Bert and Ernie and Big Birds segments from the TV show *Sesame Street*	Yes	No	'Audio only' (*n* = 24)	No	Story comprehension (2 measures)	0.59
Ricci	2002	No	'Interactive participant' (*n* = 16)	*The Ugly Duckling* Interactive story	Yes	Yes, relevant and irrelevant	'Audio only' (*n* = 17)	No	Story comprehension (4 measures)	0.23
Robb (dissertation)	2010 Contr 1	No	'Interactive reading with parent' (*n* = 23)	*Curious George Goes to a Chocolate Factory* Read With Me DVD System	Yes	Yes, relevant	'Print book reading with parent' (*n* = 12)	Yes	Story comprehension (3 measures) Engagement (1 measure)	0.21 -0.54
Robb (dissertation)	2010 Contr 2	No	'Interactive reading alone' (*n* = 23)	*Curious George Goes to a Chocolate Factory* Read With Me DVD System	Yes	Yes, relevant	'Print book reading with parent' (*n* = 12)	Yes	Story comprehension (3 measures) Engagement (1 measure)	-0.06 0.10
Segal-Drori	2010 Contr 1	Yes (low SES)	'E-book independently' (*n* = 32)	*The Tractor in the Sandbox Confused Yuval* Researcher-constructed CD-ROM stories	Yes	Yes, relevant	'Print book with adult' (*n* = 16)	Yes	Code-related skills (3 measures)	-0.05

First author	Year	Disadvantaged	Technology-enhanced condition	Material	Multimedia features (animation and/or music and sound)	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Outcome measures	Average effect size (Hedges' g)
Segal-Drori	2010 Contr 2	Yes (low SES)	'E-book with adult instruction' (*n* = 32)	*The Tractor in the Sandbox Confused Yuval* Researcher-constructed CD-ROM stories	Yes	Yes, relevant	'Print book with adult' (*n* = 16)	Yes	Code-related skills (3 measures)	1.69
Segers	2006	Yes (special needs, physical disabilities)	'Computer story' (*n* = 9)	*Treasure Chest with the Mouse* Researcher-constructed CD-ROM stories	Yes	Yes, relevant	'Teacher reading' (*n* = 8)	Yes	Vocabulary (2 measures) Engagement (1 measures)	0.62 -0.12
Segers	2004 Contr 1	No	'Computer reading' (*n* = 41)	*Treasure Chest with the Mouse* Researcher-constructed CD-ROM stories	Yes	Yes, relevant	'Teacher reading' (*n* = 41)	Yes	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	-0.08 -0.02
Segers	2004 Contr 2	Yes (immigrant)	'Computer reading' (*n* = 30)	*Treasure Chest with the Mouse* Researcher-constructed CD-ROM stories	Yes	Yes, relevant	'Teacher reading' (*n* = 30)	Yes	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	-0.41 -0.18
Shamir	2012	Yes (developmental delays)	'E-book' (*n* = 42)	*Confused Yuval* Researcher-constructed CD-ROM story	Yes	Yes, relevant	'Printed book with adult' (*n* = 34)	Yes	Vocabulary – receptive (1 measures) Code-related skills (2 measures)	0.45 0.24
Sharp	1995	Yes (low SES, small vocabulary)	'Helpful video' (*n* = 18)	Commercial video clips with researcher-constructed narratives	Yes	No	'No video' (*n* = 18)	No	Story comprehension (2 measures)	1.43
Silverman	2013 Study 1	Yes (low SES, limited English proficiency)	'Video' (*n* = 42)	*Arthur, Martha Speaks* TV shows	Yes	No	'Read aloud' (*n* = 36)	Yes	Vocabulary (2 measures)	-0.24

First author	Year	Disadvantaged	Technology-enhanced condition	Material	Multimedia features (animation and/or music and sound)	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Outcome measures	Average effect size (Hedges' g)
Smeets	2014A Contr 1	No	'Animated e-book' (*n* = 36)	*Pete on the Pavement, Bear is in Love with Butterfly, Rokko the Crocodile, Bolder and the Boat, Cycling with Grandpa* Het Woeste Woud	Yes	No	'Static e-book' (*n* = 17)	Yes	Story comprehension (3 measures) Vocabulary (3 measures)	0.11 -0.18
Smeets	2014A Contr 2	No	'Interactive animated e-book' (*n* = 33)	*Pete on the Pavement, Bear is in Love with Butterfly, Rokko the Crocodile, Bolder and the Boat, Cycling with Grandpa* Het Woeste Woud	Yes	Yes, relevant	'Static e-book' (*n* = 16)	Yes	Story comprehension (3 measures) Vocabulary (3 measures)	0.19 0.13
Smeets	2014B Exp 1	Yes (SLI)	'Video book' (*n* = 28)	*Pete on the Pavement, Rokko the Crocodile, Bolder and the Boat, Little Kangaroo, Imitators, Dear Dear* Het Woeste Woud	Yes	No	'Static book' (*n* = 28)	Yes	Vocabulary – expressive (1 measure)	-0.25
Smeets	2014B Exp 2	Yes (SLI)	'Video with music and sounds' (*n* = 21)	*Pete on the Pavement, Rokko the Crocodile, Bolder and the Boat, Little Kangaroo, Imitators, Dear Dear, Bear is in Love with Butterfly, Sweat-Naughty Bear Baboen* Het Woeste Woud	Yes	No	'Static-no music or sound' (*n* = 21)	Yes	Vocabulary – expressive (1 measure)	0.07

First author	Year	Disadvantaged	Technology-enhanced condition	Material	Multimedia features (animation and/or music and sound)	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Outcome measures	Average effect size (Hedges' g)
Stine (dissertation)	1993	Yes (low SES)	'CD-ROM interactive computer-based books' (*n* = 8)	*Stories and More* by IBM	Yes	Yes, relevant	'Print books' (*n* = 8)	Yes	Story comprehension (1 measure) Vocabulary (1 measure)	1.31 1.55
Terrell	1996	No	'Videotape' (*n* = 26)	An animated segment, including music, from a children's TV show with a researcher-constructed narrative	Yes	No	'Storybook' (*n* = 26)	Yes	Vocabulary (3 measures)	-0.58
Valkenburg	1997	No	'Television' (*n* = 64)	*Strega Nonna* *Doctor de Soto* Animated by Weston Woods Studios	Yes	No	'Radio' (*n* = 64)	No	Story comprehension (1 measure)	0.14
Verhallen	2006 Contr 1	Yes (low SES, 2nd language)	'4x Multimedia' (*n* = 10)	*Winnie the Witch* Bombilla	Yes	No	'4x Static' (*n* = 10)	Yes	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	1.16 1.07
Verhallen	2006 Contr 2	Yes (low SES, 2nd language)	'1x Multimedia' (*n* = 10)	*Winnie the Witch* Bombilla	Yes	No	'1x Static' (*n* = 10)	Yes	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	0.36 0.62
Verhallen	2009a Contr 1	Yes (low SES, 2nd language)	'4x video' (*n* = 22)	*Winnie the Witch* Bombilla	Yes	No	'4x static' (*n* = 20)	Yes	Story comprehension (1 measure) Vocabulary – expressive (1 measure) Engagement (1 measure)	0.54 0.54 0.28

First author	Year	Disadvantaged	Technology-enhanced condition	Material	Multimedia features (animation and/or music and sound)	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Outcome measures	Average effect size (Hedges' g)
Verhallen	2009a Contr 2	Yes (low SES, 2nd language)	'1x video' (*n* = 21)	*Winnie the Witch* Bombilla	Yes	No	'1x static' (*n* = 23)	Yes	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	0.39 0.59
Verhallen (dissertation)	2009b Contr 1	Yes (low SES, 2nd language, low L2)	'Video' (*n* = 22)	*Winnie the Witch* Bombilla	Yes	No	'Static' (*n* = 20)	Yes	Story comprehension (2 measures) Vocabulary – expressive (1 measure)	0.98 0.02
Verhallen (dissertation)	2009b Contr 2	Yes (low SES, 2nd language)	'Video' (*n* = 13)	*Winnie the Witch* Bombilla	Yes	No	'Static' (*n* = 12)	Yes	Story comprehension (2 measures) Vocabulary – expressive (1 measure)	-0.23 0.89
Verhallen	2010	Yes (low SES, 2nd language)	'Video' (*n* = 34)	*Winnie the Witch* Bombilla	Yes	No	'Static' (*n* = 29)	Yes	Vocabulary (2 measures)	0.36
Williamson	1983 Contr 1	No (kindergarten)	'Animated film' (*n* = 10)	*Petunia* Animated film of the story while researcher reads it	Yes	No	'Tradebook' (*n* = 10)	Yes	Story comprehension (2 measures)	0.15
Williamson	1983 Contr 2	No (third grade)	'Animated film' (*n* = 10)	*Petunia* Animated film of the story while researcher reads it	Yes	No	'Tradebook' (*n* = 10)	Yes	Story comprehension (2 measures)	1.00

*Winsorized value

The Effect of Technology Added to Stories for Young Children

To answer the first research question, we inspected the average effect sizes regarding the differences between technology-enhanced stories and more traditional story presentations on children's literacy outcomes. See Table 2 and Figure 1 for a summary of the findings.

Story comprehension. Thirteen contrasts assessed story comprehension with story retelling measures, nine contrasts used story comprehension questions, and 15 were based on a combination of the two. Technology had a small but significant effect on children's story comprehension (see Table 2). As this effect was heterogeneous, $Q(37) = 96.21$, $p < .01$, we conducted a moderator analysis to test the effect of assessment. For one contrast, we were unable to code how story comprehension was measured due to insufficient information. Excluding that contrast, a moderator analysis revealed that there was no significant difference among the contrasts based on retelling, comprehension questions, or a combination of these measures, $Q_{between}(1)$

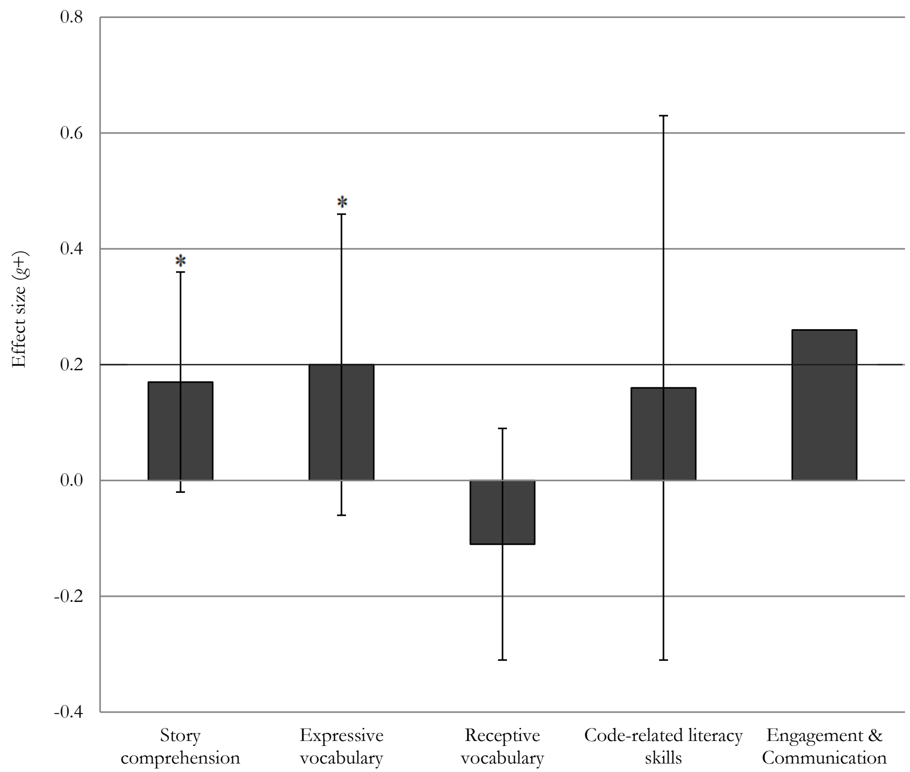

Figure 1. The effect of technology added to stories as compared to a more traditional story sharing comparison condition on various outcome measures.
Note. *$p < .05$

Table 2
The Results on the Different Outcome Measures Overall and for Disadvantaged and Non-Disadvantaged Groups

Outcome measure	Samples	Number of contrasts included	Average effect size ($g+$)	Standard error	95% confidence interval	p	Difference between disadvantaged and non-disadvantaged samples ($Q_{between}$)
Story comprehension							
	Overall	38	0.17	0.08	[0.01, 0.34]	.04	
	Disadvantaged	13	0.22	0.15	[-0.08, 0.51]	.15	$Q_{between}$ (1) = 0.13, p = .72
	Non-disadvantaged	25	0.15	0.10	[-0.04, 0.35]	.13	
Expressive vocabulary							
	Overall	18	0.20	0.10	[0.01, 0.39]	.04	
	Disadvantaged	13	0.27	0.12	[0.04, 0.50]	.02	$Q_{between}$ (1) = 1.10, p = .30
	Non-disadvantaged	5	0.05	0.17	[-0.29, 0.39]	.78	
Receptive vocabulary							
	Overall	9	-0.08	0.12	[-0.31, 0.15]	.51	
	Disadvantaged	5	0.07	0.13	[-0.19, 0.33]	.60	$Q_{between}$ (1) = 2.97, p = .09
	Non-disadvantaged	4	-0.30	0.17	[-0.63, 0.03]	.08	
Code-related literacy skills							
	Overall	14	0.16	0.10	[-0.04, 0.36]	.11	
	Disadvantaged	7	0.27	0.15	[-0.03, 0.56]	.08	$Q_{between}$ (1) = 0.84, p = .36
	Non-disadvantaged	7	0.07	0.15	[-0.21, 0.36]	.62	
Engagement and child-initiated communication during reading							
	Overall	12	0.26	0.24	[-0.21, 0.74]	.28	
	Disadvantaged	6	0.32	0.35	[-0.37, 1.01]	.36	$Q_{between}$ (1) = 0.05, p = .82
	Non-disadvantaged	6	0.21	0.35	[-0.48, 0.90]	.55	

= 1.60, p = .45. A second moderator analysis comparing disadvantaged with non-disadvantaged children also did not indicate a significant difference in effectiveness of technology (see Table 2).

Vocabulary learning. For one contrast with vocabulary as outcome measure, there was not sufficient information to code whether the measure assessed receptive or expressive word knowledge, so this contrast was excluded from further analysis. Seven contrasts were based on book-based receptive vocabulary and two contrasts targeted general receptive vocabulary. Technology did not have a significant additional effect on receptive vocabulary as compared to more traditional storybook reading conditions.

With regard to expressive vocabulary, 15 contrasts targeted book-based expressive word knowledge and three contrasts were based on a combination of book-based and general expressive vocabulary. The average effect size for expressive vocabulary equaled 0.20. This effect was heterogeneous, $Q(16) = 28.81$, $p = .04$, so moderator analyses were performed. There was a significant effect for disadvantaged children, but not for non-disadvantaged children, and this difference was not significant (see Table 2). As the effect found for disadvantaged children was heterogeneous, $Q(12) = 25.54$, $p = .01$, we inspected differences between subsamples. A significant effect was found for children who were at risk because of environmental factors like low parental education, $g+ = 0.35$, $k = 10$, $SE = 0.15$, 95% CI = [0.06, 0.65], $p = .02$. There were only three contrasts including samples with developmental delays or learning problems with a non-significant average effect size, $g+ = 0.06$, $SE = 0.27$, 95% CI = [-0.47, 0.59], $p = .82$. Therefore, the kind of disadvantage could not be tested as a moderator for expressive vocabulary outcomes. Due to the low number of studies including a general expressive vocabulary measure, a moderator analysis contrasting only book-based and a mix of book-based and general word knowledge could not be carried out.

