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Reading with hotspots: Young children's responses to touchscreen stories

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ABSTRACT

Worldwide estimates indicate that toddlers and preschoolers are introduced to mobile technology at an early age, with many now using touchscreens on a daily basis. One of the appeals of touchscreen technology is that it seems to be intuitive to very young children and, at least from anecdotal evidence, they seem to enjoy it. Even the simplest forms of children's touchscreen media often contain hotspots, which are interactive elements of a screen that allow children to touch a picture and obtain an immediate visual and/or auditory response. Despite the fact that children seem to engage haptically with these technological features, little is known about how they use them and how these features may influence their attention to and comprehension of the media content. A detailed understanding of children's verbal and haptic responses, as well as their visual attention and comprehension, is key to gaining a more complete understanding of children's use of this medium. Using an experimental design, in this pilot study, we examine Dutch preschoolers' (age 2–5, n = 78) haptic use (how much and when they use hotspots), verbal responding (i.e., narrative relevant and irrelevant comments), attention, and story comprehension when hotspots are either activated or turned off. Implications for the use of touchscreen media in early childhood, as well as the design of such media, are offered.

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As the debate continues about how, and whether, digital technologies fit in the lives of young children, adoption of these technologies, including smart phones, tablet computers, and game consoles, continues at a rapid pace (Common Sense Media, 2013). In 2006, Rideout and Hamel (2006) found that 91% of American children aged 2 to 3 consumed screen media at least several times per week, with the frequency and duration of use increasing throughout the preschool years. By 2011, children under 2 had an average of 53 min daily of screen time (Common Sense Media, 2011), and by 2013, this number had increased to 58 min for children under 2 and 1:58 for children 2–4 (Common Sense Media, 2013). These increasing numbers are due, in part, to the increased presence of mobile technology in young children's lives. In 2011, for example, 52% of parents reported that their young children use one of the newer forms of mobile media such as a smartphone, a video iPod, or a tablet device (Common Sense Media, 2011), a number that has increased to 75% in the most recent report (Common Sense Media, 2013). Indeed, more recent data with non-representative American samples suggests that children's access to mobile technology may be approaching saturation (i.e., 96.6% of children under 4 reportedly have used mobile devices at home; Kabali et al., 2015). Importantly, these patterns are not exclusive to American children. Estimates from other industrialized countries similarly indicate that toddlers and preschoolers are introduced to mobile technology at an early age, with many now using touchscreens on a daily basis (Holloway, Green, & Livingstone, 2013).

One of the appeals of touchscreen technology, of course, is that it seems to be intuitive to very young children and, at least from anecdotal evidence, they seem to enjoy it. Even the simplest forms of children's touchscreen media, such as e-books, often contain hotspots, which are interactive elements of a screen that allow children to touch a picture and obtain an immediate visual and/or auditory response. Touching a picture of a cow, for example, may result in a mooing sound and some movement in the cow. Despite the fact that children seem to engage haptically with these technological features, little is known about *how* they use them, and importantly, how these features may influence their attention to and comprehension of the content. Although there does exist some previous work with children's touchscreen use (e.g., Krcmar &

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Cingel, 2014), these researchers examined parent-child reading from touchscreens, looking only at situations in which parents read the story and importantly, focusing solely on stories which mirrored a traditional book in every way except the format (i.e., no hotspots). Yet, many tablet-based children's books include hotspots and, despite this wide availability, little research has looked at how children respond to stories presented on a tablet computer when hotspots are present. In order to better understand the larger issues regarding children's use of various tablet-based content, it is important to obtain a descriptive understanding of how young children interact with tablet-based applications.

To address this gap, in this pilot study we ask how children behave and respond to a story read to them by a tablet computer when that story either contains or does not contain hotspots. Past research has shown that both verbal interaction and haptic responses are key elements in how well children attend to and learn from media including tablet computers (e.g., Krcmar & Cingel, 2014) and television (e.g., Anderson et al., 2000). Thus, a detailed understanding of children's verbal and haptic responses, as well as their visual attention and story comprehension, is key to gaining a more complete understanding of children's use of this new medium. Using an experimental design, we examine preschoolers' (age 2–5) haptic use (how much and when they use hotspots), verbal responding (i.e., narrative relevant and irrelevant comments), attention, and story comprehension when hotspots are either activated or turned off. We utilize the capacity model as a general framework for understanding children's initial processing of touchscreen technology.

