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Published in:
Proceedings - Pervasive Displays 2020

DOI (link to publication from Publisher):
10.1145/3393712.3395342

Publication date:
2020

Document Version
Accepted author manuscript, peer reviewed version

"Do you think it is going to be the cock?" - Using Ambient Shadow Projection in Dialogic Reading

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ABSTRACT
In this paper we present a lamp prototype that projects controllable shadows to create an ambient backdrop for dialogic reading between parents and their children. The lamp uses four electrochromic displays that allow masking the light and thereby control the shadows that are projected upward onto the ceiling. The displays can switch between general ambience picture and a certain story point in a Smurf book. These displays were used in a reading study with parents reading for their children and a focus group session. The results indicate that the lamp helped in spurring interest and a dialog about the story being read. The used technology proved to be implicitly triggering questions and discussion about the story by creating suspension when switching between the different shadows.

Author Keywords
ambient display; dialogic reading; electrochromic displays;

CCS Concepts
•**Human-centered computing** → **Human computer interaction (HCI); Ubiquitous and mobile computing;**

INTRODUCTION
Language acquisition in young children is important to their development in later literacy skills and language. One method that has proven to effectively increase acquisition is dialogic reading where the storyteller, typically adult, interacts with the children by prompting questions as part of the reading or even letting the children be the storyteller during a reading session. However, as more families get access to computers and tablets with e-books and interactive applications, the children start to divide their attention between the technology and the story that is read to them. This might be one of the reasons that the change to e-books and interactive applications has shown to have a negative affect on story comprehension [21]. Prior approaches to support dialogic reading through technology have focused on e.g. making the stories interactive so that e.g. the children's pointing would have an effect [13] or through supporting the reader with alternative words or questions [17].

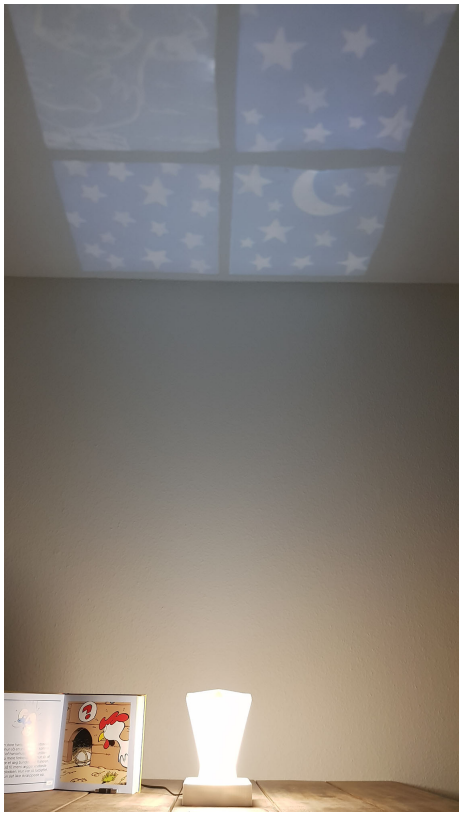

Figure 1. Lamp lighting up room while projecting shadows.

Here we want to follow a slightly different approach, in which we try to introduce technology without distracting the audience by projecting shadows of story points on the walls or ceilings. We hope that this prompts the children to ask questions of or reflect on what they see, which can augment and create interest in the story during reading. To realize this we utilize a combination of electrochromic (EC) displays and LED's to provide background illumination for reading while simultaneously projecting shadows that create interest in the story being read. An EC display can consist of two graphics printed on a transparent substrate with a conductive layer, and powering using a low current will make one of the graphics visible while the other will become near invisible. Which graphic is visible depends on the polarity of the current [10]. As EC displays can be transparent they also can function as light masks; there-

ACM ISBN 978-1-4503-7986-1/20/06.
DOI: 10.1145/3393712.3395342

fore, one display can provide changing shadow projections and potentially project different illustration from a story.

In this paper we present a novel pervasive lamp prototype that consists of a 3D printed lamp casing to provide soft illumination and electrochromic displays to project shadows. Wireless enabled hardware drive the lamp through a web interface allowing a wide range of devices to control it. We fabricated four electrochromic displays that each in combination with LEDs project either a pattern with stars or an illustration from a children's book.

