How Parents Engage Children in Tablet-Based Reading Experiences: An Exploration of Haptic Feedback

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ABSTRACT
While recent work examines parents and children reading together on tablet computers, the ways in which interactive elements within e-books affect parent-child interaction are not well understood. We examine haptic feedback as a new form of e-book interactivity and analyze how parents and children exploit this dimension when reading together. Results from a laboratory study with 18 parent-child dyads (*N*=36) reveal that participants reading a haptic e-book talked more about the technology compared to those reading a regular e-book, and this additional talk was a way in which parents elaborated the story narrative. Parents reading a non-haptic e-book, however, engaged in higher rates of expressive behavior (e.g., making sounds, gestures). This suggests that haptic interactivity provides a new resource for parents to draw out the story narrative but may also result in less parent expressivity when reading, both of which have implications for child comprehension and literacy.

Author Keywords
E-books; haptics; reading; parent-child interaction.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION
The literature on parent-child interaction during e-reading has increased dramatically, as the percentage of parents who report reading on tablet computers with their young children rose from just 4% in 2011 to 30% in 2013 [19]. E-books can motivate reading among children described as reluctant readers [14] and the addition of electronic hot-spots (e.g., sounds, animations, questions) designed around developmentally-appropriate content can result in positive child outcomes, such as emergent story understanding [5]. These positive literacy outcomes largely depend on parent interaction during the reading experience [6,8,18], however, and the format and type of interactivity within e-books affects the ways in which parents interact with their children [10,12]. Considering the increasing number of parents who read e-books to their children, it is important to understand how different forms of e-book interactivity influence the parent-child reading experience. Therefore, we examine how parents interact with their children during joint reading experiences while using a novel form of e-book interactivity: haptic (or tactile) feedback. The addition of tactile cues in reading experiences can be especially valuable [2,21] and have the potential to support embodied interaction that aids in learning [22]. In the present paper, we use a TPaD tablet [23] (Fig. 1) to explore the influence of tactile interactivity, compared to a non-interactive e-book, on parent-child interaction while reading. Specifically, we attend to the ways in which parents make use of haptic feedback to engage their children in the reading experience, including how they talk about the technology and their expressiveness in reading (e.g., intonation), both of which have the potential to impact children's comprehension [10,15]. Thus, we contribute new insights into how haptically-enhanced reading experiences influence the parent-child reading interaction and discuss the implications of using this novel form of interactivity to promote literacy development.

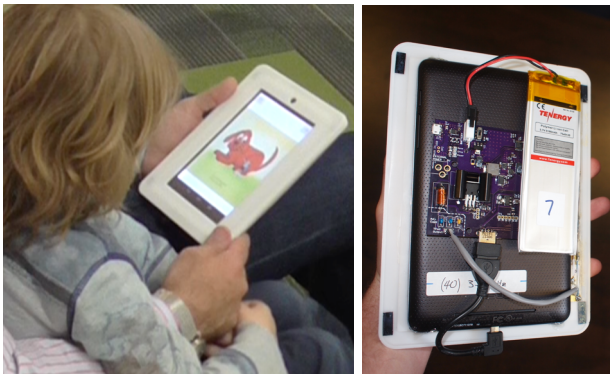

Figure 1. *Left*: TPaD Tablet device. *Right*: tablet mounted with circuit board, actuators, and battery (back cover removed).

RELATED WORK
Parent-child joint media engagement can promote feelings of closeness among parents and children [17] and can also promote verbal interaction and language development (e.g., [13]). When reading books with children, parents ask questions, provide responses, and discuss content [6]. This type of parent-child talk is also characterized by greater lexical diversity and more complete syntax [9]. Extra-textual exchanges that occur around the actual words of the book can

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also help to increase children's short-term comprehension and language skills [6,18]. Thus, dialogue about the story, especially the use of evaluations, questions, and answers, is related to children's comprehension.

Considering the relationship between parent engagement in the reading process and children's literacy skills (e.g., [6,11,18]), recent work has begun to focus on parent-child interaction during e-reading experiences. A recent study found that parents and their children talked less about the book content and asked fewer questions about the content when reading an e-book compared to a print book; instead, parents talked more about the format of the e-book, and this increased technology talk was related to lower child comprehension of story content [10]. Another study, however, found that a parent's ability to actively engage their child in the story content was higher among parents who read to their children on a desktop computer compared to those who read to their children using a traditional paper book [12]. Additionally, reading educational e-books with developmentally-appropriate interactivity is associated positively with emergent literacy skills, as such interactivity promotes a parent focus on the reading experience and opportunities to scaffold child learning [9]. These results suggest that the book format, type of interactivity, and level of interactivity can influence parent-child interaction and shape the ways parents engage their children in the reading experience.