Code-related literacy skills. Of the 14 contrasts with code-related literacy as the outcome measure, one contrast targeted letter knowledge, one phonological awareness measures, one word reading skills, and 11 a combination of measures tapping phonological awareness, word reading and recognition, word writing, name writing, letter knowledge, and print concepts. The combined effect for the 14 contrasts measuring the additional effect of technology was not significant. As the effect was heterogeneous, $Q(13) = 23.65$, $p = .03$, we tested effects in disadvantaged and non-disadvantaged groups separately. For disadvantaged children, the effect of technology did not attain significance. For non-disadvantaged children, the difference was not significant, neither was the difference between the groups (see Table 2).

Child engagement and communication during reading. Of the 12 contrasts related to engagement and communication, five targeted communication initiated by the child; six targeted children's engagement during reading including on-task behavior, looking at the material or skin conductance; and one contrast was based on a combination of the two. There was no significant effect of the technology-enhanced condition on child engagement and communication during reading. The effect was heterogeneous, $Q(11) = 50.55$, $p < .01$. However, there were not enough contrasts to compare the effect of technology for disadvantaged and non-disadvantaged children.

The Role of Multimedia and Interactive Features

To answer the second and third research questions, the effects of multimedia and interactive features were compared. For a summary of the findings see Figure 2.

Story comprehension. As the effect of the technology-enhanced condition on story comprehension was heterogeneous, we tested the differences among stories including only multimedia, only interactive features, and the ones with

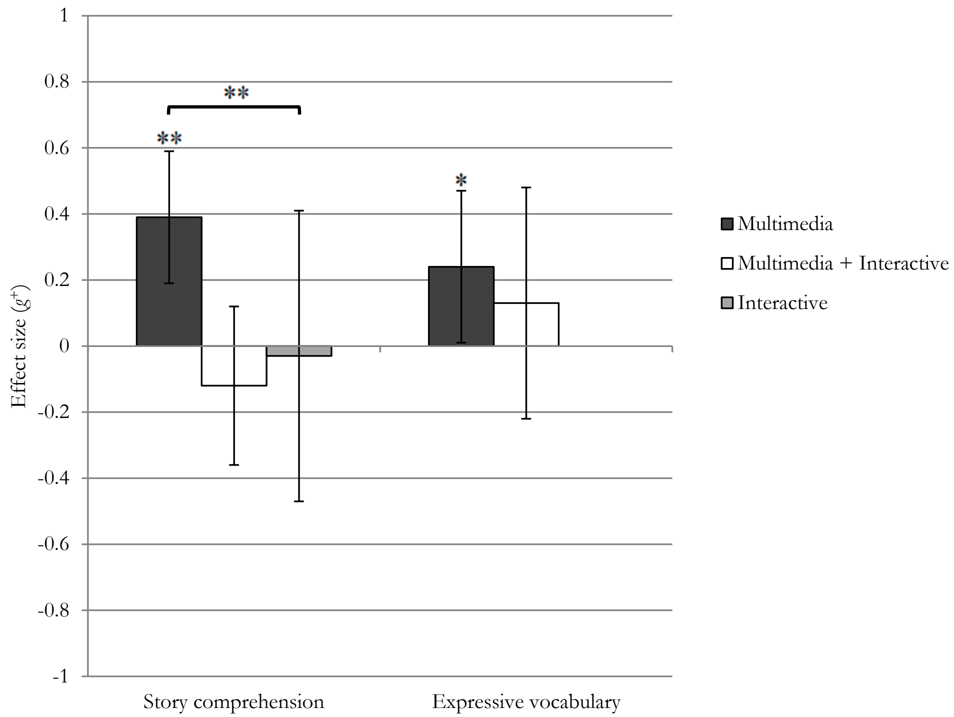

Figure 2. The effects of multimedia, multimedia-interactive and only-interactive stories on story comprehension and expressive vocabulary measures.
Note. **$p < .01$

both multimedia and interactive features. This test revealed a significant contrast, $Q_{between}(2) = 12.10$, $p < .01$. As shown in Table 3, stories including only multimedia had a positive additional effect on story comprehension compared to more traditional story sharing activities, $g+ = 0.39$, whereas this effect was not significant for stories including both multimedia and interactive features. As the effect in the multimedia condition was heterogeneous, $Q(20) = 41.03$, $p < .01$, another moderator analysis was conducted to assess whether the control conditions—only oral text or oral text plus static illustrations—made a difference for the effect of multimedia. However, the presence of illustrations in the comparison condition was not a significant moderator, $Q_{between} = 0.11$, $p = .74$. Multimedia stories had a significant advantage over both only orally presented stories, $g+ = 0.43$, $k = 9$, $SE = 0.14$, 95% CI = [0.15, 0.71], $p < .01$, and stories presented with static illustrations, $g+ = 0.36$, $k = 12$, $SE = 0.14$, 95% CI = [0.08, 0.64], $p = .01$.

As shown in Figure 3, for non-disadvantaged children, the difference between multimedia stories, $g+ = 0.28$, $k = 14$, $SE = 0.10$, 95% CI = [0.10, 0.47], $p < .01$, and stories that also included interactive features, $g+ = -0.04$, k = 8, SE = 0.13, 95% CI = [-0.29, 0.21], p = .74, was significant, $Q_{between}(1) = 4.18$, $p = .04$. However, in the disadvantaged group multimedia stories revealed much higher scores than interactive stories; the difference was slightly less than a whole point. For disadvantaged children

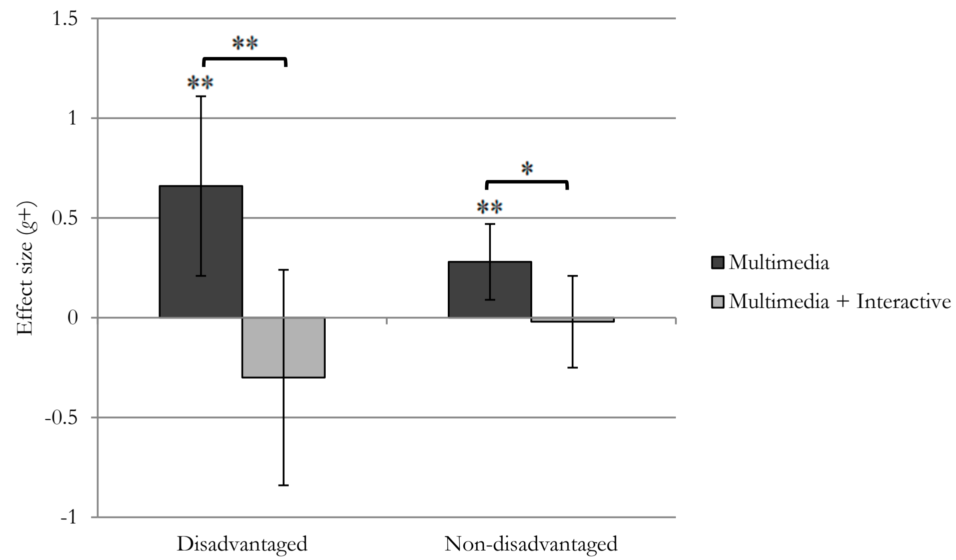

Figure 3. The effects of multimedia and multimedia-interactive stories on disadvantaged and non-disadvantaged children's story comprehension.
Note. *$p < .05$, **$p < .01$

Table 3

The Effects of the Different Types of Stories on Measures of Expressive Vocabulary and Story Comprehension

Type of technology story	Number of contrasts included	Average effect size ($g+$)	Standard error	95% confidence interval	p
Multimedia only					
Story comprehension	21	0.39	0.10	[0.20, 0.59]	<.01
Expressive vocabulary	12	0.24	0.12	[0.004, 0.47]	.046
Interactive-multimedia					
Story comprehension	13	-0.14	0.13	[-0.38, 0.11]	.27
Expressive vocabulary	6	0.13	0.18	[-0.22, 0.48]	.48
Interactive only					
Story comprehension	4	-0.03	0.23	[-0.47, 0.41]	.89
Expressive vocabulary	0	-	-	-	-

the difference was significant, $Q_{between}$ (1) = 7.22, $p < .01$, with a strong additional effect of multimedia stories, $g+$ = 0.66, k = 7, SE = 0.23, 95% CI = [0.21, 1.11], $p < .01$, and a non-significant effect for stories also including interactive features. We could not test differences between children growing up in disadvantaged environments and children with developmental delays or learning difficulties because only one study that included children with developmental delays or learning difficulties assessed story comprehension.

To investigate the effect of the congruity of interactive features with the story content on story comprehension, interactive stories with only relevant features were compared with stories including irrelevant interactive elements. Stories including only irrelevant or both relevant and irrelevant features did not have a significant effect, $g+$ = -0.21, k = 7, SE = 0.17, 95% CI = [-0.54, 0.13], p = .22. More surprisingly, stories with only relevant features did not have a significant additional effect compared to more traditional stories either, $g+$ = -0.06, k = 10, SE = 0.13, 95% CI = [-0.32, 0.21], p = .67. Relevance was not a significant moderator, $Q_{between}$ (1) = 0.49, p = .48.

Expressive vocabulary learning. We tested the difference between multimedia-only and multimedia-interactive stories on expressive vocabulary as the overall effect was heterogeneous. Although the contrast was not significant, $Q_{between}$ (1) = 0.26, p = .61, a similar trend appeared. As shown in Table 3, multimedia-only stories showed a significant advantage over more traditional stories on expressive word learning; in contrast, multimedia-interactive stories did not. We could not test whether characteristics of the control condition, only oral text or oral text plus static illustrations made a difference for the effect of multimedia on expressive word learning because there were no contrasts with only oral text.

For disadvantaged children there were not enough contrasts with multimedia-interactive stories to test the difference between multimedia-only and multimedia-interactive stories. However, for these groups of children multimedia-only stories showed a significant advantage over traditional story materials on expressive word learning, $g+$ = 0.32, k = 10, SE = 0.15, 95% CI = [0.03, 0.62], p = .03. We could not test differences between children growing up in disadvantaged environments and children with developmental delays or learning difficulties because only two contrasts including children with developmental delays or learning difficulties targeted expressive vocabulary. For non-disadvantaged children there were only two contrasts including a multimedia-only story and three contrasts including a multimedia-interactive story, so the presence of interactive features could not be tested. The effect of the relevance of interactive features could not be tested on expressive vocabulary either because there were only two contrasts including irrelevant interactive features.

Again, the average effect size of interactive stories including only relevant features was not significant, $g+ = 0.04$, $k = 4$, $SE = 0.14$, 95% CI = [-0.23, 0.31], $p = .77$.

Discussion

The present study synthesized the available empirical evidence on how technology added to narratives changes the effects of listening to stories on young children's literacy development. In 43 studies including 2,147 children, we found a small, significant positive additional effect of technology on measures of story comprehension and expressive vocabulary. Although small, the mean effect size is of great relevance as they reflect the *additional* effect of technology on top of the benefits of more traditional story presentations. So in reply to the first research question, we found evidence that technology can enhance the effects of storybooks on young children's literacy development. In addition, it is worth noting that these effects were heterogeneous, which may reflect the wide variety of technology-enhanced stories and measures used in the studies. This result underscores the relevance of investigating the effects of different technological features on literacy development.

We found no significant advantage of technology-enhanced stories on receptive vocabulary, code-related literacy skills, or behavior during listening to the story. The small overall effects of technology on comprehension and expressive word learning are in line with a previous meta-analysis showing small to moderate effects on comprehension-related outcomes (Zucker et al., 2009). The non-significant finding for receptive vocabulary might result from ceiling effects: scores on receptive knowledge of words are high even after a more traditional story presentation (Verhallen & Bus, 2010). Technology-enhanced stories did not have a significant effect on code-related literacy skills, probably because most studies in the meta-analysis measuring these skills used programs with interactive features. Although this finding makes sense given the practice that suffices for the development of code-related skills, it also means that code-related skills and interactive features were confounded in the present study. Finally, technology did not contribute significant additional variance to children's engagement or communication during the reading session. This outcome suggests that the effects of technology on literacy skills may not be a function of increased attention and excitement while listening to the story, although technology can be beneficial for cognitive processing of the information in the story.

Multimedia and Interactive Features

Multimedia stories had a significant positive effect as compared to more traditional presentations on story comprehension, and expressive vocabulary, whereas interactivity combined with multimedia and interactive-only stories did not significantly differ from the non-technological comparison conditions. As the moderator, static illustrations available in the comparison condition or not, was not significant, multimedia-only stories had a significant advantage over traditional print books including static illustrations. Thus, the advantage of multimedia-enhanced stories was not due to the addition of illustrations but to features that can only be realized with the help of multimedia (e.g., animated pictures, sounds and music). Children from disadvantaged family environments (low SES and/or immigrant, bilingual families) benefited most from multimedia, which had a moderately strong effect on story comprehension and a small effect on expressive vocabulary. Thus, multimedia elements were found to be beneficial additions to stories with small to moderate effect sizes.

This finding supports our hypothesis that extra nonverbal information such as animated visualizations, background sounds, and music, as long as congruent with the narration, aid children's comprehension, especially when children are at risk of language delays. This finding also aligns with the multimedia learning theory (Mayer, 2003), which proposes that the stronger match between verbal and nonverbal information in multimedia stories, compared to stories with static pictures, supports learning (Bus et al., 2014). Thus, instead of causing cognitive overload, nonverbal information optimally attuned to the narration is beneficial for learning. Multimedia may not be helpful when the nonverbal information is not designed in a way to attract attention to details that illustrate the story text (Bus et al., 2014). We were unable to test the prediction that only when nonverbal information closely corresponds to the narration, multimedia stories enhance effects of story reading because we were unable to code whether animations and sound effects were supportive of the oral text or had a purely decorative function in the primary studies.

Regarding the third research question, interactive elements did not make a significant contribution to the effects of listening to a story, even when combined with multimedia features. Interactive features negatively affected story comprehension and expressive word learning, probably because interactivity may interfere with the line of the story and children's processing of the narrative. Strikingly, even interactive features designed to develop story understanding and literacy skills do not seem to enhance the effects of listening to stories. These results confirm that interactive features are possible distractors from the story, whether they are relevant to the story and developing literacy skills or not. These findings are in line with the cognitive load theory (Sweller, 2005) and support our conclusion regarding interactivity, that is, interactive elements seem to distract from understanding the story and result in cognitive overload in the child (Bus et al., 2014). This outcome is probably because the processing of games and extra animations can be considered as extraneous materials that interfere with the processing of the story content (Mayer & Moreno, 2003). Bus and colleagues (2014) proposed that interactive features in technology-enhanced stories are distracting, probably most when there is an abundance of possibilities for interaction, because the child is required to juggle two tasks at the same time: listening to a story and engaging with interactive elements like games and hotspots. This finding may also explain why positive effects of multimedia fade out when books include interactivity.

Disadvantaged Children

Larger effect sizes were found in groups of disadvantaged children as compared to the mean effect sizes in the samples as a whole. Although the effect of technology on story comprehension for disadvantaged children was similar to the effect found for non-disadvantaged children, the same effect on expressive vocabulary was only significant for the disadvantaged groups. Likewise, the effects multimedia and interactive features have on story comprehension were larger for disadvantaged groups. There was a trend suggesting that disadvantaged children profited more from multimedia stories on story comprehension as compared to non-disadvantaged children, but the difference was not significant.

Although not significant, disadvantaged children tended to be also more distracted by interactive features than non-disadvantaged children, suggesting not only no advantage but also a disadvantage of interactivity for disadvantaged children but not for non-disadvantaged groups. To further illustrate this, for disadvantaged groups the difference between the effects of multimedia and interactive-multimedia stories on story comprehension was almost a whole point; in contrast, this difference was significant but small for non-disadvantaged groups of children. When results were further inspected for different groups of disadvantaged children, we found that this pattern was most pronounced in the group that was at risk due to environmental factors like SES and immigrant status or growing up in bilingual families. Due to the small number of studies targeting children with developmental delays and learning difficulties, the role of multimedia and interactive features could not be tested for this group. These children might also benefit from multimedia-only stories but, alternatively, it may be that technological additions to stories do not provide sufficient support for children with serious disabilities.

In the present meta-analysis, children from low socioeconomic status and immigrant families and children already experiencing a lag in language and literacy development were considered disadvantaged. These children might have smaller vocabularies and may be experiencing difficulties understanding the sophisticated language of narrative stories, which seem to make them more sensitive to the effects of multimedia and interactive features. In sum, both the benefits of multimedia and the pitfalls of interactive features tend to be elevated for disadvantaged children.