1. The capacity model and children's responses to media

Although several theories have been posited to explain children's processing of media, one of the more frequently cited theories is the capacity model. Designed specifically to explain how children extract educational content from television, the capacity model is based on an information processing approach to cognition. The model posits that children have limited cognitive capacity available to process and comprehend information (Fisch, 2000). The capacity of working memory dictates these limits and children, with their necessarily smaller working memory capacity, may easily be overtaxed. Fisch (2000) argues that demands on children's cognitive capacity arise from three areas: the processing of *narrative* or story content, the processing of the *educational* content embedded within the program, and the degree to which the educational content is necessary for or integral to the processing of the narrative. Narrative content is argued to take precedence over educational content such that the amount of resources available for educational content is dependent on the amount of resources not *already* committed to the narrative. Accordingly, Fisch argues that television content can be educational only if the memory system is not overloaded (Fisch, 2004). When the system is overloaded, insufficient processing resources are allocated to the educational material and learning suffers. Thus, according to the capacity model, learning occurs only when the system is not overburdened.

Fisch (2004) argues that the structure of media content can either reduce the amount of processing resources necessary for comprehension, or conversely, increase the amount of resources necessary and potentially overload the cognitive system. For example, research has shown that the inclusion of participation cues in children's television increases the processing complexity of the media content and, on their own, results in weaker comprehension of the educational content (Piotrowski, 2014) while other work has shown that other structural features, such as cuts, zooms or complex formal features, may similarly stress the cognitive system (Krcmar & Cingel, 2014). Although initially developed for educational television, researchers now argue that the capacity model can also be reasonably applied to children's interactive media, including touchscreen stories (Kirkorian & Anderson, 2009). As with educational television, it is expected that children have limited working memory to devote to processing digital story content, and when overloaded, processing (and subsequent comprehension) is expected to suffer. Moreover, as with educational television, it is reasonable to argue that there are structural features which may influence children's responses to touchscreen stories.

2. Structural features and responses to touchscreen stories

Structurally, one of the most relevant features to consider when investigating children's responses to touchscreen stories is the hotspot. Indeed, the very nature of touchscreen technology, and being able to touch or tap pictures and icons in order to experience some immediate outcome, is not only one of the key features that differentiates these screens from other, older technologies but is a feature that makes the screens so intuitively appealing to very young children. These interactive hotspots, designed to elicit immediate visual or auditory responses from the child, are a core feature of many touchscreen stories for children. Yet, their impact on *young* children's responses to the screen remains unknown. To address this gap, in the present study, we examine children's haptic responding, verbal responding, attention, and story comprehension. First, we ask how the inclusion of hotspots may influence frequency and timing of hotspot haptic interaction since such descriptive patterns can provide relevant information as to how young children engage with these features:

RQ1. *For children reading a touchscreen book with active hotspots, what is the frequency and timing of hotspot haptic interaction?*

Following this, we investigate whether the inclusion of hotspots in touchscreen stories may influence verbal responses, attention, and story comprehension.

2.1. Verbal responses

In terms of verbal responses, there is some precedent to suggest that the inclusion of hotspots in touchscreen stories may influence the type of verbal comments (i.e., narrative-relevant comments; narrative irrelevant comments) that occur during reading. Whereas narrative-relevant comments are seen as potential aids for processing stories, narrative irrelevant are more likely to distract processing (Haden, Reese, & Fivush, 1996; van Kleeck, 2003). Thus, while narrative-relevant comments are typically seen as helpful to children's processing of the narrative, narrative irrelevant comments are often seen as more problematic. In previous research, Krcmar and Cingel (2014) found that, when reading a tablet book, parent-child conversations focused less on the narrative content and more on book format and environment. Conversely, when reading a traditional book, parent-child verbal interactions focused more on the narrative of the book. Krcmar and Cingel (2014) argued that the additional cognitive load required by the tablet computer may have influenced parent-child dialogue, particularly decreasing the child's ability to focus upon the narrative content. Similarly, in the present study, it is possible that the inclusion of hotspots may tax children's cognitive load and subsequently results in fewer comments associated with the narrative of the story and instead an increase in narrative-irrelevant comments.

