

“The girl who wants to fly”: exploring the role of digital technology in enhancing dialogic reading

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1 ABSTRACT

Research suggests that dialogic reading and wordless picture books may improve narrative production and comprehension leading to better school readiness. We aim to understand children’s experiences using a wordless picture book scaffolded by audio prompts. We designed, implemented and assessed the Spring-a-story web app with 35 children aged 3 to 6 in a socio-economically-disadvantaged area in the UK. We sought to comprehend to what extent the application supports children in creating a narrative, and which type of prompts (basic dialogic reading and theory of mind prompts) better support their meaningful responses. Initial findings suggest how children were able to respond meaningfully to prompts and reported high levels of enjoyment of the activity. Furthermore, theory of mind prompts resulted in a marginally higher percentage of meaningful responses and theory of mind language compared to basic dialogic reading prompts. Study outcomes helped to delineate the design space that we shaped into six design challenges that aim to inform the community and guide the future design of tools to support children in independent dialogic reading of wordless picture e-books.

1.1 Author Keywords

Children-Computer Interaction; e-book; dialogic reading; theory of mind; co-reading.

2 INTRODUCTION

Shared storybook reading is popular with young children with emergent literacy skills who cannot yet decode traditional written text. Research has shown that storybook reading can have positive effects on narrative production [57], oral language skills improvement [16], school readiness, and narrative comprehension [34]. Often storybook reading for young children consists of dialogic reading (or co-reading), a comprehension exercise scaffolded by an adult who poses questions and prompts to children while looking at the pictures in the book. However, adults (parents, caregivers, teachers) cannot always be available to engage in this intensive, one-on-one activity with children. Furthermore, some adults may not be comfortable reading to their children because of low levels of literacy. Thus, an alternative reading activity that may have some of the same benefits for children’s language skills involves children using a wordless picture book made mainly

of images without text. These special types of books are used to support children in elaborating a narrative and creating different stories based on the pictures and provide opportunities for children to develop narrative skills that may not be present with traditional books using pictures and text [11].

Our research aims at understanding children's experience creating a story based on a wordless picture book and accompanying e-book prompts. In order to explore this issue, we have designed and developed a digital wordless picture book app enhanced by prompts called Spring-a-story, as research shows that well-designed digital multimedia books can offer valuable scaffolding when features support, rather than distract from, the primary story content [8]. The e-book prompts are intended to support children's creation of a narrative using the wordless picture book. In this way, they mimic some of the characteristics of an adult reader who may engage the child in conversation during storybook reading. Notably, however, the prompt technology explored here plays a much simpler role than a back-and-forth interaction with an adult. Instead, we designed these prompts to spur children's independent narrative building and see this technology as an alternative or supplement to, not a substitute for, shared dialogic reading with a caring adult. We also explore two different types of prompts based on previous literature on dialogic reading to enhance children's ability to elaborate a meaningful story line and consider characters' mental states. We approached this research issue by conducting a study in which 35 children aged 3 to 6 used Spring-a-story. We seek to understand to what extent the application could sustain children in creating a narrative, and which type of prompts better supports the development of a meaningful story. Specifically, our research questions are:

RQ1 To what extent do children enjoy creating a story using a prompts-based wordless picture book app?

Understanding children's enjoyment of this type of application is important because adult-child dialogic reading, although valuable, is not always possible, due to adults' time limitations or lack of literacy skills. Well-designed prompts-based wordless picture books apps may serve as an alternative or supplement to shared dialogic reading. However, we must first understand whether children enjoy the experience in order to assess its likelihood of being adopted in real-world settings.

RQ2 To what extent do audio prompts stimulate meaningful responses in children?

Audio prompts are likely to only be valuable to the extent that children can understand them in context and respond to them in meaningful ways. If children are unable or unwilling to provide meaningful responses to prompts, it is likely that the application will not be effective in promoting children's narrative or literacy skills. Thus, it is important to assess the extent to which prompts result in meaningful responses as an indicator of significant engagement and potential benefits.

RQ3 Which type of audio prompts best support the creation of a meaningful story?

Understanding the type of audio prompts that best promote children's meaningful responses is important because there are many choices that creators of e-book applications may make in designing audio prompts. However, prompts that encourage children to consider characters' mental states may promote deeper processing of the story than prompts that focus solely on surface-level features. Understanding which prompts best promote meaningful responses will have implications for the design of future applications for children in this age range.

Data collected during the study were analyzed following a quantitative approach. Study design and data analysis was done in collaboration with a developmental psychologist with specific knowledge on co-reading which was also a co-author.

Our contribution is twofold: 1. Exploring how the use of prompts could support the development of a meaningful narrative, and 2. Understanding how to design a digital reading experience in which a pre-literate child could engage independently from an adult's presence.

In the paper we present the technology used (Spring-a-story), the context of the study, and the method. We conclude with theoretical reflection, design implications for developing co-reading activities using a digital artefact, and suggestions for the community on future research directions.

3 RELATED WORKS

In this section, we summarize existing related works that motivated our work and in which our research is grounded. First, we present the main theoretical approaches to narrative skills development and dialogic reading practices. Then we illustrate literature within the HCI and education communities about digital reading and storytelling.