Limitations

Due to the limited number of primary studies available, we could not assess the separate effects of different kinds of multimedia (e.g., animation, music and sound effects) and interactive features (e.g., games, hotspots, dictionary function), nor the effects of how well they correspond to the narration. Moreover, the participants consisted of a broad range of disadvantaged children with different risk factors like low SES, second language learner immigrants, children with small vocabularies in addition to struggling beginning readers and children with learning disabilities, severe language impairments, special needs and developmental delays. Thus, they were not a homogenous group of children, and technological additions may have different effects for different risk statuses (e.g., Smeets et al., 2014). More specific results were reported for groups of disadvantaged children who are at risk of developing language delays and learning problems and for groups showing delays and difficulties. Still, a larger number of primary studies may enable more fine-grained analyses leading to a thorough understanding of the effects of different technological features, specifically for different groups of at-risk children.

Conclusion

Technology provides a small but significant addition to the effects of listening to stories on young children's literacy development and especially on story comprehension and expressive word learning, evidencing the potential of electronic stories and books. Multimedia features such as animated illustrations and music and sound effects were found to be beneficial; in contrast, interactive elements such as hotspots and games—even the ones that are intended to facilitate understanding of the story content—were not. Moreover, children who were at risk of language and literacy delays, especially due to disadvantaged family backgrounds, were shown to be more sensitive to both the benefits and the pitfalls of technological additions: multimedia elements were especially helpful and interactive features were especially distracting for these children. Developers of technology-enhanced stories and individuals who have the responsibility for selecting high quality electronic stories should choose ones without interactive features that might distract children from the story and opt for stories with multimedia support that is congruent with the story and provides nonverbal scaffolding for children to understand the story.

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Chapter 4

Can the Computer Replace the Adult for Storybook Reading? A Meta-Analysis on the Effects of Multimedia Stories as Compared to Sharing Print Stories with an Adult

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Abstract

The present meta-analysis challenges the notion that young children necessarily need adult scaffolding in order to understand a narrative story and learn words as long as they encounter multimedia stories. Studies assessing story comprehension and vocabulary learning were searched. Including 29 studies and 1272 children, multimedia stories (without adult support) were found more beneficial than encounters with traditional story materials that did not include the help of an adult for story comprehension ($g+ = 0.40$, $k = 18$) as well as vocabulary ($g+ = 0.30$, $k = 11$). However, no significant differences were found between the learning outcomes of multimedia stories and sharing traditional print-like stories with an adult. It is concluded that multimedia features like animated illustrations, background music and sound effects provide similar scaffolding of story comprehension and word learning as an adult.

There is ample evidence that storybook reading is one of the most important sources of language and literacy development during the preschool, kindergarten and elementary school years (Bus, van IJzendoorn, & Pellegrini, 1995; Mol & Bus, 2011). Adult guidance is a vital element of the traditional storybook reading paradigm. Beyond reading the print text, adults can involve the child in interactions regarding the story such as evoking comments from the child and providing feedback to their responses (Whitehurst et al., 1988). Such dialogic reading practices are more facilitative for children's vocabulary development than simply reading the story (Mol, Bus, & de Jong, 2009; Mol, Bus, de Jong, & Smeets, 2008). Adult scaffolding is especially important for children below the age of four in order to enable their active involvement to promote story comprehension or vocabulary (Whitehurst et al., 1988).

Since the appearance of electronic stories that include an oral narration, children can "read" picture storybooks by themselves. Electronic storybooks include multimedia features that may support story understanding (Bus, Takacs, & Kegel, 2014; Takacs, Swart, & Bus, 2015). In accordance with the multimedia theory of learning (Mayer, 2005), we found evidence for the hypothesis that, if nonverbal information like animated illustrations, sound, and music are congruent with the story text, such multimedia features may facilitate story comprehension and learning new vocabulary (Bus et al., in 2014; Takacs et al., 2015). For instance, animated illustrations are more helpful in explaining difficult words like 'fanning' or 'appearing' than a book with still illustrations. Animated scenes showing how someone fans a fire or how little crocodiles crawl out of their egg may be much more informative about these verbs than static pictures (Smeets, van Dijken, & Bus, 2014; Smeets & Bus, 2014). Similarly, music and sound effects might depict abstract expressions or emotions like 'puzzled' or 'heartbroken' and thus contribute to children's meaning making processes (Smeets et al., 2014). According to the dual coding theory (Paivio, 2007), the human mind processes verbal and nonverbal information in two separate but interconnected channels. When nonverbal multimedia elements are processed simultaneous to the oral narration they may facilitate comprehension of verbal information and the story line.

The question arises: Can multimedia elements be just as effective as an adult as a scaffold for learning from book reading? We focus on vocabulary and story comprehension as outcome measures as those are most affected by multimedia features. Although book reading is shown to have benefits for other aspects of children's literacy development such as phonemic awareness and alphabet knowledge (Bus et al., 1995; Mol & Bus, 2011), those skills do not seem to benefit from multimedia elements (Homer et al., 2014; Korat & Shamir, 2007; Segal-Drori, Korat, & Shamir, 2010) as also appeared in a previous meta-analysis (Takacs et al., 2015).

Intuitively it is assumed that support of an adult during storybook reading is superior to the benefits of multimedia features. The present meta-analysis challenged the notion that young children need adult scaffolding in order to understand a narrative and learn words as long as the multimedia material is optimally designed. We compared the effects of multimedia books including supplemental nonverbal information to shared book reading of print books. As motion and zooming may direct children's attention to a detail of the illustration in a similar way as an adult pointing at the detail and providing comments or explanations, multimedia may be just as beneficial in supporting story and language comprehension as interaction with an adult explaining the meanings of the story and sophisticated words in the narration.

We found several studies that do not show differences between how much children in this age range (preschool, kindergarten and elementary school ages) understand and learn from multimedia stories that they "read" by themselves as compared to sessions in which an adult reads a story to them (de Jong & Bus, 2004; Homer et al., 2014; Korat & Shamir, 2007; Silverman, 2013). Based on these findings the benefits of multimedia features seem comparable to adult scaffolding. However, there are also erratic outcomes in the literature. Shamir, Korat and Fellah (2012) found a significant advantage of working with an animated story over reading a print book with an adult on learning new vocabulary. In contrast, a study by Segers, Takke and Verhoeven (2004) showed that in a sample of immigrant children a teacher reading a storybook to the class was more facilitative of word learning as compared to a computer story with animations that children encountered on their own. The authors speculated that this might be explained by the computer software which included minimal animations. In the same study similar results were found for native speaking children. This mixed set of findings warrants a quantitative research synthesis on this issue.

Interactive features in electronic storybooks like dictionaries, hotspots and questions have been proposed to scaffold children's learning (Caplovitz, 2005; McKenna, Reinking, Labbo, & Kieffer, 1999). However, in a recent meta-analysis (Takacs et al., 2015) we found that interactive features, regardless of whether relevant to the story or not, decreased the benefits of electronic stories. We assume that these additions may require young children to switch between story comprehension and other tasks like playing games or listening to word explanations which may cause cognitive overload (Bus et al., in 2014). There is evidence showing that multimedia stories without or including only a limited number of interactive features are more advantageous for literacy skills than highly interactive electronic ones, whereas electronic books with a lot of interactive features are more advantageous for engaging children and prompting physical interaction (Chiong, Ree, Takeuchi, & Erickson, 2012). We therefore did not include in the current meta-analysis studies of electronic books that include interactive features alone.

We expected that multimedia stories with motion pictures, sound, and music, all congruent with the story text, provide scaffolding that is equal to the support an adult offers during more traditional story sharing activities. Accordingly, we expected the following outcomes from book reading on children's comprehension of the story and word learning:

1. an overall advantage of multimedia stories as compared to print stories without support from an adult,
2. no advantage of multimedia stories when those are compared to print stories with support from an adult.

Methods

Operational Definitions

The goal of the present study was to compare children's comprehension and word learning from narrative stories including multimedia elements to more traditional presentations of print stories with and without the support of an adult. Thus, we selected studies comparing stories including multimedia features to stories that were verbally presented (like during parent-child storybook sharing), either accompanied by static illustrations or not. We considered any verbally told story including multimedia features like animated or video illustrations, sound and background music a multimedia story. This broad definition of multimedia stories allowed for inclusion of studies testing television programs in addition to studies focusing on digital storybooks.

To be included there had to be a comparison condition in the experiment in which the same or a similar story was presented in a way that resembled the more traditional circumstances of children listening to stories, that is, listening to someone either telling a story or reading one from a picture storybook. To meet this criterion a comparison condition was required with either only orally presented stories or an oral rendition of the print in addition to a print book-like presentation with static illustrations, either supported by an adult (e.g., Korat & Shamir, 2007) or not (e.g., Smeets & Bus, 2014). We included studies assessing the differences between stories presented through "television" and "radio" formats, that is, an audiovisual and an audio presentation (e.g., Beagles-Roos & Gat, 1983; Gibbons, Anderson, Smith, Field, & Fischer, 1986) and studies that compared children encountering multimedia storybooks on their own with an adult reading the story from a print picture storybook to the child. In so far as adults were involved they were either instructed to keep their interaction with the children to a minimum (e.g., Critelli, 2011) or they were encouraged to interact with the child during the reading, imitating a natural interactive shared reading session (e.g., de Jong & Bus, 2004; Homer et al., 2014; Korat & Shamir, 2007). In comparison conditions without adult the computer "read" the story while static pictures appeared on screen (e.g., Smeets & Bus, 2014).

Search Strategy

We searched the databases of PsychInfo, ERIC and Web of Science for journal articles, reports and book chapters with a detailed search string including different terminology for literacy outcomes, technology-enhanced narrative stories and young children (see Appendix A). Secondary search involved inspection of the reference lists of review articles and the included articles for other suitable studies in addition to checking handbooks on technology and children's literacy development (see Appendix B for the list). Furthermore, we searched for dissertations and theses reporting data that might be suitable for the present meta-analysis. Over 3000 reports were scanned based on the titles and the abstracts, from which almost 300 full-text studies were checked. Finally, 29 studies were found eligible. For an overview of the procedure and the number of reports scanned see Appendix D.

When we could not find a full text we contacted the authors. If we did not succeed, we contacted authors referencing the study for a copy. Four studies (two conference papers and two reports) did not enter the meta-analysis because we could not locate those (George & Schaer, 1986; Hudson, 1982; Meringoff, 1982; Montouri, 1986).

Inclusion Criteria

According to our operational definitions, intervention studies were included based on the following criteria:

1. Experimental or (quasi-)experimental design with a contrast between a multimedia story and a comparison condition
2. The study included a condition in which an orally presented narration was combined with multimedia features such as animations, music, and sound effects
3. The comparison condition included an orally presented narration with or without static illustrations, with or without the support of an adult
4. Participants were preschool-, kindergarten- or elementary school-aged children
5. The study included as outcome measures the child's vocabulary and/or story comprehension

There were no restrictions regarding the publication status of the manuscripts or the participants' country of origin as long as the article was written in English.

Exclusion Criteria

We excluded non-experimental studies (e.g., Kendeou, Bohn-Gettler, White, & Van den Broek, 2008), studies with foreign language learning (e.g., Tsou, Wang, & Tzeng, 2006), and no eligible comparison condition (e.g., Trushell, Maitland, & Burrell, 2003). We disregarded multimedia interventions focusing on expository texts (e.g., Silverman & Hines, 2009), stories with sign language (e.g., Wang & Paul, 2011) or without oral narration (e.g., Doty, Popplewell, & Byers, 2001). We also excluded studies without any outcome measures (e.g., Reissner, 1996), and studies presenting the same data as in a study already included (Korat, Segal-Drori, & Klein, 2009), or data only for a group of children and adults together (Pratt & MacKenzie-Keaing, 1985). Moreover, we excluded studies utilizing the support of an adult in the multimedia story condition (e.g., Korat, Shamir, & Heibal, 2013) in order to assess whether adult support in traditional story sharing activities is more beneficial than the scaffolding that multimedia elements provide. See Appendix D for a prisma diagram of the literature search.

Coding

We coded the following information:

1. bibliographic information (e.g., authors, year, and title of study, published or not, kind of publication and the country in which the study was conducted),
2. characteristics of the sample (e.g., the number of participants and mean age),
3. the design of the study (a. experimental or quasi-experimental, and b. between- or within-subject design),
4. multimedia (e.g., animation, music and sound effects) and interactive features (e.g., hotspots, questions, games),
5. features of comparison condition (only oral text or oral text and static illustrations)
6. whether there was an adult in the comparison condition supporting the story encounter by interacting with the child (simply reading the text of the story to the child thus did not suffice as adult support),

7. the number of repeated interactions with the stories,
8. outcome measures (a. story comprehension (retelling of the story or comprehension questions), b. vocabulary (expressive or receptive vocabulary, and whether assessing book-based or general vocabulary).

For information that was not available in the reports of the studies regarding the details of the multimedia stories we looked the software up on the Internet, for example checking videos and demos on Youtube.com. When more information was needed, the authors of the study were contacted via e-mail, if possible.

As shown in Table 1, whenever results were reported separately for subgroups of children, based on age (e.g., Pezdek, Lehrer, & Simon, 1984; Williamson & Silvern, 1983), disadvantage status (e.g., Segers et al., 2004), or ability level (e.g., Verhallen & Bus, 2009b), separate effect sizes were calculated for the separate subgroups. When studies included two or more suitable multimedia conditions (e.g., Smeets & Bus, 2014; Verhallen, Bus, & de Jong, 2006) all contrasts were calculated. This was accomplished by dividing the number of participants in the comparison group by the number of suitable multimedia story conditions, without adjusting the scores, in order not to include children twice or more in the analyses (for a similar procedure see Bakermans-Kranenburg, van IJzendoorn, & Juffer, 2003; Mol et al., 2008). In case there were more comparison conditions in a study, the condition most similar to a traditional print book reading activity was chosen (e.g., the 'adult reading' condition in Terrell & Daniloff (1996) and the 'text and accompanying illustrations' condition in Williamson & Silvern (1983)).

In some cases (e.g., de Jong & Bus, 2002) one multimedia condition was chosen in order to have no less than 10 children in each condition in each contrast. In these cases we chose the most technology-enhanced condition (e.g., the 'video with music and sound condition' in Experiment 2 in Smeets, van Dijken and Bus (2014); the 'Kinect with activities' condition in Homer et al. (2014); the 'interactive' condition in Ricci and Beal (2002); and the helpful video condition in Sharp, Bransford, Goldman, Risko, Kinzer and Vye (1995)). However, in the study by de Jong and Bus (2002) the 'restricted/no-game electronic book' condition was chosen because when children had the option to play with the games, they hardly spent time listening to the story.

All studies were coded by two independent coders to assess inter-rater reliability. Agreement was on average $\kappa = .80$ (*SD* = 0.19).

Meta-Analytic Procedures

Since different outcome measures were included with different scales, the standardized mean difference, Hedges' *g* was calculated for each contrast between the multimedia and comparison conditions. To calculate Hedges' *g* raw post-test means and standard deviations were favored over other statistics but in some cases only gain scores (e.g., Critelli, 2011) or only frequency distributions, *F*, *t* or chi-square statistics (e.g., Segers et al., 2006) were available. We entered the available statistics in the Comprehensive Meta-Analysis software (version 2.0; Borenstein, Hedges, Higgins, & Rothstein, 2005) to calculate Hedges' *g* for each contrast for each outcome variable, as presented in Table 1. We preferred Hedges'*g* to alternatives because sample sizes were rather small (Lipsey & Wilson, 2001). If two or more vocabulary or story comprehension outcome measures were available in one study, the effect sizes for the different measures were averaged to compute an overall effect for each study. Interpretation of Hedge's *g* statistics is similar to that of Cohen's *d*. In previous meta-analyses of print exposure, effect sizes averaged around $d = .50$ (Bus et al., 1995; Mol & Bus, 2011). We expected an advantage of multimedia stories but lower than overall effects of print exposure. A positive effect size shows an advantage for the multimedia story condition, while a negative effect size suggests an advantage for the comparison condition.