The present study extends this prior work while building on the literature on the effects of tactile cues in physical books on young children's reading (e.g., [2,21]). Enhancing e-books with haptic or tactile feedback has the potential to provide a more immersive and engaging reading experience. Prior work that augmented an e-book through a jacket, armband, and sofa with vibration showed initial positive effects of haptic feedback on short-term recall of storybook content among adolescents between the ages of 12-18 [1]. Other work has examined visual enhancement of books through augmented and mixed-reality (e.g., [3]) and joint reading at a distance [17]. While the integration of haptic feedback into e-reading is promising, we have a limited understanding of how parents – given their critical role in their child's reading experience and subsequent literacy development – react to and incorporate interactive haptic features during joint reading.

METHOD

Participants and Procedure

We conducted a laboratory study with 18 parent-child dyads (N=36; children age 4-7). Parent-child dyads were assigned to a haptic e-book condition (n=9 dyads; M(child age)=5.2 years; 4 female children) or a non-haptic e-book condition (n=9 dyads; M(child age)=4.9; 3 female children). All 18 children had experience using a tablet computer to play games, watch movies, read books, etc. One adult participant in the haptic condition had previously used a haptic tablet, although their exposure was minimal, and all other participants had no prior experience with this form of interactivity. A researcher first interviewed each dyad about their experience using tablet computers. Then, the researcher provided parent-child dyads in the haptic condition with a period of exposure to the haptic tablet by allowing them to try out the technology for 5-10 minutes.

The haptic tablet we used in this study is a TPaD Tablet [23], which incorporates a first generation Google Nexus 7™ tablet, a glass sheet with piezoelectric actuators, a microcontroller circuit, and a lithium polymer battery. The TPaD surface generates haptic feedback by changing the friction of the glass surface through high frequency (~35 kHz) and low amplitude (~1 μm) out-of-plane oscillating motion. Varying friction in this way provides the sensation of textures by gripping and releasing the fingertip.

All dyads read the same e-book on a haptic tablet (haptic feedback was disabled in the non-haptic condition). For this study, we selected the popular e-book "Clifford's Good Deeds" based on its age-appropriateness (recommended for grades pre-K through 3, or children age 4-9) and narrative structure. Researchers added haptic feedback to this e-book by working with a team of researchers from child development and surface haptics. We added haptic feedback throughout each page, such as on Clifford, other objects in the scene, the background, and motion lines, following from formative design work reported in [4]. All dyads were instructed to read the e-book as they normally would at home. After reading the e-book, participants individually answered Likert-style attitude statements (5-point scales; 2 = "strongly like/agree" and -2 = "strongly dislike/disagree"; smiley/frowny face scale for children) and answered open-ended questions about their experience.

Data Analysis and Coding

All sessions were video recorded, transcribed, and coded for interaction between the dyad, with the e-book, and with the tablet technology. We iteratively created a coding scheme based on initial review of the data and prior studies of e-book reading behavior [7,10,12]. Members of the research team coded talk for *statements* or *comments* ("He's very big."), *directives* ("Turn the page."), *questions* ("What do you think is going to happen?"), and *answers* ("It went flying."). Each turn of talk was then coded as being about the *story content*, the *reading experience*, or the *technology* (creating 12 unique codes). Specifically, technology-related talk refers to parent-child talk about either the haptics or the tablet computer itself. Additionally, we coded points of interaction that involved increased expressiveness, which we define as the purposeful addition of verbal or non-verbal elements to enhance the story reading experience (e.g., makes sound effects, changes intonation when reading, or gestures). Table 1 provides a listing of all codes with definitions and examples. A second coder independently assessed 20% of the decisions in order to compute reliability (all kappas > .95).