RELATED WORK

Reading and storytelling to children is an important part of development of literacy skills and language [8, 4]. Feedback, utterances and prompting from parents during reading sessions has showed increased effectiveness in language development of the child [22]. Dialogic reading is one method of telling stories to children and is proposed to have three levels: *1)* introduction of new words, *2)* practice and expansion, and *3)* relation [5, 15, 20, 24]. In the first level the reader asks "wh" questions to the new words introduced during reading e.g. "*what is that?*", "*what color is this?*". When the child has repeated the new words several times the reader can proceed to the second level where open-ended questions are asked e.g. "*What do you see on the page?*". Finally the third level asks questions to the plot or characters of the story e.g. "*Why is he/she happy?*", "*What happens next?*". Additionally the child should be asked to relate the story to personal experience. With the increase in children who has access to electronic devices such as smart phones and tablets researchers have investigated their use for story telling as these devices lend themselves well for it. However, studies have shown that the electronic features deflect the attention from the story resulting in interactions where the reader's prompting is more likely to be "*Don't click that*" than the previously mentioned dialogic related prompts [23, 3, 19, 13]. However Nadarajah et al. also demonstrated that technology can support the person that reads through facilitating support with alternative words and questions [17]. The here presented prototype builds on that idea, the ambient backdrop that we create through hard shadows, is meant to facilitate a conversation between the child and the reader about the content of the story.

In the field of calm computing, researchers have focused on using different types of ambient displays to present and communicate information. These displays mostly present information abstractly by either light, sound, vibration or movement. One of the earlier projects ambientROOM, fitted an office room with a range of ambient displays to provide information for a personal interface environment [9]. Fortman et al. focused on embedding the ambient information into everyday objects e.g. an ambient display desk lamp for workspaces that notify the user when to get physical to increase health [6]. The aim for embedding the ambient display into everyday object is to allow easier integration into workspaces or homes. Gleamy [1], a lamp designed to be aesthetically pleasing provides changing light by altering the transparency of it's frame. As the frame is composed of 40 individually controlled triangles it can provide a wide range of information either statically or through animation. Using Gleamy to show physical activity at the end of the day was one suggested application case. Our work differs from these previous ambient display approaches by providing an ambient backdrop that contains story related shadows. We aim to encourage an active dialog instead of just displaying ambient information, nevertheless, it is still meant to be ambient and not the focus of attention.

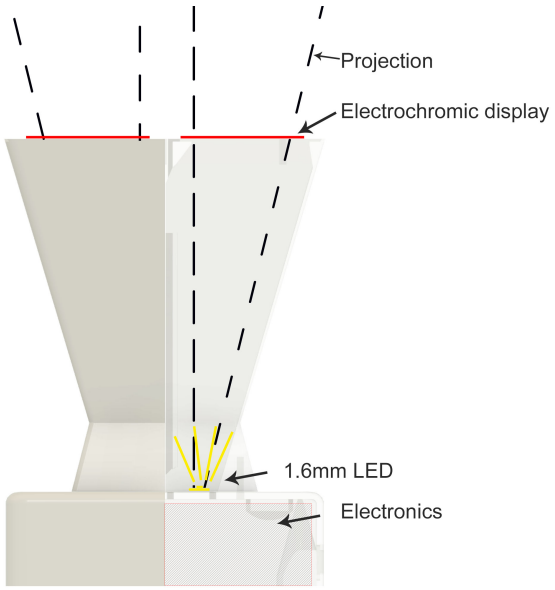

Figure 2. Lamp design. Left: No cross section view. Right: Cross section view.

In human-computer interaction, shadows are a subject that has not received much attention. This, in spite of, puppet theatre and shadow play having been around for centuries [18]. To our knowledge few studies have researched the use of shadows for interaction. One study presented ShadowPuppets, a system that allows casting shadows as input for a mobile projector phone [2]. Interestingly, this use of shadows as an input is intuitively easy to understand as everyone can use they hands for casting shadows as long as there is light. Maybe the closest related to the work presented in this paper is the approach of Häkkilä et al. [7, 14]. They presented an ambient display that uses the light from a candle and cardboard cutouts to project shadows. The candle light display projected smileys for emotional communication and rotated the cardboard cutouts to change which smiley to project. A Bluetooth connected smartphone would control which smiley to project based on incoming messages. Our approach is very similar but utilizes electrochromic displays to mask the light for the shadows and can be controlled similar to the panels in Gleamy's lamp. Furthermore, by using multiple separately controlled electrochromic displays we can present a range of individually controlled shadows.