3.1 Children's narrative abilities

According to Piaget's four stages of cognitive development [35], children aged 2-7 years old are at the pre-operational stage. Children are still in their egocentric phase and they have difficulty in communicating and taking the perspective of others (young and adults) including their emotions. Concerning language development, children progressively learn how to use symbols. Pre-reading activities support logical thought development as children start to realize that words represent ideas, and, in some cases, these are connected with actions. Children in this age group love reading or listening to the same story over and over again and these repetitions are beneficial for learning [21]. Running these activities with peers or adults can be highly beneficial considering that children's cognitive abilities originate within social interactions [51]. In addition, according to Bruner [7], narrative is a primitive function of human psychology and a fundamental aspect in the construction of meaning even for very young children. In this perspective, narrative is an important way of mediating the construction of meaning and organization of knowledge. According to Chall [10] children until age 6 are in the "Pseudo reading" phase such as "Child "pretends" to read, retells story when looking at the pages of book previously read to him/her". They can understand "picture books and stories read to them" [10]. Reading and creating stories helps pupils in reinforcing the development of logical thought by introducing the story sequence and the book's organization as means to understand the reality [7].

In our research we explore how to design a digital tool that could foster children to tell a story as this type of storytelling may contribute to the development of other pre-literacy skills and, eventually, to reading.

3.2 Dialogic reading

We use the term dialogic reading to describe the activity of children sharing the reading of a book, or a story, with an adult. This practice fosters various oral language skills [17] [29] and it is quite popular with young children.

During shared book reading between adults and children, dialogic reading practices have been shown to support children's language and literacy development (e.g. [52]). Dialogic reading strategies epitomize principles of optimal learning derived from research in the learning sciences [20]. First, dialogic reading encourages children to be active through responding to adults' questions. Second, dialogic reading invites engagement as adults both follow children's interests and help focus children's attention on aspects of the story. Third, the use of "distancing prompts," which relate something in the story to children's lives, can help give the story a meaningful context [19]. Finally, shared book reading includes contingent interactions between adults and children.

One of the main pillars of dialogic reading is that children have to be active through responding to adults' questions. This is based on Vygotsky's concept of Zone of Proximal Development (ZPD) [51]. According to ZPD, adults scaffold children's experience at developmentally appropriate levels. Thus, the adult stimulates children in making sense of the story by scaffolding them with

specific questions that were challenging but still within their ZPD. A second pillar concerns how the dialogic reading invites engagement as adults both follow children's interests and help to focus children's attention on aspects of the story. Dialogic reading prompts include questions encouraging children to explore the main ingredients of the story (what, who, where) and make inferences about the story (how and why). [57]. *Theory of Mind (TOM)* prompts aim to stimulate the child to reflect on characters' feelings and thoughts. Theory of mind skills refer to the ability to understand that mental states, including thoughts, intentions, and desires, drive individuals' actions [53]. These skills develop gradually across childhood. Notably, exposure to mental state discourse [46] and exposure to children's literature [30] are both related to better theory of mind skills. Other studies show that the extent to which mothers refer to cognition during storybook reading is related to children's understanding of mental states a year later [1]. Further, an intervention with school-age children focused on reading storybooks and having a related discussion focusing on mental states can improve theory of mind skills [5]. Thus, we hypothesized that encouraging children to use theory of mind language during wordless picture book reading could have positive long-term effects on children's theory of mind skills and ability to engage in mental state discourse.

We took inspiration from some of the successful dialogic reading practices and techniques that have been documented in the literature in order to design Spring-a-story. As an alternative to shared adult-child dialogic reading, pre-literate children often use a wordless picture book in the form of a book made mainly of images without text. Explicit visual connections between the narrative components allow the reader to create a meaningful storyline [26]. Indeed, the child is stimulated by the images and the reading turns into a sense-making exercise complemented by many related activities (e.g. acting, singing and playing) with a specific emphasis on posing and answering questions triggered by the interaction with the book. The enactment of the story has a strong positive influence on how much children understand its narrative [22].

3.3 Digital reading

When the content of a book is digital, we refer to it as an e-book. E-books can contain digital stories and multimedia content including images, text, recorded audio, video and music. These features are combined with the purpose of telling a story. If this combination is designed to provide engaging interactions with the readers, we have enhanced e-books. In enhanced e-books, digital stories animated by video, sound and music can support children in "expanding vocabulary and syntax" even when they are not assisted by adults [50]. The co-reading of wordless picture digital stories is a shared activity between an adult and a child in which a meaningful storyline is created by making sense of the content of a digital wordless picture book [37]. Research suggests that the multimedia dimension of stories may serve "as an anticipatory set or hook to capture the attention of students and increasing their interest in exploring new ideas" [41]. Rhodes and Walsh [40] elaborated recommendations for the development of new reading technologies to compensate for the difficulties experienced when dealing with the co-reading process. While Takacs et al [47] in their study provided evidence that well-designed digital multimedia stories can offer children a similar scaffolding effect than that provided by adults. Rubegni and Landoni explored the challenges in designing an authoring system to support the co-creation of stories by preschoolers [43]. Among the emerging design directions, they highlighted the need of having turn taking and collaborative activities. They concluded by highlighting how such an authoring tool would have to support and facilitate adults and children when collaboratively creating new stories and that particular attention has to be paid to sharing tasks.