H1. *Children reading a touchscreen story with active hotspots will have fewer narrative-relevant verbal comments than children reading the same story with deactivated hotspots.*

H2. *Children reading a touchscreen story with active hotspots will have greater narrative-irrelevant verbal comments than children reading the same story with deactivated hotspots.*

2.2. Attention

Although little research has examined children's attention to digital story books, substantial research has been done on young children's attention to television. Given that digital storybooks present some moving images and likely provide a similar visual experience as television, it is possible that children's attention to digital storybooks is similar to that of television. Research on structural features of television, such as zooms, cuts, noises, and music, has indicated that these features are among some of the most reliable ways to gain young children's attention (Huston & Wright, 1983). Often referred to as formal features, a host of studies have demonstrated that these program attributes play numerous roles in the viewing process including eliciting orienting responses, marking important content, helping the viewer parse the content, and highlighting content expected to be most comprehensible to the viewer (see Anderson & Burns, 1991 for a review). If indeed attention to touchscreens is similar to that of television, it seems reasonable to posit that hotspots will work similarly to other formal features by eliciting attention to the screen. In other words, books with activated hotspots are likely to elicit children's attention in much the same way that music and cuts/zooms do on a television screen. Therefore we posit:

H3. *Children reading a touchscreen story with active hotspots will have greater visual attention than children reading the same story with deactivated hotspots.*

2.3. Comprehension

In terms of content comprehension from tablet computers, although little work has examined tablet screen hotspots and preschoolers, there are several studies which have investigated the effects of these technologies with slightly older children. Results from these studies have shown, for example, that hotspots which highlight links between letters and their sounds tend to improve children's phonological awareness (Chera & Wood, 2003) and that story comprehension is improved when hotspots focus on the plot (Korat & Shamir, 2007; de Jong & Bus, 2004). Despite these positive outcomes, not all use of e-readers and computer-based reading has found positive effects on comprehension. In their research on parent-child book reading, Krcmar and Cingel (2014) found that there was less book-related talk between the parent and child when using a tablet computer as opposed to a traditional storybook and these differences translated into lower story comprehension among preschool-aged children.

When combining earlier research findings with more recent results, we see a somewhat mixed set of findings for the influence of touchscreen books on comprehension. Essentially, it seems that when adults and *older* children simply read from a screen versus traditional book, little differential effects are evident. For books with interactive hotspots, it seems that well-designed content which appropriately integrates hotspots within the plot can benefit older children, such as those in early elementary school (Korat & Shamir, 2007; de Jong & Bus, 2004). The question is whether younger children (e.g., preschoolers and kindergarteners) may similarly experience such benefits from hotspots. On the one hand, such hotspots may lead to greater working memory allocated to the story content – leading to improved story comprehension. On the other hand, given the comparably smaller working memory of young children (compared to that of older children in other studies), young children may be less equipped to successfully capitalize on these hotspots and, instead, may be distracted by them and ultimately comprehend less of the narrative content. Given that both directions are theoretically feasible with this young audience, we ask:

RQ2. *How do active hotspots influence young children's comprehension of a touchscreen storybook?*

3. Method

3.1. Participants

Parents in medium-sized European city were initially contacted through primary and preschools, asking for permission for their child's participation. A total of 78 children completed this pilot study (n = 36 girls). The average age of the children was 4.90 ($SD = 1.29$). From the parents' sample, the mothers were asked for their educational level. 6.8% reported having completed primary education, 1.4% special primary education, 4.1% lower secondary education (VMBO/MAVO/MULO), 4.1% secondary education (HAVO/VWO), 16.2% vocational education (MBO), 35.1% higher education (HBO) and 32.4% University.