The effect sizes for all vocabulary and story comprehension measures were inspected for outliers, which resulted in two outlying values (a *z*-score exceeding ± 3.29) (Tabachnick & Fidell, 2007). The two outliers were winsorized into a value of .01 higher, or lower in the case of the one negative effect size, than the highest or the lowest non-outlying effect size. Average effect sizes were computed over both outcome measures (story comprehension and vocabulary) and separately as well. This was decided because story comprehension and vocabulary measures are highly related constructs (Smeets & Bus, 2014; Verhallen & Bus, 2009b) since both tap on children's understanding and internalization of the narrative. At the same time, we intended to test any differences due to measurement issues so we also inspected average effect sizes separately for the different measures.

Overall effect sizes and 95% confidence intervals were computed based on the random effects model. This model was chosen because it is most conservative in handling between-study variability as a result of differences among study designs and intervention, and heterogeneity of the effect sizes (Lipsey & Wilson, 2001; Raudenbush, 2009). Heterogeneity of the effect sizes was estimated using the *Q*-statistic, with a significant *Q* indicating a heterogeneous effect, which means that more variability is found within the included studies than may be expected from sampling error on a subject level only (Lipsey & Wilson, 2001). Studies were weighted by the inverse of their variance, so that studies with larger sample sizes and more accurate estimates of population parameters had a greater weight on the mean effect size (Lipsey & Wilson, 2001; Shadish & Haddock, 2009).

It is referred to as publication bias when studies with significant and/or large findings are overrepresented because these are more likely to get published (Borenstein, Hedges, Higgins, & Rothstein, 2009; Lipsey & Wilson, 2001). Publication bias can be observed by visual examination of the funnel plot. In case of asymmetry around the mean effect size, Duval and Tweedie's "Trim and Fill" procedure is widely used to adjust the overall effect size for publication bias (Duval & Tweedie, 2000).

Moderator analyses were performed, using a random effects model, to contrast subsamples based on different categorical study variables. Moderator analysis was only carried out when outcomes were heterogeneous according to *Q*-statistics. Only moderator variables were used that had at least four contrasts in one cell (cf. Bakermans-Kranenburg et al., 2003). For continuous study variables, as for example publication year, a meta-regression analysis was performed. Moderators were significant in cases of categorical variables, if $Q_{between,}$ or, for continuous variables, the regression model was significant.

Results

Descriptive Statistics

A set of 29 studies including 38 contrasts, was eligible for this meta-analysis. It included 25 journal articles and four dissertations, all published between 1980 and 2014. All studies had an experimental design. A total of 1272 preschool and primary school children, aged three to eleven years, were included. The mean sample size in the primary studies was 41.03 children (SD = 20.00). The average number of repeated readings of the stories was 2.25 (SD = 1.63). Six of the studies only focused on vocabulary learning, sixteen studies only included story comprehension measures and in seven studies both vocabulary and story comprehension were measured. From the fourteen studies that included an adult in the comparison condition, one study (Robb, 2010) focused on parents, two on teachers (Segers et al., 2004; Segers et al., 2006), and in eleven studies the researchers themselves carried out the intervention. Thus, due to the low number of studies we were unable to test this variable as a moderator, which requires a minimum of four contrasts in each cell.

Overall Effect of Technology in Stories

For all included contrasts (see Table 1), an effect size of $g+$ = 0.19 was found, which represents a small but significant effect (k = 38; SE = 0.07; 95% CI = [0.06, 0.33]; $p < .01$). This effect was heterogeneous, Q (37) = 76.23, $p < .01$. After transforming the effect sizes into Fisher's Z, the funnel plot of the standard errors showed a symmetrical distribution around the overall effect and no studies had to be imputed using Duval and Tweedie's trim and fill procedure. Publication status (journal article vs. dissertation) was not a significant moderator ($Q_{between}$ = 0.05; p =.83), indicating the absence of any publication bias. To test for other biases, moderator analyses were performed for country and subject design (within vs. between) and meta-regression analyses were performed for publication date, number of repeated readings, sample size, and whether the children were from the preschool and kindergarten or the primary school age range. No significant regression models or moderators were found, indicating the absence of any bias.

Thirteen contrasts assessing story comprehension were based on measures of children's retelling of the story, 9 used questions and 8 utilized a mix of the two measures. For story comprehension, a significant effect of $g+$ = 0.23 was found when comparing multimedia stories to traditional story reading (k = 30; SE = 0.08; 95% CI = [0.07, 0.40]; $p < .01$). This effect was heterogeneous, Q (29) = 62.64, $p < .001$.

All contrasts assessing vocabulary focused on book-based word knowledge except for three that included a mix of measures regarding general and book-based vocabulary (Segers et al., 2006; Smeets & Bus, 2014). Furthermore, from the 20 vocabulary contrasts 12 assessed expressive word knowledge, 3 measured receptive knowledge and 5 contrasts used a mix of expressive and receptive vocabulary tests. For vocabulary learning, we found a marginally significant effect ($g+$ = 0.16; k = 20; SE = 0.09; 95% CI = [-0.02, 0.33]; p = .08). This effect was heterogeneous, Q (19) = 34.05, $p < .02$.

Multimedia Versus Adult Support

To test whether multimedia can make up for the support of an adult we contrasted the multimedia condition with two types of comparison conditions: with and without the support of an adult. The presence of an adult in the print-like comparison condition was a significant moderator of the effect sizes, $Q_{between}$ (1) = 8.09, $p < .01$ (see Figure 1). Studies (k = 17) that compared multimedia stories to a print-like condition having an adult present to support the child showed no overall effect ($g+$ = -0.02; see Table 2). In contrast, studies (k = 21) that compared a multimedia story to a print-like condition in which no adult was present to support the child showed

Table 1
Overview of the Studies in the Meta-Analysis Including the Moderators and the Effect Sizes.

First author	Year	Age (years)	Technology-enhanced condition	Material	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Interaction with an adult	Outcome measures	Average effect size (*g*+)
Beagles-Roos	1983	6 – 10	'Television' (*n* = 24)	*A Story, a Story, Strega Nona* Animated by Weston Woods Studios	No	'Radio' (*n* = 24)	No	No	Story comprehension (3 measures)	0.34
Critelli (thesis)	2011	4 - 6	'E-book' (*n* = 5)	*Bubbles* CD-ROM story	No	'Print book' (*n* = 5)	Yes	No	Story comprehension (1 measure)	0.00
De Jong	2002	4 - 6	'Computer book – restricted' (*n* =12)	*P.B. Bear's Birthday Party* Bombilla	Yes, relevant and irrelevant	'Regular book' (*n* = 12)	Yes	No	Story comprehension (2 measures)	-0.27
De Jong	2004	4 - 6	'Electronic book' (*n* = 18)	*I'll Make You Well Again Said the Bear, Big Party for Tiger, Tiger and Bear in Traffic* Het Spectrum Electronic Publishing	Yes, relevant and irrelevant	'Printed book' (*n* = 18)	Yes	Yes	Story comprehension (1 measure)	-0.53
Gazella	2003	4 – 5	'Audiovisual' (*n* = 15)	Researcher-constructed story with videotaped puppets	No	'Audio-only' (*n* = 14)	No	No	Story comprehension (2 measures)	-0.11
Gibbons	1986	4 – 7	'Audiovisual' (*n* = 48)	Researcher-constructed stories with animated puppets	No	'Audio' (*n* = 48)	No	No	Story comprehension (1 measure)	0.52
Hayes	1986	3 – 6	'Television' (*n* = 22)	*How the Whale Got Its Throat* Television segment	No	'Radio' (*n* = 22)	No	No	Story comprehension (2 measures)	-0.45
Homer	2014	5 – 7	'Kinect with activities' (*n* = 12)	*Children Make Terrible Pets* by Microsoft Games Studio for the Kinect	Yes, relevant and irrelevant	'Book reading' (*n* = 14)	Yes	Yes	Story comprehension (3 measures) Vocabulary – expressive (1 measure)	0.26 0.37
Korat	2007 Contr 1	5 – 6	'E-book' (*n* = 25)	*The Tractor in the Sandbox* Researcher-constructed CD-ROM story	Yes, relevant	'Adult book reading' (*n* = 25)	Yes	Yes	Vocabulary – receptive (1 measure)	0.06
Korat	2007 Contr 2	5 – 6	'E-book' (*n* = 25)	*The Tractor in the Sandbox* Researcher-constructed CD-ROM story	Yes, relevant	'Adult book reading' (*n* = 25)	Yes	Yes	Vocabulary – receptive (1 measure)	-0.03
Korat	2007 Contr 1 & 2	5 – 6	'E-book' (*n* = 50)	*The Tractor in the Sandbox* Researcher-constructed CD-ROM story	Yes, relevant	'Adult book reading' (*n* = 50)	Yes	Yes	Story comprehension (1 measure)	-0.13
Meringoff	1980	6 – 10	'Television' (*n* = 24)	*A Story, a Story* Animated by Weston Woods Studios	No	'Book' (*n* = 24)	Yes	No	Story comprehension (3 measures)	-0.21
Neuman	1989	8 on average	'Televised version' (*n* = 17)	*Simon's Book*	No	'Storybook' (*n* = 10)	Yes	No	Story comprehension (3 measures)	0.32
Pezdek	1984A Contr 1	8 on average	'Television' (*n* = 24)	*A Story, a Story, Strega Nona* Animated by Weston Woods Studios	No	'Radio' (*n* = 24)	No	No	Story comprehension (3 measures)	1.02
Pezdek	1984A Contr 2	11 on average	'Television' (*n* = 24)	*A Story, a Story, Strega Nona* Animated by Weston Woods Studios	No	'Radio' (*n* = 24)	No	No	Story comprehension (3 measures)	0.55
Pezdek	1984B	5	'Audiovisual match' (*n* = 24)	Bert and Ernie and Big Birds segments from the TV show *Sesame Street*	No	'Audio only' (*n* = 24)	No	No	Story comprehension (2 measures)	0.59
Ricci	2002	6 – 7	'Interactive participant' (*n* = 16)	*The Ugly Duckling* Interactive story	Yes, relevant and irrelevant	'Audio only' (*n* = 17)	No	No	Story comprehension (4 measures)	0.23

First author	Year	Age (years)	Technology-enhanced condition	Material	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Interaction with an adult	Outcome measures	Average effect size ($g+$)
Robb (dissertation)	2010 Contr 2	4 – 5	'Interactive reading alone' (n = 23)	*Curious George Goes to a Chocolate Factory* Read With Me DVD System	Yes, relevant	'Print book reading with parent' (n = 12)	Yes	Yes	Story comprehension (3 measures)	-0.06
Segers	2006	4 – 7	'Computer story' (n = 9)	*Treasure Chest with the Mouse* Researcher-constructed CD-ROM stories	Yes, relevant	'Teacher reading' (n = 8)	Yes	No	Vocabulary (2 measures)	0.62
Segers	2004 Contr 1	5 on average	'Computer reading' (n = 41)	*Treasure Chest with the Mouse* Researcher-constructed CD-ROM stories	Yes, relevant	'Teacher reading' (n = 41)	Yes	Yes	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	-0.08 -0.02
Segers	2004 Contr 2	5 on average	'Computer reading' (n = 30)	*Treasure Chest with the Mouse* Researcher-constructed CD-ROM stories	Yes, relevant	'Teacher reading' (n = 30)	Yes	Yes	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	-0.41 -0.18
Shamir	2012	5 – 7	'E-book' (n = 42)	*Confused Yuval* Researcher-constructed CD-ROM story	Yes, relevant	'Printed book with adult' (n = 34)	Yes	Yes	Vocabulary – receptive (1 measures)	0.45
Sharp	1995	5 - 6	'Helpful video' (n = 18)	Commercial video clips with researcher-constructed narratives	No	'No video' (n = 18)	No	No	Story comprehension (2 measures)	1.43
Silverman	2013 Study 1	Kindergartners (5 - 6)	'Video' (n = 42)	*Arthur, Martha Speaks* TV shows	No	'Read aloud' (n = 36)	Yes	Yes	Vocabulary (2 measures)	-0.24

First author	Year	Age (years)	Technology-enhanced condition	Material	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Interaction with an adult	Outcome measures	Average effect size ($g+$)
Smeets	2014A Contr 1	4 – 5	'Animated e-book' (n = 36)	*Pete on the Pavement, Bear is in Love with Butterfly, Rokko the Crocodile, Bolder and the Boat, Cycling with Grandpa* Het Woeste Woud	No	'Static e-book' (n = 17)	Yes	No	Story comprehension (3 measures) Vocabulary (3 measures)	0.11 -0.18
Smeets	2014A Contr 2	4 – 5	'Interactive animated e-book' (n = 33)	*Pete on the Pavement, Bear is in Love with Butterfly, Rokko the Crocodile, Bolder and the Boat, Cycling with Grandpa* Het Woeste Woud	Yes, relevant	'Static e-book' (n = 16)	Yes	No	Story comprehension (3 measures) Vocabulary (3 measures)	0.19 0.13
Smeets	2014B Experiment 1	5 - 6	'Video book' (n = 28)	*Pete on the Pavement, Rokko the Crocodile, Bolder and the Boat, Little Kangaroo, Imitators, Dear Dear* Het Woeste Woud	No	'Static book' (n = 28)	Yes	No	Vocabulary – expressive (1 measure)	-0.25
Smeets	2014B Experiment 2	5 – 7	'Video with music and sounds' (n = 21)	*Pete on the Pavement, Rokko the Crocodile, Bolder and the Boat, Little Kangaroo, Imitators, Dear Dear, Bear Is In Love With Butterfly, Sweat-Naughty Bear Baboen* Het Woeste Woud	No	'Static-no music or sound' (n = 21)	Yes	No	Vocabulary – expressive (1 measure)	0.07

First author	Year	Age (years)	Technology-enhanced condition	Material	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Interaction with an adult	Outcome measures	Average effect size (*g*+)
Terrell	1996	5	'Videotape' (*n* = 26)	An animated segment, including music, from a children's TV show with a researcher-constructed narrative	No	'Storybook' (*n* = 26)	Yes	No	Vocabulary (3 measures)	-0.58
Valkenburg	1997	6 – 10	'Television' (*n* = 64)	*Stega Nona* *Doctor de Soto* Animated by Weston Woods Studios	No	'Radio' (*n* = 64)	No	No	Story comprehension (1 measure)	0.14
Verhallen	2006 Contr 1	5	'4x Multimedia' (*n* = 10)	*Winnie the Witch* Bombilla	No	'4x Static' (*n* = 10)	Yes	No	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	1.16 1.07
Verhallen	2006 Contr 2	5	'1x Multimedia' (*n* = 10)	*Winnie the Witch* Bombilla	No	'1x Static' (*n* = 10)	Yes	No	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	0.36 0.62
Verhallen	2009a Contr 1	5 on average	'4x video' (*n* = 22)	*Winnie the Witch* Bombilla	No	'4x static' (*n* = 20)	Yes	No	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	0.54 0.54
Verhallen	2009a Contr 2	5 on average	'1x video' (*n* = 21)	*Winnie the Witch* Bombilla	No	'1x static' (*n* = 23)	Yes	No	Story comprehension (1 measure) Vocabulary – expressive (1 measure)	0.39 0.59

First author	Year	Age (years)	Technology-enhanced condition	Material	Relevant and irrelevant interactive features	Comparison condition	Illustrations	Interaction with an adult	Outcome measures	Average effect size (*g*+)
Verhallen (dissertation)	2009b Contr 1	5	'Video' (*n* = 22)	*Winnie the Witch* Bombilla	No	'Static' (*n* = 20)	Yes	No	Story comprehension (2 measures) Vocabulary – expressive (1 measure)	0.98 0.02
Verhallen (dissertation)	2009b Contr 2	5	'Video' (*n* = 13)	*Winnie the Witch* Bombilla	No	'Static' (*n* = 12)	Yes	No	Story comprehension (2 measures) Vocabulary – expressive (1 measure)	-0.23 0.89
Verhallen	2010	5	'Video' (*n* = 34)	*Winnie the Witch* Bombilla	No	'Static' (*n* = 29)	Yes	No	Vocabulary (2 measures)	0.36
Williamson	1983 Contr 1	Kindergart-ners (5 - 6)	'Animated film' (*n* = 10)	*Petunia* Animated film of the story while researcher reads it	No	'Tradebook' (*n* = 10)	Yes	No	Story comprehension (2 measures)	0.15
Williamson	1983 Contr 2	Grade 3 (8 - 9)	'Animated film' (*n* = 10)	*Petunia* Animated film of the story while researcher reads it	No	'Tradebook' (*n* = 10)	Yes	No	Story comprehension (2 measures)	1.00

Table 2
Overview of the Effects of Multimedia Stories as Compared to Children Encountering Traditional Stories Alone and with the Support of an Adult on the Different Outcome Measures

Outcome measure	Adult support in print-like condition	Number of contrasts included	Effect size ($g+$)	Standard error	95% confidence interval	p	Difference between the contrasts with a comparison condition including an adult or not ($Q_{between}$)
Overall	Yes	17	-0.02	0.10	[-0.22, 0.17]	.81	$Q_{between}$ (1) = 8.09, p < .01
	No	21	0.35	0.08	[0.18, 0.51]	< .01	
Story comprehension	Yes	12	-0.07	0.12	[-0.30, 0.16]	.56	$Q_{between}$ (1) = 10.04; p < .01
	No	18	0.40	0.09	[0.22, 0.58]	< .01	
Vocabulary	Yes	9	0.00	0.12	[-0.24, 0.24]	.99	$Q_{between}$ (1) = 3.06; p = .08
	No	11	0.30	0.12	[0.07, 0.53]	.01	

a significant moderate effect favoring the multimedia story ($g+$ = 0.35; see Table 2). A test for homogeneity indicated that the effect was heterogeneous, Q (20) = 39.92, p < .01.