3.4 Designed solutions for digital reading and shared storytelling.

A number of specific tools have been developed to support young children's reading and shared storytelling. Some of these addressed the design of enhanced e-books to engage children on reading experience. Sargeant and Mueller [44] presented a study in which visual, textual and audio content were used to create engaging interactive digital storybooks. They defined a set of design tactics to support and motivate adults in assisting children in the exploration of a book for assigning narrative meanings to its content. Similarly, Hebe [12] explored the design of enhanced e-books that would offer multimedia elements and fun interactions to support flow in reading with read-aloud narration in order to have a positive effect on children's reading experience. Hybrid books, where a tangible component is used to augment an e-book, have proved successful with children, [15] as a means to motivate and engage reluctant readers. An interesting example of a hybrid book is the Bridging Book [15] project that promised to have a longer lasting impact on children's reading habits as it builds on popular and widely available devices. Another example of hybrid book is Mobeybou, an interactive app to be used by pre and primary school children together with physical blocks to create multicultural narratives with the purpose of promoting the development of language and narrative competences [45].

Other projects focused on providing an interactive system to guide children through a workflow to support collaboration in storytelling. Storybird [58] is a collaborative story writing website for children and adults, Q-tales [28] is a platform for co-creating new or transforming available children's books, Fiabot! [42] is a web-based authoring tool to support children in the narrative production of digital stories via a tablet.

Recently a few projects explored the role of Conversational Agents (CA) in interaction with the child through dialogic reading. For example, StoryVisit [36] enabled children and adults to read storybooks over a distance. StoryVisit [36] offered three features: reading tips for every page, suggesting questions the adult reader might ask on that page; a "shared pointing" feature so that adult and child could see where the book has been clicked by their reading companion, and an Interactive Social Agent, in the shape of Elmo, the famous character from Sesame Street. The adult reader could engage Elmo in a dialogic style, ask a question or make a comment about what was happening on that page of the book, and could also make Elmo laugh, or answer simple yes and no questions. The tool proved particularly effective with young children whose communication sessions with long-distance relatives lasted on average five times longer than those when using a simple video chat system. Exploring further the potential of CA in reading and learning for children, Xu and Warschauer [55] designed a user study in which children were read to by the CA while looking at a hard copy of the same picture book based on scaffolding reading using conversational prompts and specific follow up prompts for each of the questions. These proved particularly effective in scaffolding the reading activity where children produced a high percentage of active responses, above 90%, and all of them reported having fun with reading. Moreover, a few studies have investigated the use of prompts and turn taking in dialogic reading with technology. In Teepe et al [48], authors studied parent-child interaction and vocabulary acquisition in pre-school children during a (Technology - Enhanced Storytelling) activity.

Technology was used to support the overall storytelling process, giving parents and children the control of the storyline, and enabling turn taking. Thus, different types of prompts were introduced: textual, visual and auditory. These would take the form of dialogic reading questions used during story creation. The study highlighted a link between the use of prompts and the quality of the parent-child interaction. Another study on collaborative reading was based on the MyTurnToRead app [23]. MyTurnToRead aims at providing children with a highly engaging shared reading experience by letting them take turns in reading aloud with a virtual partner: an audiobook narration. In order to check whether children are paying attention to reading,

comprehension questions are asked, with surface-level questions referring to important elements of the story being read, and with answers stated in text. Authors developed a novel measure of independent reading behavior and discussed the role that “automated reading tutors” could play in children’s reading and overall literacy in the future.

The literature review demonstrates that dialogic reading with adults is highly beneficial for language development (long and short term) [54]. Research has suggested that co-reading a wordless picture book may also stimulate narrative skills development (e.g. [25]) and that engagement increases when stories include multimedia elements [41]. Furthermore, the literature provides evidence on how the proper use of digital technology and media can increase children’s level of engagement in reading, foster oral language skills and narrative ability (production and comprehension).

Inspired by these findings and the literature on dialogic reading theory and practices, we built a web application namely Spring-a-story.

4 THE SPRING-A-STORY

Spring-a-story is a web-based application that can be accessed using computers, tablets and mobile devices in order to create an audio story based on a digital wordless picture book stimulated by prompts.

4.1 The book contents

As a wordless picture book we used a selection of pages from the Spring Loaded e-book from the Free Kids Books library [59] who offer a range of unique children’s books. The book shows a series of pages with pictures of a girl and her dad as they invent a hat and spring-boots. This book was selected by our pre-school educational experts. They found the story engaging for children and found it easy to create a narrative.

4.2 The digital prompting mechanism

Inspired by the literature on dialogic reading, we identified a set of open-ended prompts that could help the child to contextualize the narrative and elaborate the story. In each page of the Spring-a-story, three questions are provided in the form of open-ended audio prompts. These prompts were created by experts and were related to the specific page of the book. Experts included a developmental psychologist with expertise in co-reading. During the study this expert advised on the creation of the prompts, the definition of the protocol, and the design of questionnaires. A total of 23 audio prompts (2 or 3 in each page) were built to trigger children’s answers.

The need for tools to collect children’s feedback is well documented in CCI literature [38]. Furthermore, the design of effective, appealing and non-ambiguous semantic scales for questionnaires for children is the focus of a growing body of research. From the influential work by Read and MacFarlane [38], to an investigation into the importance of their graphical component as described by Reynolds-Keefer et al. [39]. Hall et al. [18] provide an overview of existing efforts and propose the “the Five Degrees of Happiness Smiley Face Likert scale” as an effective way to let children, ages 9-11, express their judgement. An interesting exploration into the complexity of dealing with very young children can be found in [56] and their Fun Semantic Differential Scales (FSDS). Targeting the same age group is the Emotion Questionnaire [3], adapted from [31] that has shown to be effective in prior studies and thus provides an ideal tool for us to use.