3.2. Design

After receiving approval from the sponsoring institution's Institutional Review Board, a cross-sectional parent survey and between-subjects experiment was conducted. Parents completed a questionnaire sent home to them with their children or sent to them via email, depending on their preference indicated when they signed the consent form. The questionnaire assessed children's birth date, sex, experience with books and technology, parents' own work and education status as well as a number of additional demographic variables to ensure that random assignment worked as intended.

The experimental portion was conducted either in a quiet location in the child care center/school or at home, depending upon parental preference. The study employed a 2 group (hotspots on vs. hotspots off) between-participants design to measure the effect of hotspots on a child's haptic uses of the tablet, children's verbal responding, attention, and story comprehension. Children were randomly assigned to condition. In total, 40 children participated in the no hotspot condition, and 38 in the hotspot condition. Preliminary analyses revealed no significant differences by condition for gender, maternal educational level, child age, technological familiarity, or book familiarity - indicating successful random assignment.

3.3. Procedure

For those tested in a classroom environment, children were met in their classrooms and walked to the quiet testing area. Two research assistants were on hand, one designated as the researcher, who interacted with the child, and the other designated as the recorder who ran the video equipment and organized the research materials. Before the experiment began, the researcher who worked with the child made sure the child felt at ease by asking them simple questions (e.g., what is your favorite color? What is your favorite thing to do at school?) and explaining the project in terms the child would understand. Once the experiment started, the researcher tried to have as little interaction as possible with the child, with the exception of asking the necessary questions. During reading, the second researcher filmed the child over the child's

shoulder so the tablet and the child's hands were visible. In addition, the recorder coded several factors about the child's behavior, including the child's overall attention (see measures section). After the story was complete, the child completed a brief comprehension assessment. The researcher then thanked the child for his/her help and brought the child back to his/her class. For those tested at home, two research assistants arrived at the child's home at a predetermined time. Identical to the classroom procedures, one assistant was designated as the researcher, the other as the recorder. Before the experiment began, the researcher made sure the child was at ease and requested that the parent sit off to the side, out of view of the child and not interact with either the child or the researcher unless the child became distressed. The protocol then proceeded identically to the classroom procedures.

3.4. Stimulus material

In both conditions, children listened to the same story ("Victor Wil Spelen" (Victor Wants to Play) by Mark van Overveld) via the tablet. The story was chosen based on a number of factors: length and appropriate level of narrative complexity for the age group, potential story interest, availability of the story with a hotspot option and without, and availability of the story in English and Dutch, (i.e., the two primary languages of children in the study). In the no hotspot condition, children were instructed to listen to the story. The experimenters made sure the pages were "turned" so the child could continue listening to the story. In the hotspot condition, children were first shown a page of another interactive book on the iPad (i.e., "Meneer Big En Het Gouden Ei" (Mr. Big & the Golden Egg) by Gitte Spee) and the child was allowed to touch and interact with the content. This was done in order to help the child become familiar with hotspots as well as understand that s/he was allowed to touch the pages of the book. For all but 2 of the children, the Dutch version of the books was used. For the two children for whom English was their first language, that version was used.

3.5. Measures

Hotspot use, verbal comments, and attention were measured after the testing was complete via video coding in which two trained coders viewed the recordings and coded for the specific content. Comprehension was measured via a multiple choice questionnaire administered after the book reading was complete. More detail for each variable is provided below.

3.5.1. Hotspot frequency and timing

For each hotspot in the book (n = 46 hotspots), two trained coders recorded the actual number of taps on each hotspot. Krippendorff's alpha indicated high inter-coder reliability (KAlpha $M = 0.98$, Range = 0.85 to 1). In addition to number of taps per page, assistants also coded if children generally tapped each page in one of 4 ways: 1) while the page was being read, 2) after the reading of a page was completed, 3) both during and after the reading, or 4) did not tap on the page at all. Thus, for each child, coders identified when they tapped the hotspots (from among the 4 choices) for each of the 19 book pages. Krippendorff's alpha demonstrated high reliability (KAlpha $M = 0.95$, Range = 0.76 to 1) for hotspot timing.