CONCEPT AND PROTOTYPE

The concept for the lamp is based on prior experimentation [12]. The idea is to provide ambient illumination in the form of a shaded bed table lamp while being able to project hard shadows onto the ceiling that work as an ambient back-

Figure 3. Electrochromic display designs. ***Left:*** **2by2 grid shows the story illustrations.** ***Right:*** **2by2 grid shows the generic stars.**

drop. Through the projected images we hope to encourage a conversation about the story which further can stimulate and support dialogic reading. Illuminating with soft light should provide enough light for reading a story without needing to add extra lights in the room and without disturbing the shadow projection abilities of the lamp. The lamp projects four separate shadows onto the ceiling arranged in a two by two grid projecting one big rectangular shadow with each separate projection switchable between two shadow patterns. The frame of the lamp contains four holders for electrochromic displays that enable the switching of shadow patterns. This allows the lamp to be used with different stories or for different purposes than just augmenting points in a read story.

For the projection of the shadows we use electrochromic displays which recently have been used in a variety of context ranging from wearables [11] to ambient notifications [16] and have proven their capabilities. They consist of two sheets of Polyethylene Terephthalate (PET) treated with Indium Tin Oxide (ITO). The designs for the display were printed using electrochromic ink on the ITO side of the PET-ITO by either ink-jet or silkscreen printing. To complete the display a thin spacer material (double sided tape) with a width of 3-5mm was used along the circumference of the display. The spacer keeps the two PET-ITO sheets together and allows electrolyte to be deposited in the center of the display. Which in turn keeps the two ITO layers from short circuiting. Applying a low voltage (1.2v - 3v) oxidizes one side and reduces the other side. Depending on the electrochromic ink used, the oxidized side will become visible whereas the reduced will become near invisible and changing the polarity to the display changes which side is visible [10]. The length of the time it takes to switch can be modified by altering the amount of the applied voltage. We opted for a longer transition period so that their would a form of suspension and some time to switch focus while reading.

As seen in Figure 2, the prototype consists of a white frame 3D printed in three separate parts. The bottom part provides enough space to contain the electronics that power and control the LEDs and EC displays. The middle part is 13.5cm in width and depth and is 15cm tall with thinly (0.8cm) printed outer walls allowing light from the LEDs to bleed through providing soft illumination from the circumference of the lamp. At the top surface of the middle part electronic connection points in addition to insets allow EC displays to be easily switched for different books. The top part has the function to keep the EC displays in place and electronically connected. The total height of the lamp is 21cm. This provides overall clear shadows at 2-3m distances

For electronics we used an ESP32 connected through I^2C to an SX1509 GPIO extender board. This provides wireless connectivity with enough outputs to control both LEDs and EC displays. Four high powered 1.6mm LEDs (max 350mA) are connected through MOSFETs to the ESP32's outputs and the EC displays are connected to the GPIO extender board. The GPIO extender board is needed because the EC displays require two controllable connections to provide bidirectional switching of the display. The ESP32 functions as an wireless access point that provides a HTML web interface to control the lamp. To this the user can connect via a smartphone and select which screen to switch.

Shadow Pattern Designs

We used the "The best Smurf stories" compilation book as it lends itself to reading and story-telling in a dialogic setting and has illustrations that easily transfer to shadow patterns. The illustrations were traced to a vector graphic and resized to fit in a 5 by 5cm display (see Figure 3). Alternative to the illustrations from the book are a side with stars to create an cozy ambient setting where each display will change into the corresponding illustration from the book as the story is being read. To ensure the reader know when to switch a specific projection from stars to story illustration, markers were added to pages were the reader has to interact.

FOCUS GROUP

To evaluate the concept and identify usability issues we organized a focus group session. The goal of the focus group was to get feedback from users on usability as well as experiences from parents reading to their kids besides more general questions towards the prototype and idea.

Procedure

The following tasks were followed: consent form and background questionnaire, short open discussion on their experiences reading to their children, showcase and explanation of the lamp, discussion on the lamp and its aesthetics, trying out the lamp control interface, and finally open feedback.