4.3 e-book Interaction design elements and patterns

To ensure the application is fun and engaging, interactive features such as swiping through pages and tapping buttons are included. The three main gestures that are required are to tap, drag/slide

and drag & drop. These gestures are shown to be successful on children age 3 and above, according to a study completed by Abdul Aziz et al [4]. The child is able to move between the pages by either swiping the page or by tapping the arrows or the page numbers below. Allowing the user to be in control of the navigation is essential. All the buttons, icons and text are of large size making it easier for children to interact with the application, as their motor skills have not been fully developed [27]. Icons and symbols are used to aid children in navigating around the application. These are all consistently placed, to help with ease of identification due to the spatial relationships that are presented through graphics rather than text. Many young children do not know how to read, meaning that they are reliant on symbols to understand the meaning of the buttons through symbolic representations which are familiar to them [2]. Bright colors such as pink, red, yellow, green, purple and blue are used in the application. This is shown to have positive reactions with children such as creating happiness and excitement and therefore stimulating interaction [6]. Including multimedia elements, such as audio, is recommended in order to support child's understanding of the storyline [9] [25]. In addition, the audio we provided was a friendly human voice and the language appropriate to children of this age [13]. Once completed, all the recordings are available for the user to listen back and download (Figure 2). To listen to the prompt the child has to tap on the question mark (Figure 1) to play an audio and the system automatically starts to record the audio of the child's answer to that prompt.

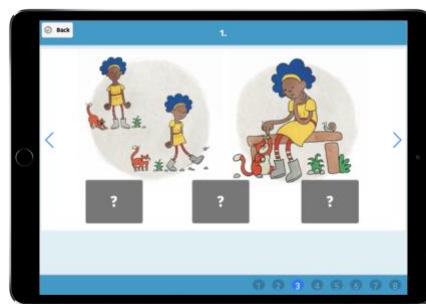


Figure 1. Page number three: below the image the squared buttons with the question marks activates the audio prompts Recording of the child's voice is a feature of the tool that we have developed for children to listen to their story. However, it was also functional for collecting data and recording the audio interaction. In the future, we will explore potential benefits of allowing children to listen to their own stories.

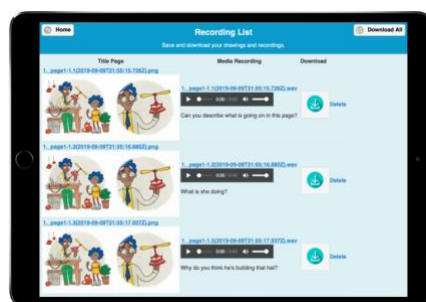


Figure 2. The interface for listening the child's story

5 METHOD

The first step of our project consisted of a review of the literature about co-reading in order to identify the basic requirements for the development of the prototype: Spring-a-story. Following the main relevant theoretical approaches, we identified relevant features that we included in the

web app. We merged those with the expertise of children user experience researchers and developmental psychologist experts involved in the project. The review of related works allowed us also to select the specific methods to be used during the case study to ensure respect for the young people (i.e. preschoolers) involved as well as the inclusion of their perspective. We developed a study that allowed the team to do a real context assessment of the Spring-a-story application. The case study allowed us to observe children creating a story by using the tool. During the case study we adopted a holistic approach and collected different types of data. The case study was conducted by two researchers of the team. In each session one of them recruited the child and the other facilitated the activity.

5.1 Research Design and Conditions

In order to explore our research issues, the tool was designed to support two conditions that differed in the type of open-ended prompts provided to the child:

1. basic dialogic reading prompts [57],
2. basic dialogic reading prompts plus theory of mind prompts [5] (TOM).

In the first condition (C1) the Spring-a-story provides basic dialogic prompts (for example “*What is the cat doing while she is so busy?*” and “*Why do you think he’s building that hat?*”) to stimulate the child in the description of the context and characters. These open-ended questions were included to help the child to develop a storyline based on the images in the Spring-a-story. The second condition (C2) was made of one or two basic dialogic reading prompts, and the second or the third one is a theory of mind prompts addressed to the characters’ thoughts and/or feelings (such as “*How does the girl feel?*” and “*Why?*”). According to the literature, these types of prompts aimed to stimulate a contextualization of the elements on the story as well as a reflection on the character’s mental states (e.g. feelings, thoughts, intentions).

Our hypothesis is that this second condition would better support children in creating more meaningful narratives than those created in the C1. In addition, we expect that TOM prompt in C2 would help children to reflect on the characters’ mental states and thus their stories would include more these elements than in C1.

The study is between-subjects, thus, we assigned one of the two conditions randomly to each child. For each page we created three questions for each condition (1 and 2) to stimulate children in the creation of the narrative (Table 1). Prompts were created by experts (developmental psychologist with expertise in co-reading) and were related to the story (Figure 3).

Condition 1	Condition 2
What is happening now?	What is happening now?
What is she doing? How is he flying?	How does the girl feel? Why?