3.5.2. Narrative comments

In order to assess narrative relevant and irrelevant comments, two trained coders recorded children's verbal comments per page (n = 19 pages), and then, using dummy coding, indicated the comment category. For the purposes of the present study, child utterances were identified as narrative-relevant comments, including comments about the story itself (e.g., "This one is a spider") or questions about the story content (e.g., "Is this a real horse?"), and narrative-irrelevant comments including hotspot related questions and comments (e.g., "Can I push it here?") and interpersonal comments (e.g., "I have to go to the bathroom"). From this data, two variables were constructed for the present analyses: (1) number of narrative-relevant comments which totalled all narrative relevant comments across the 19 pages and (2) number of narrative-irrelevant comments which similarly totalled all narrative irrelevant comments across the 19 pages. Similar coding has been used successfully in other research (Krcmar & Cingel, 2014). Krippendorff's alpha indicated high inter-coder reliability for the variables (KAlpha $M = 0.99$, Range = 0.98 to 1).

3.5.3. Attention

Two trained coders evaluated children's attention to the book using a single measure that asked how attentive the child was to the story. Specifically, coders were asked to rate "how much attention did the child have for what was happening in the story" on a 5-point scale ranging from very little attention (coded as 1) to a lot of attention (coded as 5). This item was adapted from self-report versions of attention that have been used successfully in research with older children (Bordeaux & Lange, 1991; Field & Anderson, 1985). Krippendorff's alpha indicated high inter-coder reliability (KAlpha $M = 0.84$, Range = 0.79 to 1).

3.5.4. Comprehension

Each participant completed the narrative content comprehension assessment after viewing the testing stimuli. The assessment was designed to measure recall of central story elements. To create the assessment, procedures developed by Collins (1970) were followed (see Piotrowski, 2010 for details). A total of 10 multiple choice questions were analyzed (e.g., "Which animal wanted to play with Victor?"). Response options were pictorially represented (e.g., "the spider, the cat, or the mouse"). Correct answers received one point while incorrect answers received zero points. Composite scores were created with higher scores reflecting greater comprehension ($M_{\text{central}} = 7.86$, $SD = 2.90$, Range = 0.0 to 10.0).

4. Results

4.1. Frequency and timing of haptic use (RQ1)

Research question 1 posited a description question – asking how children in the hotspot condition use these features. All told, children utilized the hotspots with great variability, ranging from 7 to 223 times during the session, with an average of nearly 88 touches across all of the hotspots in the book ($M = 88.2$; $SD = 55.8$). In addition to examining the frequency of hotspot use, we also examined when they used them. Children used the hotspots most often (51.9% of the time) after the page reading was completed; whereas children tapped hotspots during reading only 6.6% of the time. They tapped the hotspots both during and after reading 14.6% of the time and children did not tap at all 26.9% of the time.

In order to more clearly consider whether children played with hotspots *while* the story was being narrated or listened to the story without hotspot interruption, we collapsed the data further. Specifically, a child was considered listening without interruption if s/he was coded as not tapping at all on a given page or tapping only after the story page was completely read. A child was considered listening *while* tapping if s/he was coded as tapping while the book was being read and after it was read. Thus, across each of the 19 pages children primarily listened without interruption a majority of the time (79%, n = 525 pages across the sample) and tapped while listening the remainder of the time (n = 140 pages across the sample).

4.2. Narrative comments (H1 & H2)

Hypothesis 1 posited that children in the hotspot condition would have fewer narrative-relevant comments than their peers in the non-hotspot condition while hypothesis 2 posited that children in the hotspot condition would have greater narrative-irrelevant comments than their peers in the non-hotspot condition. To test study hypotheses, the Mann-Whitney test was used to compare performance between conditions. Given the non-normality of these variables, this nonparametric alternative was a more appropriate than traditional parametric procedures. The effect size *r* is provided alongside the results of the Mann-Whitney tests.