Only in two of the studies comparing multimedia stories with a traditional story condition without support of an adult the electronic book included both multimedia elements and interactive features (Ricci & Beal, 2002; Smeets & Bus, 2014). These two studies showed a non-significant effect of $g+$ = 0.19 (SE = 0.31; 95% CI = [-0.42, 0.80]; p = .54). The other 19 multimedia stories without interactive features showed a significant effect ($g+$ = 0.36; SE = 0.10; 95% CI = [0.18, 0.55]; p < .01). However, because of the low number of studies including interactivity in addition to multimedia features, no moderator analysis could be performed.

When we inspected results separately for story comprehension (k = 30) and vocabulary learning (k = 20), the presence of adult support in the print-like condition appeared to be a significant moderator for the effect of multimedia on story comprehension ($Q_{between}$ (1) = 10.04; p < .01), while for vocabulary this moderator was marginally significant ($Q_{between}$ (1) = 3.06; p = .08). As shown in Table 2, multimedia stories showed a significant additional benefit as compared to children encountering print-like stories without the support of an adult both on story comprehension and vocabulary outcomes. With adult support in the comparison condition effect sizes were low for comprehension and vocabulary.

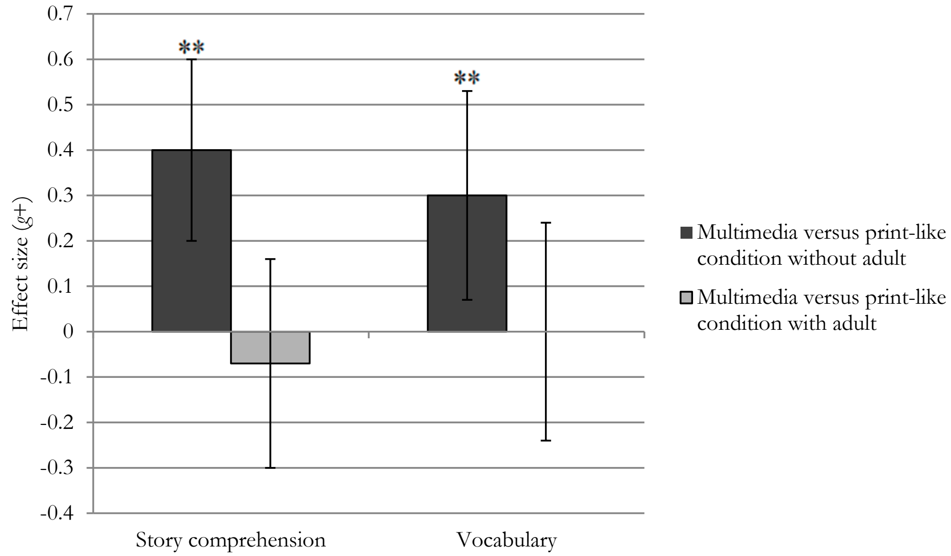

Figure 1. The effect of multimedia added to stories as compared to a more traditional story sharing comparison condition with and without the support of an adult on story comprehension and vocabulary measures.
Note. ** $p \leq .01$.

Effects for the different outcome measures were further analyzed for the group of studies that included a comparison condition without an adult. Separate meta-analyses for receptive and expressive vocabulary learning did result in a significant additional effect for expressive vocabulary ($g+ = 0.34$; $k = 11$; $SE = 0.13$; 95% CI = [0.09, 0.58]; $p < .01$), but not for receptive vocabulary learning ($g+ = -0.03$; $k = 3$; $SE = 0.16$; 95% CI = [-0.34, 0.29]; $p = .87$). However, only in three contrasts receptive vocabulary was measured. Separate meta-analyses for the different kind of story comprehension measures showed comparable effects for both comprehension questions ($g+ = 0.43$; $k = 8$; $SE = 0.14$; 95% CI = [0.16, 0.70]; $p < .01$) as well as for story retelling ($g+ = 0.33$; $k = 15$; $SE = 0.12$; 95% CI = [0.11, 0.56]; $p < .01$).

Finally, to make sure that the significant benefit of multimedia stories over more traditional stories without support of an adult was not due to the absence of visual information in the comparison condition we tested the presence of illustrations in the comparison condition as a moderator. It was not a significant moderator, $Q_{between}(1) = 0.43$, $p = .51$. Ten contrasts without adult support included a comparison condition with only oral text, showing a significant additional effect for the multimedia condition of $g+ = 0.40$ ($SE = 0.13$; 95% CI = [0.15, 0.64]; $p < .01$). However, also when the print-like condition did include static illustrations a significant positive additional effect was found for the multimedia condition ($g+ = 0.30$; $k = 11$; $SE = 0.13$; 95% CI = [0.04, 0.56], $p = .02$).

Discussion

The present meta-analysis synthesized the empirical research regarding the effects of multimedia stories on young children's comprehension and word learning as compared to the support an adult provides during traditional storybook reading. In contrast to the storybook reading paradigm (e.g., Whitehurst et al., 1988), our results show that storybook reading is not necessarily a social activity with an adult present to support story comprehension and word learning. Multimedia stories proved to be more beneficial than encounters with traditional story materials that did not include the help of an adult. We found moderate effects for both story comprehension ($g+ = 0.40$, $k = 18$) as well as vocabulary ($g+ = 0.30$, $k = 11$). This confirms the findings of a previous meta-analysis showing an advantage of multimedia-enhanced stories over print-like comparison stories on children's literacy development (Takacs et al., 2015). However, we found a non-significant effect of multimedia stories when the comparison condition included adult scaffolding. These findings indicate that multimedia elements provide scaffolding of children's understanding and word learning that is comparable to adult scaffolding during storybook reading.

Results were similar for both story comprehension and vocabulary. Furthermore, similar effect sizes were found for story comprehension questions, story retellings and expressive vocabulary measures. The only exception was receptive word knowledge for which we found no effect of multimedia as compared to traditional materials that children encountered alone. Comprehension of a word (receptive knowledge) precedes the ability to use the word or reflect on the meaning of the word (expressive knowledge) and may require more superficial learning (Verhallen & Bus, 2010). Encounters with traditional story materials appears to suffice for receptive word learning and multimedia cannot add to this. In line with this suggestion, a previous meta-analysis (Mol et al., 2008) found a smaller additional benefit of dialogic reading on receptive than on expressive vocabulary measures.

In regards to interactive features added to the multimedia stories, only two studies tested the difference between an interactive-multimedia story and a traditional story that children encountered alone (Ricci & Beal, 2002; Smeets & Bus, 2014). These studies show no difference between interactive and traditional stories, while studies with purely multimedia stories show an advantage of multimedia elements over children encountering traditional story materials alone. This finding, although preliminary due to the low number of studies, might suggest that it is not the interactive but the multimedia features that provide similar scaffolding as an adult for children's literacy experiences. In fact, Chiong and colleagues (2012) showed that e-books with many built-in interactive features are less stimulating for parent-child literacy-related interaction and children's story comprehension as compared to reading print books.

Limitations

In the present study it was not possible to test whether the quality of guidance affects learning. It would have been interesting, for instance, to test whether parental guidance has a different effect than support from a researcher interacting with the child according to a transcript. Because of the low number of studies utilizing parental support such a comparison could not be made. In contrast to a researcher, parents might connect the story to the child's own experiences and thus be more effective than less personalized guidance offered by the researcher (Jones, 1996).

Conclusion

In the present research synthesis including 29 studies and 1272 young children we found evidence that multimedia stories are more beneficial for story comprehension and word learning as compared to children encountering traditional stories without the support of an adult. In fact, we found no difference between the benefits of multimedia elements embedded in stories and reading traditional story materials while interacting with an adult. This suggests that multimedia features like animated illustrations, background music and sound effects can provide similar scaffolding of story comprehension and word learning as an adult.

It is important to note that most commercially available electronic books are not necessarily similar to the ones used in the primary studies. They most often include a large number of interactive features like hotspots and games (de Jong & Bus, 2003; Guernsey, Levine, Chiong, & Severns, 2012), which we found to have detrimental effects on children's story comprehension (Takacs et al., 2015). Thus, the present research synthesis shows the potentials of electronic stories for children's language and literacy development but we cannot generalize the results to the available electronic stories on the market.

The presence of an adult does not have advantages for story comprehension and vocabulary learning beyond multimedia books but may have for other outcomes of book sharing. Children's reading motivation and attitude might be more facilitated by reading print storybooks with an adult (Baker, 2003; Sonnenschein & Munsterman, 2002). Furthermore, the parent-child relationship and children's socio-emotional development may benefit from sharing and discussing stories together (Aram & Aviram, 2009; Bus, 2001; Laible, 2004). These aspects of storybook reading were not investigated in the present study. However, at least as far as children's language and literacy development is concerned, children seem to benefit just as much from multimedia stories as from adult scaffolding. Thus, when there is no adult available to support children's encounters with a story, well-designed multimedia stories are an effective way to scaffold children's learning.

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Chapter 5

The Benefits of Motion in Animated Storybooks for Children's Comprehension: An Eye-Tracking Study

Based on:
Takacs, Z. K. & Bus, A. G. (under review). *The benefits of motion in animated storybooks for children's comprehension. An eye-tracking study.*

Abstract

The present study provides experimental evidence regarding 4-6-year-old children's visual processing of animated versus static illustrations in storybooks. 39 participants listened to an animated and a static book, both three times, while eye movements were registered with an eye-tracker. Outcomes corroborate the hypothesis that specifically motion is what attracts children's attention while looking at illustrations. It is proposed that animated illustrations that are well matched to the text of the story guide children to those parts of the illustration that are important for understanding the story. This could explain why animated books resulted in better comprehension than static books.

Young children are attracted to screen media like cartoons and television programs that include motion, music and sound. In fact, children seem to prefer a multimedia presentation of stories over a static presentation as in more traditional print books and are more engaged with multimedia materials. Verhallen and Bus (2009) found that skin conductance – an indicator of children's mental effort during listening to storybooks - remained at the same level over four repeated readings of a story when the book included multimedia features like motion pictures, music and sound effects. However, mental effort decreased in the third and fourth repetition when the same story included only static illustrations. Moody, Justice, and Cabell (2010) revealed that children were more persistent when sharing an e-storybook as compared to sharing a traditional print storybook with an adult. On the other hand, when watching multimedia content children are especially attentive to salient formal features like rapid action (Potts, Huston, & Wright, 1986), animation, motion, lively music and auditory change (Alwitt, Anderson, & Lorch, 1980; Levin & Anderson, 1976). Such elevated attention to salient features like motion might guide children's attention when watching an illustration, which may explain the overall greater engagement with multimedia than with static stories (Verhallen & Bus, 2010). The present study investigated whether motion in animated illustrations in electronic storybooks attracts more attention and whether there is, probably as a result of looking longer at details in motion, an overall elevated visual attentiveness when listening to animated versus static books.

In contrast to concerns expressed in older literature for a "mesmerizing" effect of multimedia on children's cognitive development (e.g., Hayes & Birnbaum, 1980), there is evidence for the potential of multimedia for fostering learning. It is apparent from the literature on electronic storybooks that multimedia features, as long as the verbal text of the story on the one hand and the pictures and sounds on the other are well matched, boost the effects of storybook reading on young children's story comprehension and word learning (for meta-analytic evidence see Takacs, Swart, & Bus, 2014, 2015; for a review see Bus, Takacs, & Kegel, 2014). In explanation, we hypothesized that by processing details of pictures in books at exactly the same time as the oral text – children's eyes focus on those parts of the illustration that are highlighted by the text – children may integrate verbal and visual information which improves understanding of the text (Bus & Verhallen, 2011; Evans & Saint-Aubin, 2005; Verhallen & Bus, 2011). The human brain is able to process both sources of information - verbal and nonverbal stimuli - simultaneously without causing cognitive overload. The two kinds of stimuli are processed in separate but interconnected channels (Paivio, 2007). So far there is not much empirical evidence for an alternative account - the visual superiority hypothesis (Hayes & Birnbaum, 1980) - proposing that looking at motion pictures is more appealing to young children than listening to the oral language (Bus et al., 2014; Rolandelli, 1989). According to this view, one could argue that motion pictures may distract children's attention from the verbal narration and impose a cognitive overload on children's working memory and thus interfere with story comprehension and learning new vocabulary.

The current study zoomed in on the effect that motion in illustrations has on children's eye movements and on subsequent story comprehension and word learning. This study is, to our best knowledge, the first to test the hypothesis that multimedia features like motion direct children's visual attention to details in the picture that are highlighted by the text resulting in more attention to those details than during reading a book with still pictures. Motion in the illustration might thus help to concretize story language more than a static illustration. For example, in Figure 1 the angry director is actually jumping up and down in the animated condition and thus attracting the most attention despite many other visualized story details. Additionally, motion, better than static illustrations, guides children's attention to depictions that match the oral text that children simultaneously hear. For example, the director – the only motion in the picture - is angrily jumping while the text says: "*These are not monkeys!' he shouted jumping 'These are people!*". We may thus enhance story comprehension and learning words because the closer together the verbal and nonverbal information are presented the more the integration of the two is facilitated (Mayer, 2003). As a result, children's overall attentiveness and engagement when listening to stories may be higher with animated as compared to static illustrations (Moody et al., 2010; Verhallen & Bus, 2009).

In the present study children repeatedly listened to two stories: one with static pictures and another with animated illustrations. Both books were presented three times on an eye-tracker. We utilized eye-tracker data two ways: First, to register children's overall visual attention to the illustrations when listening to animated or static stories as an indicator of engagement. Secondly, in order to test whether motion in illustrations indeed attracted children's attention more than the same details in static illustrations, we selected three pages per book with a detail in motion and compared visual attention for this detail with attention for the same detail in the static version of the book. Total fixation time and average fixation duration were assessed. To the best of our knowledge, this was the first study comparing children's visual attention to animated and static details in pictures.

Third, we examined, apart from children's recall of the story language, their learning of new words as a function of animated versus static pictures. Previous studies have shown that it makes a difference for word learning whether children have some receptive knowledge of words or not (Smeets & Bus, 2012; Verhallen & Bus, 2010). Differences in experiences with words strongly vary across children and make it hard to determine how much learning resulted from repeated readings of a particular book. To maximally control for differences in word knowledge prior to exposure to the word in the target books we preferred adding non-words to the books for three well-visualized words from the story text. This way we were sure that children did not have any previous knowledge of the target words.