Table 1 Example of Prompts for page 2

5.2 Procedure

Our study was conducted during a summer event organized by the University of Lincoln (UK). The spirit of the event was to attract children to science and to stimulate their curiosity as well as providing an opportunity to showcase research outputs to the local community. Lincolnshire is a socio-economically disadvantaged area and one of the missions of the University is to increase the interest in science within the local community. Thus, the university organizes public engagement events during which scientists can share their work with the public. During the event, children and

parents were invited to participate in different research projects. All were informed about the specific purpose of each study and they were aware of the researchers collecting the data. Researchers had to apply for ethical consent before the event and inform each participant (and parents) of the study. The event lasted five days, with eight different sessions and a total of 22 showcases. Each showcase was installed in a room in order to allow researchers to collect data properly and for participants to have their own space. Children who participated in the event could decide to participate in one or more studies and could decide to leave it at any time.



Figure 3 Page 2 of the book

Spring-a-story was one of the showcases available for children aged 3 to 6. As requested from event organizers, the activity lasted around 20 minutes including the pre and post questionnaire. This was important in order to allow children to move smoothly from one showcase to another. Each child played the Spring-a-story individually, sitting at a child-sized table in a quiet room (Figure 1). In some cases, the parent stayed in the same room as either the child or the parent had explicitly asked for that.

The researcher acted as facilitator and, at first, showed each page of the book to the child (picture walk), then left children to play with the book without any additional training. The child was told that they needed to create a story by taking inspiration from the images in the book and prompts provided. During the activity there was a little interaction with the researcher and parent e.g. when the child had problems interacting with the Spring-a-story application adults intervened to help. For instance, in case the child did not understand the prompt the researcher repeated it and eventually rephrased it until the child appeared to understand the meaning.

Before and immediately after the activity, children were briefly interviewed to gather information on their current mood and emotions, some feedback on their engagement with the experience by using the EmotionEnjoyment Questionnaire [3], adapted from [31]. In order for the child to answer questions they were trained on how to use the bar (Fig. 2) to express their feelings such as: really really happy, kind of happy, a little happy, or not at all happy. This questionnaire was used before and after the reading activity to understand how reading changed children's mood and emotions. The overall activity lasted 20 minutes on average.



Figure 5 A child during the bar training

5.3 Participant Selection and Recruitment

Before the event we indicated the children's age range for our showcase. We selected children aged 3-6 who are on the way of developing reading and writing skills. During the event, children of

different ages (from 3 to 10) played in a common room. One member of our team recruited participants by randomly selecting them from the group of children playing in the room. They explained the type of activity to the child as well as the parent, and were asked whether they would like to participate, thus if they agreed they moved into a room with the showcase; if not, the researcher acknowledged them and asked someone else. The parent had already read about the study on the information sheet provided by the school that was attached to the ethical approval form and they permitted researchers to take pictures and videos of their children during the activity. The child could decide to withdraw at any time.



Figure 4 A child during the activity

5.4 DATA COLLECTION AND ANALYSIS

A total of 35 children participated in our study. The age (3 yearsx9, 4 yearsx11, 5 yearsx9, 6 yearsx6) and gender (F=16, M=20) distribution was quite homogeneous in respect to the overall group of children who participated in the event. A chi-square test showed that there was not a significant difference in the distribution of children’s ages between conditions, $p = .96$.

Age	C 1	C2
3	4	5
4	6	4
5	5	6
6	3	2

Table 2 Distribution according to the age

We answered our research questions by gathering evidence from different types of data: child media behavior, pre and post questionnaires on engagement, and analysis of the story created. In order to answer RQ1, we analyzed the data from the pre and post questionnaires using descriptive statistics. For RQ2 and RQ3 we transcribed and analyzed children’s stories to evaluate the creation of the storyline in the two conditions and the level of meaningfulness of the answers provided. From the transcriptions we answered RQ2 by focusing on the meaningfulness of the story’s parts stimulated by each prompt in the two conditions. Two researchers gave a score to each response: 1 (meaningful) or 0 (not meaningful): meaningful responses were defined as those that make sense in the context of the story. Non-meaningful utterances included “I don’t know” responses or non-responses, as well as unrelated or off-topic responses. Utterances in both conditions were analyzed and labelled as meaningful or not meaningful to enable comparison across C1 and C2. We then counted each meaningful and not meaningful response created by the child. We calculated the inter-rater reliability (IRR) of the scores and researchers agreed to solve the discrepancies. We analyzed data by using descriptive statistics and a regression model. For RQ3 we used word counting and compared meaningful and not meaningful responses produced

by children in C1 and C2, using a t-test to assess statistical significance. Additionally, we coded for references to characters' mental states (use of theory of mind language) to assess whether the C2 prompts encouraged children to consider these elements of the story.

6 THREATS TO VALIDITY

Internal validity. Our research questions address how different types of audio prompts influence the story production. Thus, we include two conditions and vary the types of prompts. Although it would be interesting to investigate how these experiences may differ from using a similar analog tool with an adult providing prompts, this was outside of the scope of our research. However, we note that this is a threat to internal validity as we cannot say that Spring-a-story uniquely contributed to children's enjoyment/story creation compared to another non-digital experience. This question should be explored in future studies. Another internal threat is about the short-term nature of the study. Children used the app just one time and for a short period (less than 20 min). A repetitive exposition to the app may have different effects on children's enjoyment and story retell. Multiple exposure was not possible in the context of this study, but we will explore that variation in another setting in the future.