Overall, any comments – narrative or non-narrative – occurred very infrequently. On average, children made slightly more than one narrative relevant comment during the session ($M = 1.37$, $SD = 2.45$, $Min = 0$, $Max = 11$) and similarly, slightly more than one narrative irrelevant comment during the session ($M = 1.52$, $SD = 2.59$, $Min = 0$, $Max = 12$). There was an effect of condition on total narrative-relevant comments with children in the hotspot condition making significantly greater narrative-relevant comments ($M = 1.97$, $SD = 2.85$, $Mdn = 1.0$) than their peers in the no-hotspot condition ($M = 0.80$, $SD = 1.86$, $Mdn = 0.0$), $U = 532$, $p = 0.01$, $r = -0.29$. Hypothesis 1 is thus rejected. For hypothesis 2, there was also an effect on narrative-irrelevant comments with children in the hotspot condition ($M = 2.76$, $SD = 3{,}17$, $Mdn = 2.0$) again making significantly greater comments than their non-hotspot peers ($M = 0.35$, $SD = 0.89$, $Mdn = 0.0$), $U = 359$, $p < 0.0001$, $r = 50$. Hypothesis 2 is thus supported.

4.3. Attention (H3)

Hypothesis 3 posited that children in the hotspot condition would demonstrate greater attention than their peers in the no hotspot condition. As the visual attention variable deviated significantly from a normal distribution, the nonparametric Mann-Whitney test was used to evaluate this hypothesis. The effect size *r* is provided alongside this statistic. Results indicate an effect of condition on attention such that children in the hotspot condition demonstrated less attention ($M = 3.36$, $SD = 0.96$, $Mdn = 3.0$) than children in the no hotspot condition ($M = 3.80$, $SD = 0.91$, $Mdn = 4.0$), $U = 282.5$, $p = 0.03$, $r = 0.28$, rejecting hypothesis 3.[1]

4.4. Comprehension (RQ2)

The second research question guiding this study asked whether and how central story comprehension (i.e., recall of central story points) would differ between study conditions. Given the skewness of this variable, the non-parametric Mann-Whitney test was used to evaluate this research question alongside the effect size *r*. Results indicate no effect of condition on comprehension with children in both groups recalling the majority of central story points (average of 78% correct overall). Children in the hotspot condition ($M = 8.02$, $SD = 2.74$, $Mdn = 9.0$) performed similarly to their peers in the no hotspot condition ($M = 7.70$, $SD = 3.06$, $Mdn = 9.0$), $U = 737.5$, $p = 0.82$, $r = -0.02$.

5. Discussion

More than ever before, young children are coming in contact with touchscreen technology as part of their daily lives. Popular rhetoric as to the opportunities and consequences of this technology remains decidedly mixed. On one hand, there remain a camp of concerned individuals who fear that touchscreen technology may displace other cognitively-rich activities (e.g., reading, physical play). On the other hand, there is also a belief that – by virtue of its interactive nature - touchscreen technology may provide an engaging and cognitively-rich experience. Indeed, at the time of this writing, the American Academy of Pediatrics is currently revisiting its stance on the appropriateness of touchscreens for very young children as pediatricians are beginning to note that touchscreen technology may be more analogous to construction toys like blocks than other more passive activities (e.g., television viewing) thanks to its reactivity, interactivity, tailorability, progressive nature, and ability to facilitate social connections (Christakis, 2014). While this popular rhetoric certainly voices both sides of the debate, the empirical evidence as to children's experience with this technology still remains relatively thin. At a basic level, it is useful to understand whether and if the interactive elements that are typically found within touchscreen technology do influence children's experience with the technology. To that end, in this pilot study, we evaluated the extent to which children utilize aspects of the technology (e.g., hotspots) and how they do so. Furthermore, we considered how the inclusion of hotspots in a touchscreen story influenced young children's verbal and non-verbal responding as well as their attention and story comprehension. Results indicate that children do experience a touchscreen book in qualitatively different ways depending upon the inclusion of hotspots, although not always in the hypothesized direction. Interestingly, this experience neither translates to clearly superior nor clearly inferior story comprehension.