Hypotheses

1. Based on the previous literature showing an advantage of multimedia-enhanced stories over print-like static stories (Bus et al., 2014; Takacs et al., 2015), we expected that children would recall more from the language of the story when encountering stories with animated as compared to static illustrations.
2. Animated illustrations representing the meaning of non-words may, more than static illustrations, facilitate the learning of the non-words (Smeets & Bus, 2014). Since the non-words were completely unknown we expected effects on receptive knowledge rather than on expressive word knowledge (Smeets & Bus, 2012; Verhallen & Bus, 2010).
3. We expected that children would be more visually attentive to illustrations that include motion than to static illustrations (Moody et al., 2010; Verhallen & Bus, 2009). As a result, children were expected to fixate the illustrations in an animated book longer than those in a static book.
4. Details in motion were expected to attract more attention than static details (Alwitt, Anderson, & Lorch, 1980; Levin & Anderson, 1976). Accordingly, longer fixations were predicted on the detail that is in motion compared to the same detail in a static illustration.

Method

Participants

Children were recruited in 3 public schools from 5 kindergarten classrooms with 4-, 5- and 6-years-old children who had not yet received formal reading instruction. In the Netherlands formal reading instruction including intensive daily practice starts in grade 1. Parents of 43 children gave informed consent for participation of their child in the study. Among the 43 children were 3 children who were excluded from the study because they were siblings of other participants. Also, one boy's eye-tracking data collected at the second session was lost and he was excluded from all further analyses. The final sample consisted of 39 children (22 boys and 17 girls) with a mean age of 61.26 months (*SD* = 7.69, range: 48-77 months). From the three participating schools we recruited 9, 6, and 24 children, respectively. To control for any effects of school, it was entered as a factor in the analyses.

Design

The study was a within-subject design in which every child participated in three conditions: a storybook with animated illustrations, a storybook with static illustrations and a control condition, including only post-testing and no book reading. The illustrations in both the animated and static conditions were presented for the same amount of time and with the same oral narration, the only difference being the presence of motion and zooming in on the illustrations. Three storybooks can be assigned to three conditions in six different ways. 40 participants were about equally assigned to these six possibilities. However, not completely. Four groups included 7 children, one group 5 children and one 6. As a result, the books were not completely evenly distributed over the three conditions. For instance, in the animated condition 14 children read *Bear is in Love with Butterfly* [*Beer is op Vlinder*] (van Haeringen, 2004), 12 *Imitators* [*Na-apers!*] (Veldkamp, 2006), and 13 *The Little Kangaroo* [*Kleine Kangoeroe*] (van Genechten, 2009).

Procedure

Children were taken from the classroom to a quiet location in the school on two days. As shown in Table 1, on the first day children listened twice to both stories, one in the animated format and the other in the static format. To register visual attention the books were presented on the screen of an eye-tracker. The animated version of a book was presented for the same amount of time as the static version of the same book. The order of the animated and static book was alternated and half of the children started with the animated and half with the static book.

On a second day, on average two days later (*M* = 2.00, *SD* = 1.12), a third session took place in which children listened again to the two books right before post-testing. Post-tests included a retelling of the two stories that they had heard three times and the control story. The order of the books retold was random. We also tested knowledge of 9 non-words, three from each story. We used four vocabulary tests assessing different levels of word knowledge. The order of the four vocabulary

tests was fixed and the same for all children. The order of the retellings and the vocabulary tests was counterbalanced: 19 children started with the story retelling, while 20 children completed the vocabulary tests first. See Table 1 for an example schedule.

Table 1
An Example of the Schedule of the Experiment

Day 1	Day 2
Session 1	*Session 3*
Reading of animated version of *Imitators*	Reading of static version of *The Little Kangaroo*
Reading of static version of *The Little Kangaroo*	Reading of animated version of *Imitators*
Session 2	*Post-testing*
Reading of animated version of *Imitators* Reading of static version of *The Little Kangaroo*	Retellings of the three stories *1. The Bear is in Love with Butterfly* *2. Imitators* *3. The Little Kangaroo* Vocabulary tests: Expressive vocabulary test Context integration test Receptive vocabulary test Meaning recognition test

Note. There was 1-5 days between the two days. We tried to use the three books in the three conditions as much as possible. In the case of the above example *Imitators* was used in the animated, *The Little Kangaroo* in the static and *The Bear is in Love with Butterfly* in the control condition. The order of the animated and static condition was the opposite for half of the participants who started with the static book. The order of the story retelling and vocabulary post-tests was different for half of the children who started with the vocabulary tests. The order of the books retold was random. The order of the four vocabulary tests was fixed and the same for all children.

Materials

Three animated storybooks (*The Little Kangaroo, Imitators, Bear is in Love with Butterfly*) were chosen for the 3 conditions. The text of the storybooks was slightly different from the original. In each book 3 verbs were substituted by non-words, i.e., words that do not exist in the Dutch language but sound like Dutch (see Appendix E for the list of target words). As shown in the example in Figure 1, the word 'jumping' ['springen'], for instance, was replaced by the non-word 'trinnen'. Each of the three books included 3 non-words which resulted in 9 non-existing target words. In each story two of 3 non-words were mentioned twice in the oral text and one once.

All three stories were animated by the same company (Het Woeste Woud). Background music and sound effects were present in the the animated versions of all three books but eliminated for the present study because our goal was to test the effect of motion in illustrations. To make the static illustrations similar to the animated illustrations, we selected the most representative still frame of the fragment and presented this for exactly the same amount of time as the animated illustration of the scene. There was some slight variation between the three books: *Bear is in Love with Butterfly* included 397 words, *The Little Kangaroo* 516 words, and *Imitators* 509 words. Accordingly, the duration of the readings were somewhat different too: to read *Bear is in Love with Butterfly* took 194 s, *The Little Kangaroo* 232 s, and *Imitators* 252 s. We corrected for differences in length of presentation by dividing fixation durations for the whole book by the duration of the stories.

Per book three illustrations were chosen for detailed eye-tracking analyses. We chose pictures with illustrations that clearly depicted the non-words. This detail of the illustration was in motion in the animated condition and clearly visualized in the static condition. The details were the same size in the animated and static condition. However, illustrations differed across books, not only in artistic style but also in the number of details. For example, on one of the target illustrations in *Bear is in Love with Butterfly* we see Bear playing the accordion; the only other visual element on the illustration is Butterfly with a handkerchief. In contrast, in *Imitators* shown in Figure 1 there are many smaller and larger elements beyond the angry director. The different

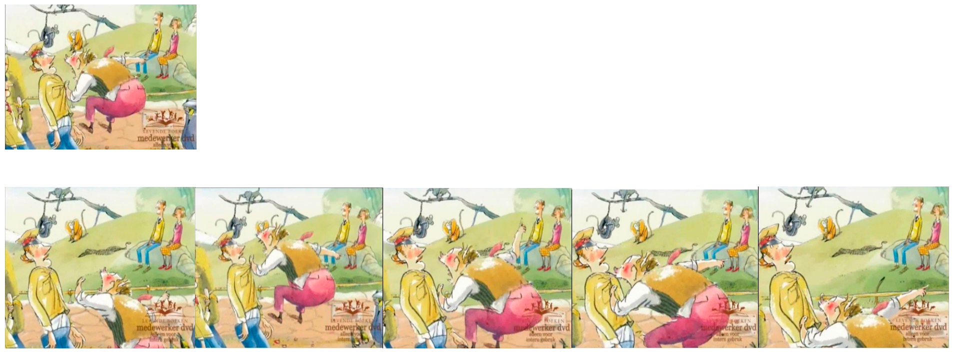


Figure 1. One of the target illustrations chosen for fine-grained analysis of the eye-tracking data. The same illustration in the static condition in the first row and still frames from the animated version[1] are shown in the second row. The director of the zoo is jumping up and down while the accompanying oral text says: *’These are not monkeys!’ he shouted *jumping* ‘These are people!’. [‘Dit zijn geen apen!’ riep hij “trinnend”, ‘Dit zijn mensen!*

[1] Copyright 2014 by Het Woeste Woud.

pages were presented for slightly different amounts of time according to the length of the corresponding oral narration ranging between 3.6 and 7.1 seconds.

Measures

Visual attention at the illustrations. While the books were read to the children their eye movements within the illustrations were recorded. The total fixation time on the illustrations in a storybook was calculated and divided by the duration of the presentation of the book. Additionally, children’s average fixation duration while looking at the storybooks was calculated. This was done for all three sessions.
We defined details that visualized the non-words as Areas of Interest (AOIs). We divided the time that children fixated the AOI by the time that they looked at the whole illustration. This was done for the three AOIs per book. The average percentage was calculated as an indicator for each condition and each session. Additionally, we divided children’s fixation duration at an AOI by the number of fixations as indicator of average fixation duration. The average fixation duration was also calculated for each condition and session.

For 4 children data quality was low, i.e., eye movements were registered for less than 50% of the time during at least one session in one of the conditions. Due to low data quality, these children’s fixation times were extremely low. For the eye-tracking analyses these 4 children were excluded and, accordingly, data of 35 children were used. Additionally, on the 24 fixation variables outlying scores were winsorized in order to normalize the distribution of the scores. In all, 20 scores.

Story retelling. Children were asked to retell the three stories while they looked at the static illustrations of the stories. The experimenter asked general questions when children stopped talking like ‘What is happening here?’ or ‘Who is this?’. Children’s retellings were transcribed and we calculated how many content words from the original story appeared in the retellings of the stories and whether or not the non-words were used. One child refused to retell the stories so analyses regarding story comprehension were conducted on the data of 38 children.

Vocabulary tests. Familiarity with the 9 target non-words was assessed with four tests measuring receptive and expressive knowledge of the words. We started with the two expressive vocabulary tests in order to avoid learning from the receptive tests in which children heard the target words.

Expressive vocabulary test. With the corresponding illustration on the screen children were asked to complete a sentence with the non-word missing. Sentences were phrased differently than in the stories. Only answers including the target word scored 1, any other answers 0. See Figure 2 for an example. Item-level inter-rater

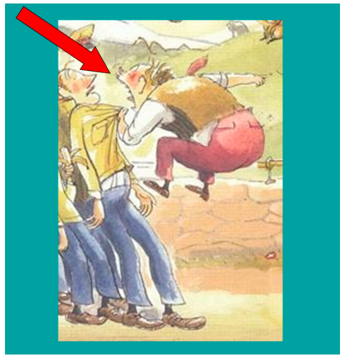
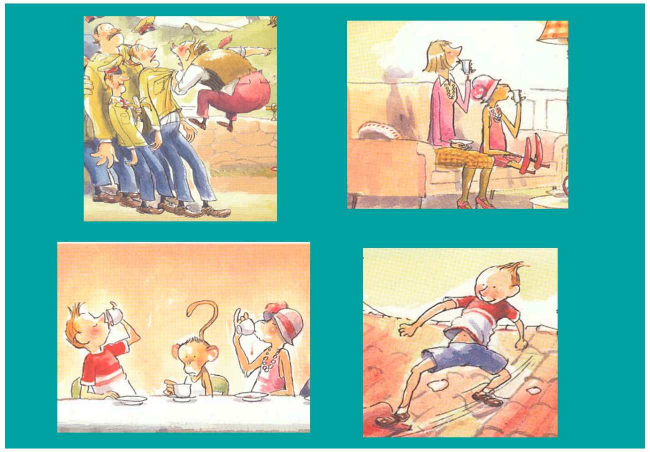
Tests	Item	Correct answer
Expressive vocabulary test	The director is so angry that he cannot stand still. He is… What is he doing here? [De directeur is zo boos, dat hij niet kan blijven staan. Hij is aan het … Wat doet hij hier?] 	‘*trinnen*’ (non-word for ‘jumping’)
Context integration test	Which way do you move when you are *jumping*? [Welke kant beweeg je op als je *trint*?]	E.g., up and down
Receptive vocabulary test	Where can you see… *jumping*? [Waar zie je … *trinnen*?] 	Picture 1
Meaning recognition test	1. *Jumping* is when a car is driving through a tunnel. [*Trinnen* is wanneer een auto door een tunnel rijdt.] 2. When you *jump* you can pick an apple from the tree. [Als je trint, kan je bij een appel die in de boom hangt.]	False True

Figure 2. Examples of the four vocabulary tests assessing knowledge of the non-word ‘trinnen’ which stands for the word ‘jumping’ including still frames from the animated version[1].

[1] Copyright 2014 by Het Woeste Woud.

reliability was excellent (average κ = 1.00). Only one child used any of the target words so no further statistical analyses were conducted on this measure.

Context integration test. The context integration test uses open-ended questions prompting an expressive explanation of the target word like (e.g., “Which way do you move when you are *jumping*?”). Only answers with information reflecting the meaning of the target word were awarded 1 (e.g., “You go up and down”), any other answers (e.g., ‘to the right’) were scored 0. Item-level inter-rater reliability was good (average κ = .89). Children rarely gave good answers resulting in a very skewed outcome. Thus, statistical analyses were not conducted on the this measure.

Receptive vocabulary test. This test was a multiple-choice test where children had to choose the corresponding picture from 4 options. Target pictures and distractors were chosen from the same storybooks. See Figure 2 for an example. Item-level inter-rater reliability was good (average κ = .78). More than half of the children performed above chance level (25%) in both the animated ($p < .001$) and the static condition ($p < .001$). This was not the case in the control condition ($p = .34$).

Meaning recognition test. The meaning recognition test assessed word knowledge independent from the context of the storybooks. Using two yes/no questions per word regarding the meaning of the word presented in a quasi-random order, children’s receptive transfer knowledge of the non-words were tested. See Figure 2 for an example. Item-level inter-rater reliability was good (average κ = .72). Children did not perform above chance level in any of the conditions (animated: $p = .75$, static: $p = .52$, control: $p = .20$) so scores on this test was not further analyzed.

Results

Story Comprehension

An ANOVA with repeated measures for recall of the story language per condition and school (school 1, 2 and 3) as a between-subject factor was carried out. Two planned contrasts were conducted regarding the effects of condition: 1. between the animated and the static conditions, and 2. between the intervention and the control conditions to test the effect of book reading. Children recalled significantly more content words from the animated as compared to the static condition ($F(1, 35) = 5.87$, $p = .02$, $\eta_p^2 = .14$) showing an advantage of animations. Also, children recalled more from the language of the animated and the static stories as compared to the control condition ($F(1, 35) = 60.45$, $p < .001$, $\eta_p^2 = .63$) suggesting an effect of book reading. See Table 2 for descriptive statistics.

Word Learning

Only three out of 38 children used non-words from the story in the retelling, one in the animated and two in the static condition. Thus, the effect of condition could not be tested on these variables.

Of the four word learning tests children only showed learning in the receptive vocabulary test. On the other three tests children did not show any learning. We carried out an ANOVA with repeated measures for the receptive vocabulary test in the three conditions (animated, static, control) and school (school 1, 2 and 3) as a between-subject factor. Two planned contrasts were conducted regarding the effects of condition: 1. between the animated and the static conditions, and 2. between the intervention and the control conditions. There was no significant difference between the animated and static conditions (F (1, 36) = 0.44, p = .51, η_p^2 = .01). However, there was an effect of book reading on receptive word learning: children performed significantly better in the animated and the static conditions as compared to the control condition (F (1, 36) = 5.76, p = .02, η_p^2 = .14). See Table 2 for descriptive statistics. None of the other vocabulary tests showed sufficient variance to carry out statistical tests.

Table 2
Descriptive Statistics on the Outcome Measures of Story Retelling and Receptive Vocabulary for Each Condition

	Animated condition *M* (*SD*)	Static condition *M* (*SD*)	Control condition *M* (*SD*)
Story retelling (number of content words recalled)	12.74 (5.75)	11.40 (6.74)	2.95 (1.86)
Receptive vocabulary test (number of correctly identified items out of three)	1.51 (0.79)	1.36 (0.81)	0.95 (0.92)

Visual Attention to All Illustrations in the Books

We carried out an ANOVA with repeated measures for the percentage of total time that it took to read the book in which children fixated the illustrations of the books. Within subject factors were condition (animated versus static) and session number (first, second or third). We carried out two planned contrasts for session number: the contrast between the first and the second, and between the first and the third session in order to test whether attention to the illustrations decreased over sessions. School (school 1, 2 and 3) was entered as between-subject factor.