Ecological validity. The setting and timing of the study represent threats to ecological validity, as children's experiences during a short session at the University may not be representative of their daily experiences. Nonetheless, by running the study during the public event at University we made sure children were positively engaged with the overall proceedings. A third concern is that the time of the activity was limited by the event schedule. Each session lasted no longer than 20 minutes, whilst ideally, we would not put any such restriction of time. Finally, the sample size was small but representative of the children's population who took part in the event.

7 STUDY OUTCOMES

A total of 18 of the children were randomly assigned to C1, and 17 were randomly assigned to C2. Children created a narrative by answering to the audio prompts, in some cases these answers were elaborated and rich while in others were mere answers to the questions.

For instance, to the prompt "What is going on in here?" an example of articulated answer can be "Her cat is having a big stretch and yawning, and she is saying hmm. She's sad and the cat, he's pointing her hand" ID 255. While another child simply answered "She is sad" ID196.

The combination of the prompts and children's answers made the story. Thus, some stories were quite rich and elaborated while others can be involuted and quite trivial. Children provided responses to 91% of the audio prompts, indicating an overall high level of usage and engagement with this central feature.

7.1 RQ1.To what extent do children enjoy creating a story using a prompts-based wordless picture book app?

In order to answer this research question, we used the Emotion Questionnaire that was completed by the child before and after the use of the app. However, there were not significant differences between pre- and post-test for children's report of how happy, excited, sleepy, nervous or sad they were. Below we report descriptive statistics for questions about children's experience of the book reading specifically.

Overall, children enjoyed using Spring-a-story. Specifically, children reported that they felt happy while reading the book ($M = 3.37$ out of 4, $SD = 1.00$), with 67.9% of children choosing the highest point on the scale ("really, really happy"). Children reported that they liked reading the book ($M = 3.13$, $SD = 1.21$), with 60.4% of children choosing the highest point on the scale ("liked a lot").

Children also reported low levels of being bored during the activity ($M = 1.12$, $SD = 1.12$), with 50.9% choosing the lowest point on the scale (“not at all bored”).

7.2 RQ2 To what extent do audio prompts stimulate meaningful responses in children?

In order to answer this research question, we transcribed the audio and coded children’s responses to prompts as meaningful (1) or not meaningful (0). We defined meaningful (M) responses dependent on the child’s response to the prompt, and whether it makes sense in relation to the context of the story. On the other hand, if the response was not appropriate to the prompts and did not make sense in the context of the story, we considered it not meaningful (NM). For instance, if the prompt is “What is happening now?” a meaningful response is “the scientist is going away and she is waving to him” (ID 178), while a not meaningful response is “I don’t know” (ID 245) or “Chocolate” (ID 62). Two researchers conducted meaningfulness coding with an IRR of 97% and discrepancies were resolved through discussion. Researchers counted each meaningful and not meaningful response created by the child and we analyzed data by using descriptive statistics and a regression model. Overall, children provided meaningful responses to 78% of prompts. Thus, we can say that in the majority of the cases the prompting mechanism provided by the Spring-a-story stimulated children in elaborating a narrative related to the intended content of the prompts. Not surprisingly, age had a strong impact on children’s responses ($B = 2.19$, $p = .004$). Thus, the younger the participants are, the fewer meaningful responses they provided: three-years-olds provided 56% whereas the 6-years-olds provided 92% meaningful responses. This effect was expected considering that older children have more developed cognitive, language, and narrative skills.

Age	N	M
	M	
3	44	56
	%	%
4	14	86
	%	%
5	14	86
	%	%
6	8%	92
		%

Table 3 Meaningfulness according to age

However, it is interesting to notice that children aged 4 and 5 provided the same percentage of meaningful responses. Thus, in our sample, children of these ages appear to respond to the spring-a-story prompts in a similar manner.

Although, not meaningful responses were more frequent on younger children, the type of answers were very similar across ages i.e. “I don’t know”.

7.3 RQ3. Which type of audio prompts best support the creation of a meaningful story?

In answering this research question, we used data analyzed for RQ2 and compared stories produced in the two conditions. Researchers counted and compared meaningful and not meaningful responses produced by children in C1 and C2 and used t-tests to assess statistical significance. Looking at the data, C2 had a marginally higher percentage of meaningful responses ($M = 82.1\%$, $SD = 13.7$) compared to C1 ($M = 74.9\%$, $SD = 12.1$), $t(44) = 1.89$, $p = .065$, with a medium effect size, $d = .56$.

	C1	C2
N	25.1	17.9
M	%	%
M	74.9	82.1
	%	%

Table 4 Meaningfulness according to the two conditions

Furthermore, children's responses in C2 included marginally more theory of mind language ($M = 4.94$, $SD = 3.40$) compared to C1 ($M = 3.00$, $SD = 2.73$), $t(29) = 1.78$, $p = .086$), with a medium effect size, $d = .63$.

In order to better understand this aspect, we also counted the number of words in children's stories, to understand whether ToM prompts simply encouraged children to speak more, leading to more meaningful responses. Notably, the number of words included in responses did not differ significantly between conditions (C1: $M = 129.4$, $SD = 48.9$; C2: $M = 134.0$, $SD = 49.9$, $p = .79$), indicating that the effect of condition was specific to meaningful responses and was not due to increasing overall length of children's responses. Notably, during the activity the researcher and, sometimes, the parent, were in the room. However, the interaction between them and the children was limited and, importantly, the number of words spoken by the researcher and the parent did not differ between the two conditions, $p = .44$.