Assessment of children's verbal and nonverbal responding to media often yields a lot of data. In examining the pattern of results, several findings emerge. First, and perhaps most prominently, children in this study simply did not make a lot of comments in either condition, averaging fewer than 3 comments per session. This is contrary to past research (Krcmar & Cingel, 2014) where children read from a tablet or a traditional book with a parent. It is likely that in this study, children did not see it as their role to speak with the relatively unfamiliar experimenter, an experience that clearly differs when children read with parents or other familiar adults. That said, of the comments children did make, their verbal responses were significantly greater when using the storybook with activated hotspots. Initially, we hypothesized that this would only be true of irrelevant-verbal comments. However, our results show that children in the hotspot condition simply commented more in general – with significantly greater irrelevant *and* narrative relevant comments. While the number of comments were relatively low overall, the effect size is reasonably robust suggesting that the addition of hotpots invites additional comments from young readers during the reading session. Perhaps by increasing interactivity, children begin to perceive the reading event as interactive, even if they are reading with a relative stranger. Krcmar and Cingel (2014) also found that children commented more while being read to from a tablet computer, as compared to reading an identical book in traditional format, but they found this to be true only for narrative irrelevant comments, and not for those related to the narrative. Thus, children's frequency and type of comments may be related to elements of the technology (such as hotspots) as well as factors related to the reading environment itself, such as who is reading and in what environment. The occurrence of helpful, narrative relevant comments are likely a result of an ideal technology in an ideal location being presented by an ideal interlocutor.

Beyond verbal interaction, we also investigated non-verbal behaviors via both haptic use and attention. In our data, it was clear that – if children were given the ability to interact with hotspots – they certainly used them. Although there was quite some variability

[1] This analysis is based on an adjusted sample size as attention data were not available for some children due to difficulties with the video recording equipment.

in terms of the extent and depth of this use, children tapped the hotspots nearly 88 times on average during the course of one book-reading session. When one considers that the book was only 19 pages in total, it seems reasonable to conclude that this particular touchscreen book elicited a good deal of engagement from these youngsters in terms of their haptic use. Of course, it may be the case that this sort of 'engagement' could distract children from the story itself. Indeed, many concerns that are voiced about hotspots in touchscreen stories are based squarely on the potentially distracting nature of this content.

Our results are somewhat mixed as to whether these hotspots were distracting. In part, this has to do with how we interpret the results for attention and comprehension. On the one hand, we looked at attention – in this study, a construct measured by a coder's overall assessment of 'how much attention the child had for what was happening in the story'. Here, we expected that hotspots would solicit greater attention to the story (akin to formal features in television). Results suggest the opposite with children in the deactivated hotspots condition reportedly having greater attention for the story content. In this vein, one might interpret the findings as suggesting that the haptic use encouraged by the hotspots was ultimately distracting.

On the other hand, consider our findings for comprehension. The comprehension task – designed to assess recall central narrative elements – suggests a different point of view. Here, we see no significant difference in performance between children in the hotspot and no hotspot condition. This finding, counter to the interpretation for attention, suggests that the hotspots did not distract from the core attributes of the narrative (nor did they serve to enhance this content). As such, while the hotspots were certainly used to a great extent when activated, and while the presence of hotspots did seem to increase the amount of narrative relevant and narrative irrelevant conversation, this ultimately did not translate to any significant differences in comprehension. Indeed, comprehension was quite high in both conditions.