We found a significant main effect of condition on percentage fixations (F (1, 32) = 19.86, p < .001, η_p^2 = .38), meaning that children attended the screen more in the animated as compared to the static condition. Contrasts showed that children attended the screen less during the second session as compared to the first (F (1, 32) = 18.56, p < .001, η_p^2 = .37) but visual attention was similar in the third session as compared to the first (F (1, 32) = 0.04, p = .84, η_p^2 = .001). See Table 3 for descriptive statistics.

The same analysis was applied to the average duration of fixations on the illustrations. We found a main effect of condition (F (1, 32) = 5.64, p = .03, η_p^2 = .15), showing that fixations on the illustrations in the animated books were longer as compared to the fixations on illustrations in static books. There was no difference between the first and the second session (F (1, 32) = 1.31, p = .26, η_p^2 = .04). However, children had significantly longer average fixations on the third as compared to the first session (F (1, 32) = 5.95, p = .03, η_p^2 = .16).

Table 3
Visual Attention to the Illustrations in Animated and Static Books during the First, Second and Third Session

	Animated condition *M* (*SD*)	Static condition *M* (*SD*)
Total fixation time on the illustrations, corrected for the length of the book (in percentages)[a]		
Session 1	.84 (.07)	.79 (.07)
Session 2	.82 (.08)	.77 (.09)
Session 3	.85 (.06)	.80 (.07)
Average fixation duration on the illustrations (in seconds)		
Session 1	0.37 s (0.09)	0.34 s (0.07)
Session 2	0.38 s (0.09)	0.34 s (0.08)
Session 3	0.40 s (0.08)	0.36 s (0.06)

Note. [a] Percentage score, children's total fixation time at the illustrations were divided by the presentation time of the book in order to correct for the slight differences between the books.

Attention to Motion while Looking at the Target Illustrations

We carried out an ANOVA with repeated measures for the percentage of total fixation time spent on the selected detail (in motion in the animated version and a still detail in the static version). Within-subject factors were condition (animated versus static) and session number (1, 2 and 3). With Tobii software we selected the same areas in both versions of the books and calculated fixation durations on these target details. These scores were divided by children's fixation duration on the whole illustration in order to control for overall elevated attention to animated illustrations. Between-subject factor was school (school 1, 2 and 3). The ANOVA resulted in a significant main effect of condition (F (1, 32) = 19.16, $p < .001$, $\eta_p^2 = .38$) indicating that children focused more on the details when they were in motion. The contrast between the first and the third session was not significant (F (1, 32) = 2.72, $p = .11$, $\eta_p^2 = .08$). However, children were more attentive to the AOIs during the first as compared to the second session (F (1, 32) = 8.05, $p < .01$, $\eta_p^2 = .20$). See Table 4 for descriptive statistics.

The same model was applied to children's average fixation duration while looking at the selected details. There was a significant main effect of condition (F (1, 32) = 23.92, $p < .001$, $\eta_p^2 = .44$), showing that children's average fixations were longer on the moving details in the animated condition as compared to the same details in the static book. Average fixation durations for the first session were not different from the second (F (1, 32) = 0.14, $p = .71$, $\eta_p^2 = .004$) or the third session (F (1, 32) = 0.97, $p = .33$, $\eta_p^2 = .03$).

Table 4
Visual Attention to the Salient Movement Depicting Non-words in the Animated and Static Condition per Session

	Animated condition *M* (*SD*)	Static condition *M* (*SD*)
Fixation time on AOIs (in percentages)		
Session 1	.80 (.08)	.70 (.12)
Session 2	.76 (.11)	.68 (.12)
Session 3	.77 (.12)	.69 (.11)
Average duration of fixations while looking at AOIs (in seconds)		
Session 1	0.38 s (0.11)	0.31 s (0.07)
Session 2	0.38 s (0.10)	0.30 s (0.08)
Session 3	0.41 s (0.12)	0.32 s (0.06)

Discussion

The effects of animated illustrations on children's story language recall, word learning and visual attention during storybook reading were investigated in the present study. We found, in line with previous research (Bus et al., 2014; Takacs et al., 2015), that children recalled significantly more story language in the animated than in the static condition. However, in contrast to the second hypothesis, there was no difference between the animated and the static condition in terms of word learning. Findings also evidence that, in particular, motion in pictures attracts children's attention. Compared to how children look at static illustrations, children pay more attention to the details in motion in animated illustrations. Children seem to use different processing strategies while looking at animated and static illustrations, with a larger focus on motion in the animated illustrations. We also found that children's fixations were longer on average in the animated condition. That is, they were less inclined to explore the whole picture by jumping to different visual elements but fixate more on particular details. Motion seems to guide children's visual attention resulting in more in-depth exploration of those details in the illustration. Furthermore, there is evidence that children are more attentive when listening to the animated as compared to the static version of the storybooks. That is, children attended the screen for a longer time in total and looked away from the screen less when the illustrations were animated.

Our results corroborate the theory of Verhallen and Bus (2010) that motion in illustrations guides children's attention and thereby facilitates story comprehension. Due to motion children pay more attention to visual details that are simultaneously highlighted in the oral text. Furthermore, the longer average fixations might reflect deeper processing of the relevant details in the illustrations (Rayner, 2009). Children's eyes were moving less between the different visual elements of the animated illustration and focused more on particular details. However, the current results do not prove that better comprehension results from this different way of processing pictures. For instance, we cannot exclude that comprehension in the animated condition as compared to the static condition improved as a result of higher engagement as may be indicated by children's longer fixations on the whole book. To exclude this alternative interpretation we would need an additional condition in which, in contrast to the animated book in the current study, irrelevant parts of the pictures were animated. In that case, a general effect on children's engagement and attentiveness may remain but such stories may fail to support the match between the story text and the corresponding visualizations.

Since there were no other multimedia additions like sounds and music in the stories in the present study but only motion in the illustrations, the current findings corroborate the hypothesis that motion can elevate story comprehension and thus is a crucial part of a well-designed multimedia environment for children's storybooks (cf. Takacs et al., 2014, 2015). This is the first study, to our knowledge, that shows the effects of motion on children's visual attention. Further studies are needed to investigate the separate effects of other multimedia features like sound and music to create clear guidelines for designers of multimedia stories.

Another interesting finding of the present study is that children showed significant word learning on a receptive level after listening to the stories three time. On expressive level there were no effects. Children hardly used the target words during story retelling or the expressive vocabulary test. They also failed to give acceptable explanations for these words. This finding is in line with previous studies showing that novel word learning starts with understanding the word in context and not until children have sufficient receptive knowledge of the word they start developing expressive knowledge after repeated exposures to the word (Smeets & Bus, 2012; Verhallen & Bus, 2010).

Children, however, did show significant word learning on a receptive level. That is, they had knowledge about the words only when they were assessed in the context of the storybooks, like in the case of the receptive vocabulary test using illustrations from the storybooks. This, again, confirms previous findings that expressive word learning does not start until children recognize the word in a familiar context (Smeets & Bus, 2012; Verhallen & Bus, 2010). In contrast, children did not perform above chance level when the test measured word knowledge outside of the context in which children encountered the novel words. Results on word learning suggest that after three repeated book readings children showed elementary knowledge of completely novel words (non-words). This might be the earliest phase of word learning: understanding a word in the context in which children encountered it previously. Transfer of this knowledge to other contexts and expressive use of the word seem to come later on with repeated exposures to the word. Similar to prior findings, we expect that especially the step from receptive to expressive knowledge is facilitated by animated books (Smeets & Bus, 2012). Results of the present study on word learning extend the literature due to the use of a novel approach, using non-words as target words in the stories thus controlling for any previous knowledge of the words.

Another result of the present study was the effect of session number on children's visual attention during the stories; that is, children were less attentive to illustrations of the stories and the moving details in the illustrations on the second repetition in both conditions. This is most probably due to the fact that the first session was conducted at the same day as the second. Children encountered the same story a couple of minutes earlier which may explain why their attention dropped. However, children were similarly attentive to the illustrations and the motion in the animations during the third repetition as they were on the first occasion in both conditions. This pattern of results supports the idea that spreading of encounters with the same books is preferable to dense practice: a few days is better than a few minutes. What optimal lags between sessions are is a question for further research.

Limitations

The non-words in the present study were inserted in place of mostly high-frequency verbs that children are likely to understand and use. Thus, children might have not been motivated to use the novel words when retelling the story or completing sentences in the expressive vocabulary test because they already know a word for these actions. It is plausible that children's expressive word knowledge was thus underestimated in the present study. It might be better to investigate novel word learning in the context of novel actions and phenomena for which children do not yet have labels in order to better estimate expressive learning of the words.

Another limitation was the use of the static illustrations of the stories in the retellings of both the static and the animated conditions as well as in the vocabulary tests. This was decided in order for the experimenter not to be influenced by the condition when interacting with the child during retelling the story. However, this might have underestimated the effects of animated illustrations on children's recall and word learning because the same animated pictures as seen during the story might have prompted more extensive recalls and better performance on a multiple-choice test based on the illustrations of the storybook like the receptive vocabulary test in the present study.

Conclusions and Suggestions

In sum, motion attracts visual attention and changes the way children look at illustrations. Animated illustrations that are closely matched to the story text have more potential to direct children's attention to specific details of the picture as compared to static illustrations and may thus promote dual-coding (Paivio, 2007). We expect that the focus on motion in pictures explains why they look longer at the illustrations of animated books as compared to static books although we cannot exclude that they are also more alert when illustrations are animated. Although children are attracted to animations and specifically to motion in the animations, they do not seem to be mesmerized by the visual stimuli.

These effects may only occur when the animation depicts the language of the narration. Bus et al. (2014) suggested that animations that have only decorative purposes may not add to children's story comprehension and might even interfere with learning. Such incidental animations with no direct connection to the text of the story are hypothesized to distract them from the story by posing a high cognitive load on their working memory. This hypothesis is in line with a meta-analytic finding of Höffler and Leutner (2007), showing no additional benefit of decorative animations for adults' learning as compared to a moderate effect of representational animations.

This study has important practical implications for designers and developers of electronic storybooks and for caregivers and teachers navigating on the market of children's storybooks. Animations and motion seem to be a powerful tool to direct children's attention to particular details that are meaningful from the story's point of view. It seems most plausible that well-designed animations will focus children's attention on the parts of the illustrations that depict the text of the story thus facilitating the integration of verbal information in the story and the nonverbal stimuli of animation and children's story comprehension. Consequently, high-quality electronic storybooks will utilize the benefits of animations and other multimedia features, creating congruency between the story text and the technological elements like animations.

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Chapter 6

General Discussion

Storybook apps are recommended for parents and educators.[1] However, there is no agreement on which apps should be recommended. On the one hand, interactive apps are praised. On the list 'Best Book Apps for Kids'[2] of Common Sense Media, a nonprofit organization in the United States, all the narrative English language story apps are highly interactive, while only about half of them include multimedia features. On the list of 'The 5 Nicest Apps for Young Children'[3] published by Mijn Kind Online, the apps *Pim en Pom* by Fiep Amsterdam B.V. and *Bobbi naar de Dierentuin* by Kluitman are included. The *Pim en Pom* app features some automatic animations that are not related to the story. The app *Bobbi naar de Dierentuin* includes both a non-interactive multimedia and a print storybook version of the story. In the multimedia version the story can be interrupted by clicking on the icons for games in the menu. It is notable that in some lists electronic stories that are most similar to traditional print storybooks are promoted. 'The Best Free Apps for Children' list[4] of Kennisnet includes three story apps for kindergarten-aged children without animation or interactive features.

Award-winning apps are also interactive, often including irrelevant elements during the story. For example, the app *Noa's Sterren* by Hanneke van der Meer offers visual and sound effects as hotspots that are not related to the story (Media Ukkie Award 2014), the English-spoken *Little Red Riding Hood* app by Nosy Crow features small games in every scene like collecting visual elements in the basket of Little Red Riding Hood (The Best Book Awards 2014 in the category 'Best Tech Stuff'), or the app *Cinderella* by Nosy Crow includes little games like choosing Cinderella's dress or the music at the ball (FutureBook Innovation Award 2013 in the category 'Best Children's Digital Book'). On the other hand, a report from the Joan Ganz Cooney Center warns against the detrimental effects of enhanced, highly interactive storybook apps for parent-child co-reading and children's story comprehension, and promotes "basic" electronic books with fewer extra features (Chiong, Ree, Takeuchi, & Erickson, 2012).

1 http://www.pbs.org/parents/childrenandmedia/article-how-to-choose-iphone-apps-for-kids.html

2 https://www.commonsensemedia.org/lists/best-book-apps-for-kids

3 http://mijnkindonline.nl/artikelen/de-5-leukste-apps-voor-jonge-kinderen

4 http://www.kennisnet.nl/fileadmin/contentelementen/kennisnet/Dossier_mediawijsheid/Publicaties/Brochure_de_beste_gratis_apps_voor_kinderen.pdf

Pros and Cons of Technology-Enhanced Stories

Interactive features are more widespread than multimedia elements in today's story apps (Guernsey et al., 2012). Some interactive storybook apps use the original artistic illustrations of famous storybooks in addition to nicely designed interactive features that can be appealing even for adults like in the apps *De Geweldige Vliegende Boeken van Meneer Morris Lessmore* by Moonbot Studios LA or the *Alice for the iPad* app by Atomic Antalope. These apps give the impression that they are high-quality books and optimal learning materials for young children. It is not surprising that parents and educators select those for educational purposes.

The results of the present thesis provide empirical evidence for the learning benefits of multimedia stories but they do not support the current trend of highly interactive electronic stories. Chapter 2 reviewed the literature on research with electronic stories as compared to print storybooks and found distinct patterns in the results. Studies with electronic books including multimedia and interactive features that are not tightly connected to the story showed negative results. On the other hand, digital stories with congruent multimedia and interactive features (e.g., dictionary function or questions and feedback provided by a computer tutor) were found promising. This differential pattern was explained by young children's limited cognitive control and inability to multitask, which is required in the case of incongruent features.

From a quantitative synthesis of the currently available empirical evidence in Chapter 3 it appeared that the technological transformation of stories can be beneficial. Similar to Chapter 2, multimedia stories were found to facilitate children's story comprehension and word learning more than print storybooks. Multimedia elements were even found to have comparable benefits as support from an adult while reading print storybooks for children's cognitive development. This appeared from a meta-analysis reported in Chapter 4. However, multimedia stories cannot replace the benefits of parent-child shared reading activities on children's social-emotional development.

Outcomes for interactive stories differed. Interestingly, even features that were relevant for the story were not found helpful. In fact, interactive features seemed to decrease the benefits of multimedia additions on story comprehension and expressive vocabulary. Results were especially articulated for groups of children who are growing up in disadvantaged and less stimulating environments and might lag behind in language development.

The benefits of animations for children's comprehension was further confirmed in an experiment reported in Chapter 5. It was found that children's attention is more focused on the moving details when looking at animated illustrations as compared to static pictures. Thus, the mechanism for the advantage of animated illustrations seems to be due, at least partially, to the capability of motion to guide children's attention to details of the illustrations that depict the narration. When animation in pictures attracts attention to details that provide a more precise and timely depiction of abstract language children understood the story better.

Guidelines for Optimal Electronic Stories

Based on the empirical evidence that is available at this point and on the results of the present thesis the following guidelines are proposed for designers of children's electronic stories and for parents and educators selecting optimal learning materials.