First Level: Type of Utterance
Statement/Comment: declarative utterance ("*Oh boy, Clifford!*", "*He got a little nervous*.")
Directive: telling partner to do something ("*Look at the woman*.", "*Touch the cat*.")
Question: interrogative utterance directed at partner ("*What happened*?", "*What is he doing now*?")
Answer: verbal response to question directed at partner ("*I don't know."*, "*Probably disappointed, too*.")
Second Level: Object of Statement
Story Content: talk about elements of the story or narrative ("*Clifford wants to get the kitty*.")
Reading Experience: talk about reading in general, not specific to story (sounding out words, "*Sit next to me."*)
Technology: talk about the tablet computer or haptics ("*Do you want to touch it*?", "*Look at the screen*.")
Third Level: Verbal and Nonverbal Expressiveness
Expressiveness: purposeful addition of verbal or non-verbal elements to enhance story (intonation changes, sound effects, "*boinga, boinga*", gestures)

Table 1. Coding scheme for parent-child interaction.

RESULTS

Parent-child interaction looked strikingly similar between conditions along several dimensions, following a series of Mann-Whitney U-tests. We observed no significant difference in the amount of time dyads spent reading the e-book (M(haptic)=373.33 seconds (SD=136.30); M(non-haptic)=303.00 (SD=101.84)). Children in both conditions reported similar ratings for enjoyment of this particular story: "How did you feel about reading the story?" (haptic: M=1.22, SD=.97; non-haptic: M=1.44, SD=.88); and "I enjoyed reading this book" (haptic: M=1.56, SD=.73; non-haptic: M=1.56, SD=1.33). There were also no differences between conditions for parent enjoyment: "How did you feel about reading the story?" (haptic: M=1.11, SD=.78; non-haptic: M=.67, SD=.87) and "I enjoyed reading this book" (haptic: M=1.67, SD=.50; non-haptic: M=1.33, SD=.71). Finally, there was no difference in the average number of turns of talk by condition (haptic: M=52.33, SD=23.98; non-haptic: M=40.67, SD=22.81), nor was there a difference in the average number of turns involving *story-related* talk (haptic: M=25.33, SD=12.11; non-haptic: M=25.22, SD=17.89) or *reading-related* talk (haptic: M=8.22, SD=10.72; non-haptic: M=7.67, SD=5.98). However, although the reading experience looked quite similar along these dimensions, results indicated that parent-child interaction differed in two important ways.

Technology-Related Talk

Specifically, dyads in the haptic condition did engage in significantly more *technology-related* talk (U=15.5, p=.02; M (haptic)=18.78, SD=9.44; M (non-haptic)=7.78, SD=7.03). Technology-related talk was distributed across the four categories of talk (statements/comments=51; questions=40, directives=39; answers/explanations=39). There was also significantly more technology talk in the haptic condition compared to the non-haptic condition in three areas: technology statements or comments (U=1.5, p<.001; M (haptic)=5.67, SD=1.93; M (non-haptic)=1.00, SD=1.32), technology questions (U=13.00, p=.01; M (haptic) =4.44, SD=4.10; M (non-haptic)=.78, SD=.97), and technology answers/explanations (U=16.00, p=.03; M (haptic)=4.33, SD=4.61; M (non-haptic)=.44, SD=.73).

The vast majority (93%) of technology-related talk in the non-haptic condition concerned turning pages of the e-book, whereas only 31% of technology-related talk in the haptic condition concerned page turning behavior. Instead, the majority of technology talk in the haptic condition (66%) involved making statements or comments ("*Oh, he does feel smooth.*"), asking questions ("*Can you feel the ground?*"), providing directives ("*That's a motion line, see that motion line.*"), and offering answers or explanations ("*They feel the same.*") related to the haptic experience. In contrast, only 3% of technology-related talk in the haptic condition concerned other elements of the technology (e.g., "*I wonder if we can make the text bigger?*"). Our detailed coding of verbal and non-verbal interaction while reading reveals that parents and children talked about the technology, specifically the haptic feedback, in ways that related back to the story narrative. In fact, parents who read the haptic e-book made use of the haptic feedback in ways that supported, elaborated, and extended the narrative. Similar technology-related talk did not occur among parents who read the non-haptic e-book to their children. For example, parents in the haptic condition discussed textures that illustrate concepts or action in the book. Consider the following excerpt, in which Clifford is attempting to do a good deed by helping collect leaves for a friend but ultimately sneezes and scatters the leaves:

> Child reads: "I didn't know that dry leaves…"
> ((both touch leaves))
> Mom says: "Do they feel dry to you? And scrunchy?"
> Child says: "Yeah"
> ((parent turns page))
> Child reads: "…makes Clifford sneeze!"
> ((both laugh))

On this page, the haptic layer over the leaves sporadically grips the fingertip with contrasting high- and low-friction areas, providing a slightly rough feeling texture. Haptics provide additional sensory information about a scene (e.g.,

Figure 2. Haptic e-book. *Left*: Parent points towards a cat flying in the air and says, "What happened?" to which the child responds by feeling the textured motion path. *Right*: Haptic rendering of book illustration (motion path with flying cat).