Participants

We invited six (5 female, 1 male, average age 47.3 (sd=9.8)) participants for the study group. All have children and four of the participants have two or more children and have read to them in the past. Two mentioned that they even have used props (toys, cutouts, models) as part of their reading and one has used electronic device to support reading. The focus group took approximately 30 minutes, was video recorded and facilitated by one researcher. The video material was analyzed and coded afterwards. The participants were asked if they pursued some form of dialogic prompting when reading stories with their children or whether they only read out loud. All the participants in one way or another talked with their children about the stories. E.g. "*I read out loud and then we always talked about what it said and the pictures*" followed by another participant "*And that could also start conversations*

Figure 4. Focus group in progress. Participants trying out lamp control interface while being very interested in the display technology used to project shadows.

about other things". When asked whether there were things in the books that made them more popular (story or amount of pictures), story was the most prominent answer with relatable books being most popular "*We've read a lot of Villads from Valby. They can relate to that because it is about a schoolboy*". None of the participants were aware of dialogic reading as such and that they, to some extend, subconsciously had used this technique with their children in prompting "wh" question and discussed relatable plot points.

The facilitator explained the purpose of the lamp while showing how its lighting and shadow projection functions. Some of the shadows were shifted during this presentation displaying the time it takes to shift from one shadow pattern to another. The connection to the Smurf book was explained while the display was shifting. The participants were reluctant towards the idea of themselves using the lamp as they would have to use a smart phone to switch the shadows. They saw this as a break in the scenario of reading and feared it would tear the concentration from the story. However, they suggested adding physical buttons to the lamp so either they or their children can switch the displays: *"I'm thinking in terms of shifting shadows, it would be smart if there would be a button on the lamp"*, add sound effects (background music, jungle sounds etc.) that fit the story being read to increase the immersion: *"Have you thought about adding sounds to it? Not text but music, sound effects etc"*, or automating the switching of the shadows directly from the pages of the book e.g. "*Can't you just put it into the pages?*". If any of these features exists in the lamp they could see themselves using it. Additionally some suggested using children themes for the lamp either a super hero or princess look. Something that would fit in a child's room.

Following a short description of how the control interface works and how the reader can see in the book when to use it; the smart phone controlling the lamp was passed around for the participants to try out (see Figure 4). When asked whether they would change anything in the interface, they all agreed that due to the minimal amount of buttons present it is easy to understand. However there were suggestions to change the icons on the buttons to resemble the actual graphics being projected: *"You could use stars or something that reminds of the pictures from the book"*, *"Then you aren't in doubt where which button you have to click"*. Another problem that

Figure 5. One child pointing towards ceiling in excitement of the changing shadows.

was brought up is the handling of a book while operating the smartphone. This was deemed to be a potential issue. As already mentioned during an earlier question, they reiterated that the lamp should somehow function automatically through flipping the pages in the book. Furthermore when asked to operate the lamp by itself they had issues orienting the lamp correctly and align the projection onto the ceiling.

Discussion

While the general concept and idea was deemed to be acceptable in terms of interaction with the prototype several shortcomings where revealed of the prototype. The first issue that participants faced while using the lamp is the orientation of the lamp towards the ceiling. Therefore we added for the second version an indicator which direction should face towards the users in from of and arrow to the lamp. The second issue was the user interface. While the participants reported no problems with respect to connecting to the lamp - switching the focus from the book to the smartphone while reading was flagged as a potential issues. The focus group participants voiced this concern from the very beginning. Several alternatives were mentioned by the participants that are feasible. Using buttons on the lamp could be problematic if it is out of reach, and having it directly integrated into the book would require some form of wireless technology inside the book hich would increase the cost of each book. Therefore we designed a clip-on element that can be attached to the book. This clip-on consisted of four buttons, a small battery and an ESP32. The ESP32 would connect to the lamp wireless and by pressing the button the displays would be switched.

READING SESSIONS

To evaluate the potential of the ambient shadow projection to stimulate dialogic reading we facilitated four reading sessions. Focus of this sessions was to analyze whether children would engage with the projection and voluntarily use them as a mean to ask questions or stimulate discussions. For this we recruited four university employees (3 female) to use the lamp during

their night time reading with their children. All participants used the lamp while reading to one or two children at a time. The age and gender of the children are as follows: 4 female (ages: 4 5, 6 and 9) and 2 male (ages: both 8).

Procedure

For the reading sessions the participants would read the Smurf stories to their children using the lamp for shadow projection while filming the session at their own home. Before the participants would take home, the lamp, book and a video camera, they received a demonstration on how to connect and use the interface that controls the lamp as well as the markers in the book that indicated a shadow switch. At this point the participants also were required to try it out themselves as part of a short training. Furthermore the participants were instructed on how to use the camera and to make sure that the projection as well as the gestures of their kids would be in the camera field of view for later annotation (compare Figure 5). After their reading session a follow up feedback session was conducted which was audio recorded.