1. Animated illustrations and the inclusion of sound and music effects to illustrate the story are encouraged. Such automatic multimedia additions were found very beneficial, especially for children who lag behind in language development. Multimedia elements should be congruent with the story both in terms of the content and in time, that is, they should illustrate the text of the story at the same time as it is read aloud. These parameters make the multimedia additions optimal for learning. Additionally, enabling options to turn off some of the multimedia features like the background music (e.g., in the app of *De Geweldige Vliegende Boeken van Meneer Morris Lessmore*) might cater for special groups of children such as the ones experiencing problems with perception of speech (Smeets, van Dijken, & Bus, 2014).
2. Multimedia seems to have the same effect as adult support during book reading. It seems to guide children's attention while looking at illustrations just as an adult does by pointing and commenting during shared reading.
3. More specifically, animated details in illustrations seem to be a powerful tool to direct children's attention to different parts of the illustration. They can be designed to guide children to select the visual details that help to understand the story text, as was done in Chapter 5. However, incidental or decorative movements in the illustrations are predicted to interfere with story comprehension.
4. Interactive features such as hotspots and games, as appealing as they might be, should be limited. Such elements were found to overwhelm children and have detrimental effects for children's story comprehension and word learning. With an abundance of interactive features children are likely to ignore the narration and only play with the hotspots and games (de Jong & Bus, 2002). The option to "turn the pages" might allow children control over the pace of the story, however, most likely it enables them to rush through the story looking for games and hotspots.

5. In Chapter 3 even the interactive features that are related to the story or language skills like a dictionary were found unhelpful. It is therefore advised against the inclusion of 'educational' interactive features. Young children do not have sufficient inhibitory and attention control to keep switching between interaction with such features while listening to a story. It is worth noting that when small animations and sound effects illustrating the story are available in the form of hotspots, in contrast to automatic multimedia features, they mostly do not appear at the same time as the oral narration. This probably renders them less optimal for dual coding and fostering comprehension.
6. Instead of disturbing the story line, hotspots and games might be better offered after children listened to the story. For example, some interactive storybook apps like the app *Pinokkio* by Chocolapps SAS include different modes including an "autoplay" option that plays the story automatically without enabling interactive features. It is plausible that the extraneous material of hotspots and games that are relevant to the story provides helpful additional learning opportunities if they are not presented simultaneous to the story. However, there is a serious risk that children never choose the Read a story option and always prefer the play mode (e.g., de Jong & Bus, 2002).
7. Since research on the effects of a digital tutor providing questions and feedback in electronic storybooks is scarce it was only superficially discussed in the present thesis. However, results are promising and it seems that a tutor, instead of being a distraction, might make children more attentive just like an adult during shared book reading (Plak, Kegel, & Bus, 2015).

Conclusions

In sum, interactive features such as hotspots and games, although making apps attractive, were not found to be beneficial for young children's story comprehension. In fact, they require children to keep switching between the story and the interactive element and, as a result of that, they interfere with story understanding and language learning. The results of the present thesis do not support the educational value of the current trend of highly interactive storybook apps. Interactivity might be helpful in the case of educational games like alphabet games (Kegel, van der Kooy-Hofland, & Bus, 2009; Kegel & Bus, 2012) but listening to a story requires a lot of cognitive effort from young children and any additional activity seems to distract them.

Multimedia features like animation, zooming, music and sound effects closely illustrating the story, in contrast, were shown to facilitate children's understanding of the story probably by depicting and concretizing the abstract language and directing children's attention to key details in the illustrations. Such nonverbal information was found to be especially helpful for children who are experiencing problems understanding the story line and language due to a language delay. Multimedia additions seem to support the creation of well-integrated, deep and meaningful mental representations.

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APPENDICES

Appendix A: Search terms for electronic database search

(literacy OR “emergent literacy” OR “early literacy” OR reading OR “early reading” OR “beginning reading” OR language OR vocabulary OR “story comprehension” OR “story retelling” OR attention OR engagement OR attitude) AND (computer OR technology OR e-book OR eStorybook OR digital OR CD-ROM OR multimedia OR multimodal OR “talking book” OR “electronic book” OR “living book” OR “living storybook” OR “dynamic book” OR animated OR animation OR video OR software OR tablet OR iPad OR television) AND (storybook OR book OR “picture storybook” OR narrative OR narration OR story OR stories) AND (children or kindergartner or preschooler)

Appendix B: Reference list of hand-searched books

Bus, A. G., & Neuman, S. B. (Eds.). (2009). *Multimedia and literacy development: Improving achievement for young learners.* New York, NY: Taylor & Francis Group.

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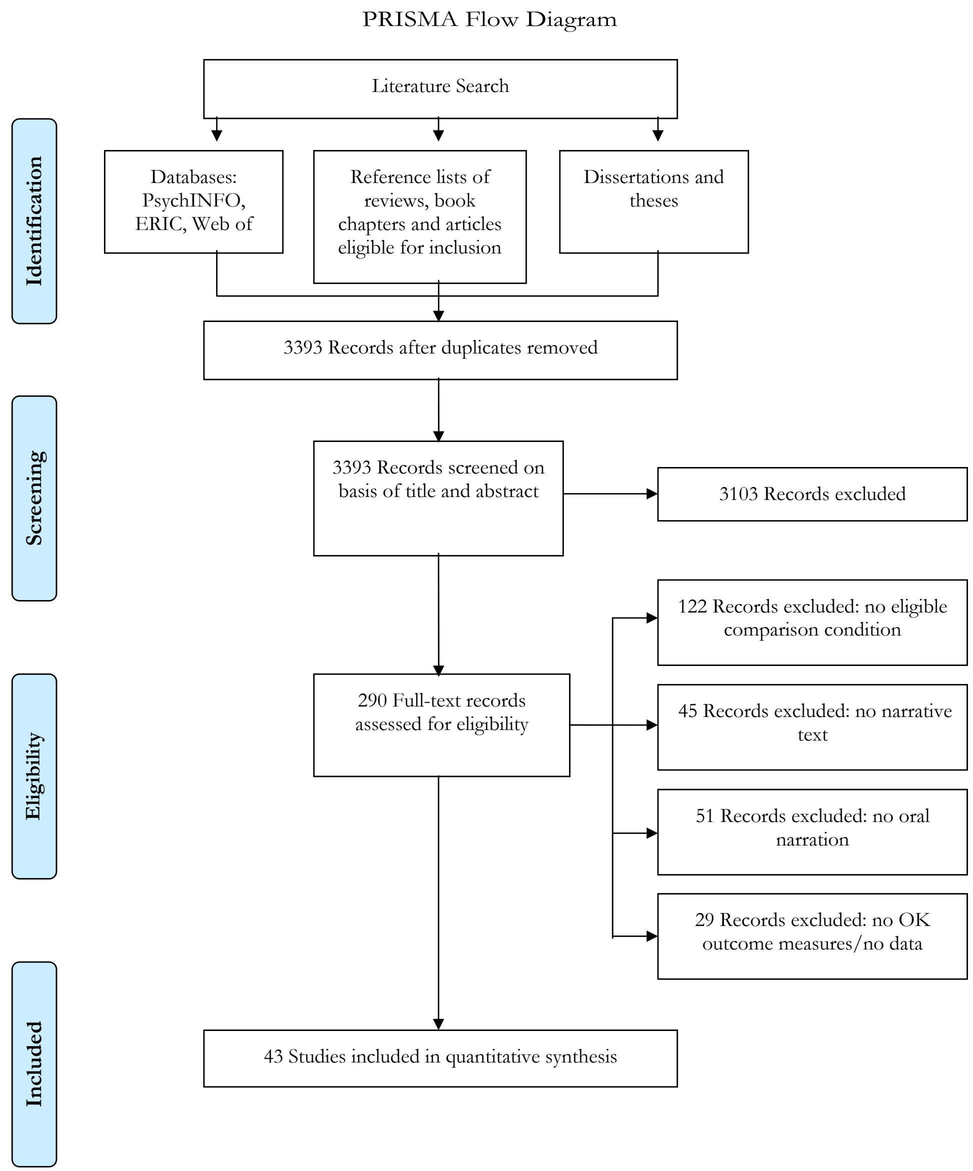
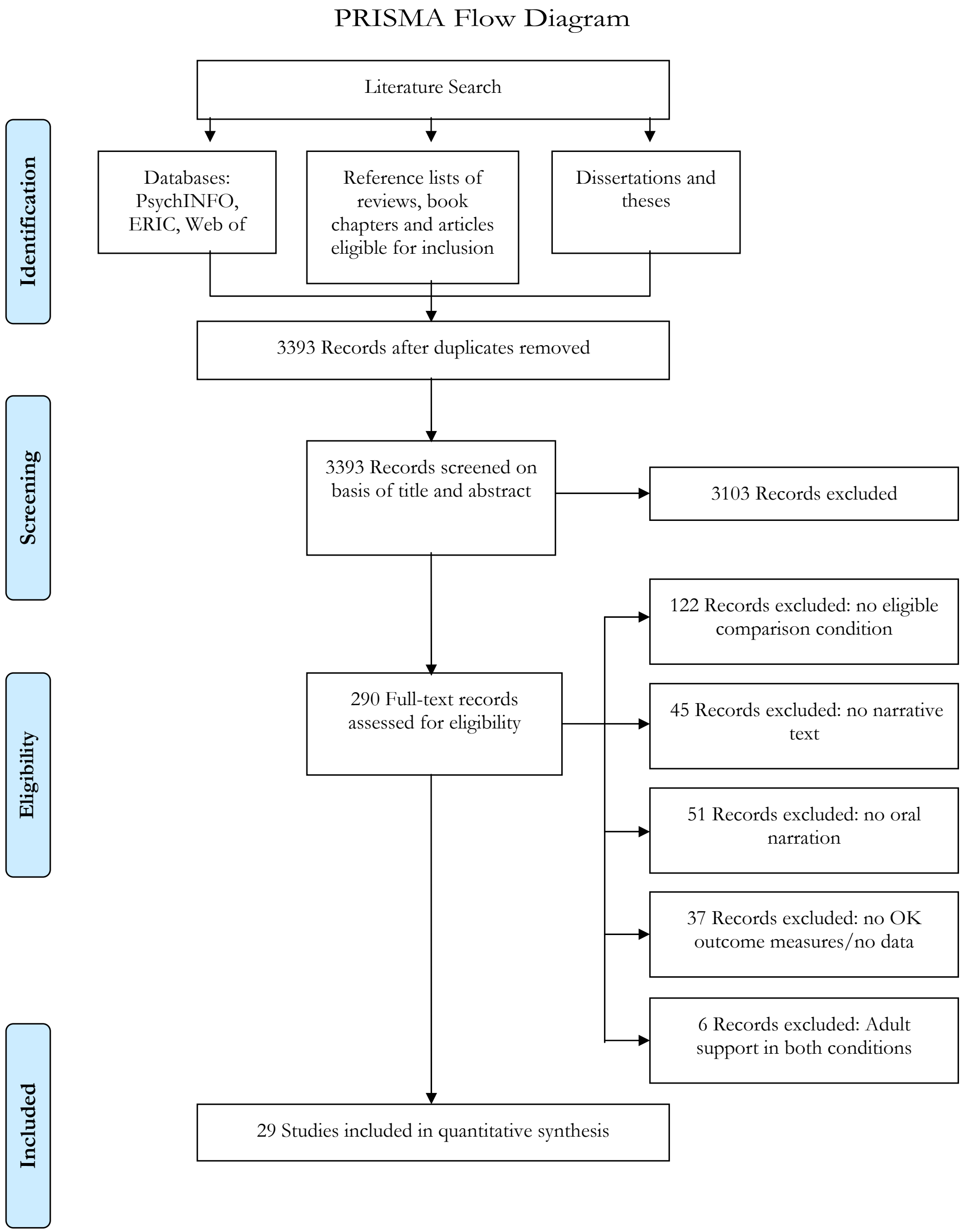
Appendix C: PRISMA diagram of the literature search (Chapter 3)



Appendix D: PRISMA diagram of the literature search (Chapter 4)



Appendix E: List of target words per book

Book	Original word (verb)	Non-word used instead of the word	The number of times the non-word mentioned in the text
Bear is in Love with Butterfly			
	to write (schrijven)	'drimmelen'	2
	to play (spelen)	'beteenen'	2
	to fan (aanwakkeren)	'blukkeren'	1
Imitators			
	to walk (lopen)	'aaften'	2
	to jump (springen)	'trinnen'	2
	to bang (bonken)	'tronkten'	1
The Little Kangaroo			
	to flutter (fladderen)	'zoofen'	2
	to run (rennen)	'pirten'	2
	to follow (volgen)	'goegen'	1

Nederlandse Samenvatting[1]

In *Noa's sterren* botst het personage Ida tegen de sterren aan. 'Oh, oh. Al die mooie sterren vallen naar beneden,' leest een stem gelijktijdig voor.

Er verschijnen steeds vaker 'voorleesapps', digitale prentenboeken, zoals *Noa's sterren* van Hanneke van der Meer. Naast het verhaal in gesproken vorm en geanimeerde illustraties bevatten ze vaak spelelementen. Bijna elk detail in de illustraties reageert op aanraking, zoals een ster die oplicht als je er een keer op tikt.

Maar wat is het effect van deze 'levende boeken' op verhaalbegrip? In hoeverre kunnen ze bijdragen aan de taalontwikkeling van kinderen? En zijn ze door hun extra functies beter of juist slechter dan gewone prentenboeken?

Wij verzamelden al het onderzoek naar digitale prentenboeken in het kader van het PROO-aandachtgebied *Creating and Implementing Technology for Early Literacy.* In maar liefst twintig studies werden multimedia-boeken, digitale verhalen met multimedia (geanimeerde illustraties, achtergrondgeluiden en muziek) vergeleken met 'gewone' voorleesverhalen.

In alle studies bleken de multimediafuncties van apps een verrijking: kinderen scoren beter wat betreft het verhaalbegrip en de woordenschat dan wanneer zij worden voorgelezen uit prentenboeken met statische illustraties. Ook bleek dat van alle kinderen de taalzwakke kinderen het meest profiteren. Op basis van taal alleen begrijpen zij het verhaal niet maar met alle extra non-verbale informatie slagen ze daar wel in.

We vonden zes studies met enkel interacties. Interactie houdt in dat een kind door het aanraken of verschuiven van dingen een effect oproept dat soms wel maar vaak geen of slechts zijdelings verband houdt met het verhaal. Digitale boeken met enkel deze optie bleken het verhaalbegrip juist te verminderen, zij het licht.

Eén ding tegelijk

De meeste apps hebben echter, net als *Noa's sterren*, beide: zowel interactie als multimedia. We vonden achttien studies waarin zulke boeken met gewone voorleesboeken vergeleken zijn. Wat blijkt? Interactie doet het positieve effect van multimedia teniet. Als kinderen tijdens het voorlezen kunnen spelen met details in de plaatjes, begrijpen ze minder van het verhaal dan bij gewone voorleesboeken. Hun woordenschat neemt niet meer toe dan bij gewoon voorlezen.

Het is voor de taalontwikkeling dus niet gunstig als een voorleesapp kinderen met meerdere dingen tegelijk confronteert. Dat lijkt ook in algemenere zin waar: vermoedelijk hebben jonge kinderen nog meer moeite met multitasken dan volwassenen. Hun 'executieve functies' zijn nog onderontwikkeld: ze slagen er minder goed in om hun aandacht te sturen en zo de negatieve effecten van multitasking te verkleinen.

Geanimeerde illustraties, achtergrondgeluid en muziek kunnen daarentegen het verhaalbegrip ondersteunen en helpen om nieuwe woorden te leren. Zij maken voorlezen met apps zelfs veel effectiever dan gewoon voorlezen. Let dus bij het uitkiezen van een voorleesapp goed op of de app (uitsluitend) deze functies bevat.

[1] Gepubliceerd in *Didactief*.

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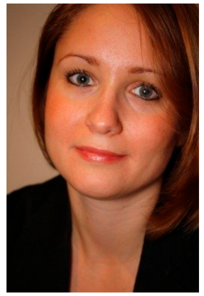
Curriculum Vitae



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List of Publications

Bus, A. G., Takacs, Z. K., & Kegel, C. A. T. (2014). Affordances and limitations of electronic storybooks for young children's emergent literacy. *Developmental Review*. doi:10.1016/j.dr.2014.12.004

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