Figure 3. Non-haptic e-book. *Left*: Parent reads "Clifford bent the limb down" and gestures downward. *Right*: Parent reads "But his paw slipped" and adds expressive language "Boing!" with an upward gesture to illustrate trajectory of cat flying.

the dry and crackly nature of leaves), which parents brought into discussion of the resulting action (sneezing) and the story narrative. This increase in technology-related talk is interesting in light of prior work that considers technology-related talk during e-reading experiences as a distraction and leading to reduced comprehension [10]. Instead, drawing on the technology as part of extra-textual exchanges may help to increase children's short-term comprehension and language skills [6,11,18].

Additionally, parents and children used the haptic feedback to experience actions that were part of the narrative. For example, a parent calls attention to a cat flying in the air and her daughter feels the motion path in response (see Fig. 2). The motion path on the page in this example has a haptic layer that allows the finger to slide rapidly up the page as it is traced (white areas have low friction). In this example, the mother asked "What happened?" to which the child responded by demonstrating her understanding of the cause and effect sequence by embodying the action of the cat flying along the motion line [22]. Here, the haptics play a role in the dynamic nature of the child's interaction with the story content by allowing her finger to move along a motion line that illustrates a cat flying in the air, which is a key point of action in the story narrative. Thus, parents who read the haptic e-book connected technology talk to the story narrative in ways that seem to promote children's embodied engagement with the content [22]. This is one key difference in parent-child interaction during the reading experience as a function of the presence of haptic interactivity.

Parent Expressiveness

A second key difference between conditions involves the expressiveness (e.g., adding noises, sounds, and gestures) of parents during the reading experience. The vast majority of expressive behavior was contributed by parents, with only three instances contributed by children (haptic=1 child, non-haptic=2 children). Interestingly, there was nearly four times as much expressive behavior among parents reading the non-haptic e-book (48 instances) compared to parents reading the haptic e-book (13 instances) (U=21.00, p=.08). Specifically, parents in the non-haptic condition used more verbal intonation changes, onomatopoeias, and gestures. For example, parents in the non-haptic condition made exaggerated gasping noises at climactic points of the story and changed their intonation to call attention to certain aspects of the story. They added words like "flop", "boom", and "boing" to elaborate the action in various scenes. A couple parents even made spitting noises when Clifford put out a fire with his mouth. While parents reading the haptic e-book may have perceived the haptics as an expressive component of the reading experience, parents in the non-haptic condition felt the need animate the reading experience themselves. Importantly, previous research indicates that parent expressiveness during read alouds is a key predictor of child comprehension (e.g., [15]), while also implicating the role of parent-child engagement [16].

As another element of expressiveness, parents in the non-haptic condition used gestures to illustrate action within the story, such as objects flying in the air or Clifford's movements. Figure 3 illustrates one example of this interaction, in which the parent uses gesture to illustrate Clifford bending a limb down to reach a cat and then expressive language and gesture to illustrate the cat flying through the air. Recall that in Figure 2 the child traced the same motion line, which was augmented with haptics, as a way of expressing action in the story. Here, however, the parent with the non-haptic e-book gestured in a space separate from the display to illustrate this action. While parents in the non-haptic condition used gesture to express action in the story, often doing so away from the display, parents and children in the haptic condition each experienced this action by touching and tracing this movement directly on the display. Thus, haptic interactivity can invite parents and children to embody action coupled to the illustrations.

One reason why parents may have behaved differently in the haptic condition is because they thought the addition of haptics would make the book more "*fun*", "*interactive*", and "*playful*" for their child. One parent said, "*We definitely spent more time looking and studying the page. I think we*

also spotted more details in the illustrations." Other parents thought that having the textures helped to convey more information and that the role of haptics is to help focus the child's attention and "*act as a support for the text*." Finally, another parent stated that the haptics are "*just another sense that they're getting and something that's stimulating them when they're reading and helps them remember*." In summary, parents may have viewed haptics as doing the work of engaging their child in the reading experience, rather than the parent needing to fill this role; however, these behaviors must be studied over time as the novelty wears off.