The reasonable question, then, is whether hotspots should be encouraged or discouraged in the use of touchscreen storybooks for young children. In truth, it is too soon to tell. This pilot study only scratches the surface of the types of questions that can and should be asked. But, the difference between 'attention' and 'comprehension' findings is worth considering for a moment. We know from a large body of research on children's learning from media that attention is a necessary prerequisite for comprehension. You cannot comprehend what you do not attend to. And yet, here we see that children in the hotspot condition were coded as being less attentive to the story and yet recalled the same amount of content as their no-hotspot peers. What might explain this? It seems that this is most likely a measurement problem, namely a problem with the validity of our attention measure. In this study, we asked the data collectors to assess how attentive the children were during the reading session. It is possible that data collectors (and reliability coders) interpreted the increased physical movement (i.e., haptic responses) and talking (i.e., verbal responses) as indicative of being less attentive to the storyline. Considering that children in the hotspot condition largely listened to the story without haptic interruption (80% of the time), and considering that nearly half of all verbal responses from children in hotspot condition were relevant to the narrative, asserting a validity problem with the attention measure seems reasonable.

With the caveat of the attention measure in mind, these findings reflect an interesting picture. Children reading the touchscreen storybook with activated hotspots had a qualitatively different experience than children who listened to the same book with deactivated hotspots. Children listening to the story with the activated hotspots were quite engaged with the hotspots in the story, touching the hotpots very frequently. Along with this, they made more narrative relevant and narrative irrelevant comments than those children reading with no hotspots (although averages in both conditions were low). On the other hand, children who listened to the story without hotspots were quite docile in their reading session. These children appeared to listen carefully to the story, with far less physical movement (as the story did not call for interaction) and less verbal commentary. Yet, despite these qualitatively different experiences, both groups ultimately performed very well on comprehension of the central content of the storyline with no significant difference detected between groups. One possible reason for this is that children in the hotspot condition tended to use the hotpots much more frequently (if they did at all) after the narrative was completed for a given page.

Does this mean that hotspots should be encouraged in touchscreen stories? After all, it would seem that the hotspot condition offered a more enjoyable experience to its young viewers and, in doing so, may be more likely to encourage repeat usage-which in the case of early literacy skills is certainly a positive behavior. However, it is unclear if this advice is yet warranted. A larger sample size would have allowed us to test if the use of hotspots *during* the reading of the narrative helped or hindered children's comprehension, which is an important question which we were unable to answer with this dataset. Such information would allow for more conclusive advice concerning hotspots in tablet books. Perhaps what we can suggest, given the great variability in the children's use of the hotspots and also when they used them, is that digital storybook creators should try to ensure that hotspots can be deactivated so that parents (or even children themselves) can determine what best meets their unique needs.

5.1. Limitations and future research

Several limitations are worth noting in this exploratory work. First and most notable, the sample size was small and certainly not random. Inherent in that are any of the problems that arise from smaller samples, most importantly lowered statistical power. Although the findings are intriguing and suggest that children respond to and use stories differently based on features such as hotspots, the findings should be replicated with a larger sample. Furthermore, the sample was also drawn from one city in the Netherlands, thus generalizability is limited. Lastly, it would be valuable to replicate this study in a more naturalistic environment, perhaps with parents and children co-reading as opposed to children reading with a trained data collector, as such naturalistic data may highlight patterns that this less naturalistic approach might have obscured.

In addition to limitations from the sample, this study also would benefit from other measures of children's processing. Although hotspots themselves might be viewed as a kind of secondary task, the secondary task paradigm (e.g., having children respond to a buzzer each time it goes off while the story is being read) may offer a closer look at their attention and processing. Certainly examining how the presence of hotspots may influence their attention using this additional method may offer more insight into the outcomes under consideration. The stimulus material also presented children with an entertainment story—no educational material per se was embedded in the narrative. Given the full-scale adoption of tablet computers into many schools it is crucial to consider how children use and respond verbally and haptically to tablets when educational information is presented to them. Furthermore, a better understanding of how the timing of hotspot use influences comprehension may allow digital storybook creators to tailor more to children's comprehension needs. For example, hotspots might be activated only after the narrative is complete. In any case,

understanding this first line of children's use: verbal and haptic use, as well as attention and subsequent comprehension, is an important step in gaining a complete picture of the place that tablet computers play in children's entertainment and educational experiences today.

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