Although the difference is marginal, we can observe a trend with C2 fostering more mental state language in the stories and this is quite relevant for our research purpose. Although outside of the scope of the current study, in future research a thematic analysis of these answers would help to shed additional light on the particular aspects of children's theory of mind language that is fostered by these prompts.

8 DISCUSSION

Reading of wordless picture books has benefits for children in terms of supporting the development of narrative production [57] [22], oral language skills improvement [16], and reading skills [49] [34]. From the literature it emerged how the methodology of stimulating story creation through prompts can lead to positive benefits. This activity is traditionally conducted by parents and/or teachers [33] and these adults help children create a meaningful narrative by asking questions, providing feedback and stimulating the child to actively participate in story creation [51] [57]. The literature highlighted that digital storytelling, co-authoring tools [47], and Conversational Agents [55] can also have a positive role on this activity and lead to supporting children's development of literacy skills.

In particular, while on one side [47] has investigated the role of multimedia in helping children make sense of a story without the support of an adult, on the other [55] has focused on how important accuracy of speech is when Conversational Agents assist young children reading. Hence, based on these findings, we could assume that a picture book enhanced with spoken interactions would provide a suitable reading experience for young children, comparable with that involving an adult reader. Taking a further step, we wanted to concentrate on one aspect yet to be studied when it comes to the design of tools to support reading in young children: what types of prompts are conducive to a more fulfilling reading experience and how we can design a tool to provide them so that to empower young children in their early reading experiences.

In our research we investigated to what extent an enhanced audio-based wordless picture book (Spring-a-story) can scaffold children's story telling. In addition, one of our aims was to find out whether including theory of mind prompts better supports the development of a meaningful story.

The outcomes of our study revealed interesting aspects that we elaborated in the form of 6 design challenges for the design of more effective enhanced wordless picture books by providing:

- C1. Combination of prompts types,
- C2. Freedom for elaboration,
- C3. Balance of visual and audio prompts,
- C4. Recapitulation for improving narrative understanding and recalling,
- C5. Stimulation of independent reflection on characters' mental states,
- C6. Recommendations for younger users.

In what follows we present the design challenges by providing relevant data from our study and literature references. Finally, we include some recommendations for each of them.

8.1 C1. Combination of prompt types.

We observed a trend showing that TOM prompts (C2) provided a better support to children in creating a meaningful story. Indeed, those questions, compared to the basic dialogic reading prompts, led to more complex narratives as well as more theory of mind language. These prompts have the effect of allowing children to talk about the characters' feelings and thoughts and subsequently elaborate the story in that direction. From the literature it is clear that discussing mental states during story/book reading is related to children's theory of mind skills [1], however, the use of basic dialogic reading prompts (e.g. *what the story is about?*) stimulates the child in defining the characters and settings, and to interconnect those elements to create a story [37]. *The combination of the two types of prompts allows children to build a story that is at the same time aligned with book pictures as well as reflecting emotional aspects of the characters. We recommend applying this combination of basic dialogic reading prompts and TOM prompts for the design of enhanced wordless picture books.*

8.2 C2. Freedom for elaboration.

The visual and audio prompts in Spring-a-story made this tool suitable and engaging for children of different age inside the pre-reading age group: not too difficult for the younger and not too easy for the oldest. However, we noticed that the open-ended prompts were probably a bit too focused; these led to a very short and narrow answers and reduced the potential breadth of the child's oral elaboration.

In order to increase the quality and the extension of child elaboration of the story prompts have to be formulated in a way that could leave more room to produce the story and invite them to elaborate more on top of the visual and audio prompts. Another option could be to have for each page a partial audio narration of the story, and after that the audio prompt asks the child to continue with the storytelling. This could lead to the creation of more meaningful stories, as well as greater enjoyment among children.

8.3 C3. Balance of visual and audio prompts

The positive role of pictures and multimedia elements in the story is documented in literature (e.g. [9] [19]), however multimedia elements if not connected with the storyline can distract the child instead of improving their literacy development [24]. On the contrary, visual and audio prompts congruent with the story can easily support children's interaction and story development. In Spring-a-story we used a combination of audio and visual prompts. The absence of textual elements facilitated the interaction of very young children who would otherwise need an adult to decode the text. Another visual strategy to attract children attention are the hotspots. In literature it is well-know the advantage of using hotspots in e-book [32]. Hotspots can be used to attract the focus on a specific area of the page/picture and to induce the child to touch it and listen to the

prompt. In our context, hotspots that pop up one after the other can work as a guide and increase children's independence in co-reading.

In order to increase independence, it is important to adopt visual strategies that can guide the child in the interaction with the tool and through the co-reading.

8.4 C4. Recapitulation for improving narrative understanding and recalling

The picture walk proved effective in familiarizing the child with the story images, the prompts and the application features. These steps helped the child to comprehend the interaction mechanism as well as to start thinking about the potential narrative to produce. Another relevant step to foster the child's narrative comprehension was asking a title and the main story's topic at the end of the activity. In both conditions, 82.8% of children provided a meaningful response to "What is the story about?" and 87.1% of them gave a meaningful title to the story. In children's literature, recapitulation has been used since the Victorian age [14] by writers as a strategy aimed at supporting the pupil to remember the story while reading. In our case, this is even more relevant considering that our children cannot read and write and are thus unable to make sense of textual clues such as headings, labels or subtitles.

We recommend fostering children's narrative understanding and recall by asking the child to recap the narrative and give a title.