DISCUSSION AND CONCLUSION

We report results from the first known study of the effects of variable friction surface haptics on joint parent-child reading experiences, which extends prior work on how to design haptic e-reading experiences [1,4]. Our analyses suggest that haptically-enhanced e-book content can foster additional discussion, and although this additional talk is related to the technology, it does not replace other forms of talk that are central to narrative comprehension [6,18]. Instead, parents used the haptic feedback as a way of discussing objects, actors, and actions that related to the story narrative. While prior work conceptualizes technology-related discussion as distracting to the child, thereby taxing their cognitive ability to comprehend the story narrative [10], we found that parents used this type of talk to make connections from what was happening in the illustrations to the overall story narrative. This points towards a deeper consideration of what constitutes technology-related talk, how parents and children use such talk, and the design of interactive elements that help readers extend and discuss the narrative.

In terms of design recommendations, we found that haptic feedback that supported the story narrative (e.g., conveyed action or enriched objects described in the text) seemed to scaffold parent-child dialog best. We observed that parents and children readily accessed and discussed haptic feedback that conveyed literal texture and action within a story. Specifically, haptics can enhance the story narrative by calling attention to characters or objects described in the text. Parents and children brought this additional sensory experience into their discussion of the story: haptic enhancements that directly corresponded to the narrative (e.g., dry leaves, slipping motion) were drawn out in discussion between parents and children. In contrast, haptic elements that had a less direct relationship with the story narrative (e.g., texture on a background) were less central to the parent-child interaction and could be minimized in future versions of haptic e-books.

In both conditions, however, parents played a mediating role in the e-reading experience. Parents in the haptic condition allowed the e-book interactivity to be the expressive component of the reading experience, while parents reading a non-interactive e-book felt as though they had to be verbally or gesturally expressive in order to entertain or scaffold their children's reading experience. This difference has important implications for future studies of child comprehension with various forms of e-book interactivity [15]. Specifically, for children reading alone or parents who may not engage in expressive behaviors, haptic interactivity may prove beneficial for comprehension. However, parents played a key role in directing the child's attention to haptic interactivity and interpreting this feedback in the context of the story narrative. The experience of a child reading a haptic e-book alone might look substantially different from the joint activity observed here. Thus, future work should examine how children make sense of haptic feedback when reading alone, as haptic feedback can be ambiguous and subject to multiple interpretations [4]. Overall, these data suggest that although enjoyment and time spent reading may not differ, haptic interactivity does influence the ways in which parents engage their children in joint reading experiences.

The difference in parent behavior observed in this study resonates with ongoing discussions of how social relations and practices are played out in reading experiences. Rouncefield & Tolmie [20] argue that focusing on one reading format replacing another misses more 'serious' questions of how new reading technology is adapted and routinized within the home as well as the situated nature of reading in a variety of contexts. Here, the multi-sensory and embodied features of reading are central aspects of study and reveal how individuals orient towards each other and the reading medium. Further, the implications of trading off one form of embodied reading (e.g., parent gesture, expressiveness) for a new form of interactivity (e.g., tactile feedback) should be considered carefully. On one hand, parent embodied expressions in the non-haptic condition are decoupled from the visual representation of the book and require the child to connect and interpret between multiple semiotic fields. On the other hand, new multi-sensory representations (e.g., texture) overlaid on story content provide a shared resource for interaction and discussion but may ultimately sacrifice opportunities for generating one's own expressive dialog about the story narrative.

Although our analysis revealed novel findings regarding the nature of parent-child interaction during e-reading experiences, the study does have two key limitations. First, our sample is relatively small and homogenous. It is unclear how the present findings might generalize to children of different ages and in different reading contexts. Second, haptic feedback is a new form of interactivity, and future studies should examine how dyads integrate haptics into the reading experience after longer term exposure. Nonetheless, haptic interactivity provides a promising way of enhancing e-books by offering a resource for parent-child interaction in which illustrations are multi-sensory and invite embodied exploration of content; yet, the addition of such interactivity also has implications for parent expressiveness in reading.

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