Results

Overall all but one child (female aged 4) actively engaged with the projection in one way or the other. The reason for this one child not to engage might have been due to the fact that the child's field of view was not aligned with the projection. As we did encourage the parents to not steer the kids attention towards the projection we expected to have these observations as well. Another child (male aged 8) did observe the shadows and realized that they changed but never actively engaged with his parent about during the reading. Only after the reading was over the child reflects on the shadows. The reactions were limited to uttering words such as "That's Smurf town" and "We have heard about the rooster, the cake and the egg" while pointing at the different shadows.

All other children actively engaged with the parents about the changing of the shadows in a matter that is preferable for dialogic reading. The interaction that triggered the change created both anticipation and excitement in the children and a slow-down in the reading. After the first shadow had changed the children knew that the shadows would change when the parent triggered a button which prompted either pointing or looking up at the shadows with utterances such as *"It's up there"* while pointing or *"This is so strange"*. Additionally it also encouraged dialogic prompting from the children throughout the reading. Speculations about what change the interaction will trigger such as *"Do you think it is going to be the cock?"* or discussions before the switch was completely finished such as *"What is it?"* followed by *"Aah it's a cock"* or *"What is that?"* could be observed in all sessions. In two sessions when the last shadow had changed and the parent said there were no more shadows to change the children were let down and uttered words such as *"But aren't there more?"* or started to look directly at the lamp and into it to see the displays changing the shadows.

In the follow up feedback session all parents mentioned that it worked well but that there were things that should be solved better. Two parents suggested automating the changing shadows based on the current book page or when flipping the page. Three parents also mentioned that ideally there should be more shadow animations, so that the time between two triggered animations would be shorter and the shadows could become a more integrated part of the story telling. Two participants explicitly mentioned that the 5-6s switching time of each of the displays was well chosen as it created a suspension that would automatically prompt discussion between everybody about what would appear. One parent mentioned that it was a bit difficult to see the shadows due to having an uneven ceiling (see Figure 6) and because the power cord was too short and the lamp had to be placed in a non-ideal position.

Figure 6. Both parent and children looking up to see shadow change.

DISCUSSION

Based on our evaluations the concept of using EC displays to project and ambient backdrop of shadows for dialogic reading as such matched well with current practices and supports the process by prompting dialog about the read story. The pointing of the children during the reading sessions, and the naturally emerging discussions and questioning, without the parent having to prompt questions are a clear indicator that the idea of the ambient background projection worked well.

The suspension that is created when the parent triggers the change in addition to the time the displays need to switch between their states seem to work in favour as it spurred discussions as soon as the children understood the workings of the lamp. Even if in future iterations of the prototype the EC displays are replaced with another technology, our current findings strongly suggest that there should be a certain switching time introduced to create suspension. The amount of projected shadows was deemed as too low, both by parents as well as children. They felt that there was too much reading-time between two display switches. While our current prototype does not support more than 4 displays, other ways of constructing the EC displays could allow for more elements that change or only partly change [10].

Additional audio elements that have been brought up in focus group where not specifically mentioned by the parents. However automatic switching when flipping has been mentioned by a parent. This would though require some form of wireless technology inside the book (e.g. Zig-Bee) which would increase the cost of each book. A connected e-book (e.g.on a smartphone or tablet) that either switches automatically would solve that problem. However, given that the explicit interaction to switch the display often triggered a dialog, we would advice against complete automatic switching. Triggering the switch could also be done by the kids and be used as an additional dialogic reading element.

CONCLUSION

In this paper, we presented a concept and prototype of a 3D printed pervasive lamp that provides soft background illumination while being able to project shadows onto the ceiling. The lamp is wirelessly controlled by either a web interface allowing any device with a browser and WiFi or a clip-on for books to control the lamp. Our evaluation indicate that projecting book illustrations as shadows increase interest and dialogic prompting during parent - children reading. Especially the suspense that is created during the switching prompted a dialog and should be taken up into future implementations of this concept.

ACKNOWLEDGMENTS

This work was funded by EU project DecoChrom, grant no. 760973 of European Union's Horizon 2020 research and innovation programme.

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