8.5 C5. Stimulation of independent reflection on characters' mental states

The principles of learning science emphasize the idea that children learn best when they are active and engaged [48]. Further, optimal learning occurs in meaningful contexts and when children create their own narrative, the story is more likely to be meaningful for them. Finally, optimal learning occurs during social interaction [7] "giving parents and children control of the story content and story pace to encourage active participation" [48]. Although the Spring-a-story app is not social in a literal sense, the tool mimics contingent social interaction through the back-and-forth nature of the activity in which the app provides prompts for children to respond to. In our study, the tool played a similar, yet simpler, role to that of the adult reader while helping the child to take control of the story. Prompts stimulated children's active participation in the development of the story and references to characters' mental states during reading: children's responses in C2 included marginally more mental state language than C1.

We recommend that the application includes a constant dialogic interaction that can stimulate the child to include more reflection on characters' feelings and mental states in the narrative.

8.6 C6. Recommendations for younger users.

In literature it is well known the benefit of dialogic reading for three-years-old in terms of narrative understanding [10] and development of the logical thought [7]. However, in the current study, we found that the Spring-a-Story task was particularly demanding for such young children who had to produce a story without any oral example to follow. Likely, the open-ended prompts were too narrow to stimulate the child to produce a story, without more significant adult scaffolding. There is a significant difference on the meaningfulness of the story produced by children in different age group: 3-year-olds provided 56% while 6-years-old 92% meaningful responses. Nonetheless, the age was not related to children's reported enjoyment, with 75% of 3-year-olds choosing the highest point on the scale ("really, really happy") for this item. Thus, in order to better support these younger children, we should rethink the task and, for instance, provide additional scaffolding, transform this activity into a retelling task, or have non-verbal response options e.g. choosing which of two pictures comes next in the story.

We recommend designing different tasks for younger users by providing additional support to scaffold meaningful interactions with the application (e.g. based on visual clues).

9 CONCLUSION

Literature showed the positive effect of dialogic reading with digital e-books [44] and the role of mental state language during storybook reading in promoting children's theory of mind skills [1] [5]. However, the activity in those studies was often regulated and led by an adult while in our case the child was asked to conduct the co-reading independently. In our research we aimed at investigating how to better design children's experience when producing a narrative based on a wordless picture e-book. In particular, our purpose is to explore how to design a digital reading experience in which a pre-literate child could engage independently from an adult's presence. We designed a prototype and we conducted a study in which 35 children aged 3 to 6 used the Spring-a-story app. The bespoke web app, Spring-a-story, allowed us to investigate whether visual and audio prompts can scaffold children to independently create a meaningful narrative. We tested two conditions: condition 1 based on basic dialogic reading audio prompts, and condition 2 based on basic dialogic reading plus theory of mind audio prompts. Outcomes suggest that the condition 2 better supports the development of a meaningful story.

In addition, on the basis of study outcomes, we elaborated six design challenges that can support further research in this field: *Combination of prompts types, Freedom for elaboration, Balance of visual and audio prompts, Recapitulation for improving narrative understanding and recalling, Stimulation of independent reflection on characters' mental states, and Recommendations for younger users*. These challenges aim to inform the human-computer interaction and child-computer interaction communities on the implications that should be considered when designing technology for supporting children's independent storybook reading. In addition, the community could take the advantage of the methods used to collect and analyze data. Details about the operationalization, the statistical analysis, and the reliability of the emotion questionnaire will enable replicability of the study and the use of this approach in other contexts.

This study is just a first step on our way to investigate this topic and it has some limitations as highlighted in the threats to validity section that will be addressed in the next steps of the research. For instance, in order to understand the impact of prompts on children's narratives we will conduct a long-term study and expose the same group of children to multiple interactions with the same wordless picture e-book. A prolonged and repetitive use of the e-book is also much closer to the actual usage of wordless picture book in their everyday life: children happily read over and over the same wordless picture book creating different stories. In this scenario we would like to investigate how this activity might change over time and assess whether it has an impact on their abilities (and which ones). In addition, we will observe whether children interact differently with the tool over a longer period of time and investigate the emerging new interaction modalities (e.g. children/adults selecting/creating prompts). In the long term, we could also explore whether this activity would have an influence on other skills/activities performed at home or at school. For instance, we are keen to assess whether and how children improve their self-confidence, given that they do not need to decode words, and perhaps take a more positive approach towards the development of reading skills.

Certainly, we will increase the size of the sample involved in the study by also including more children of different age groups. Furthermore, it would be interesting to change the tasks according to the age and to modify the type of audio prompts. For instance, to add more prompts as positive reinforcement during story creation. According to Chall [10] a way to support young children (aged 0 to 6) to further develop their skills is with someone "who responds to and warmly appreciates the child's interest in books and reading" [10]. Thus, providing encouragement

prompts could give added value to basic dialogic reading and TOM prompts. In addition, we will be interested in rethinking the way prompts are generated by the app and embrace new topics of research related to Conversational Agents (CA) area. This is a growing field and we feel that our outcomes could support and inspire future research in that area.

SELECTION AND PARTICIPATION OF CHILDREN

Prior to the study the ethical approval was submitted and obtained by the University of Lincoln. Children and parents were told about the aims of the research and why we intended to analyze the stories they had produced. Researchers acted as facilitators and made sure children did not feel under any pressure but were comfortable and felt free to leave the study at any time.

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