LightSight: A Dice to Meet the Eyes

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Abstract
This paper introduces LightSight, a new interactive toy for children with cerebral visual impairment (CVI). Since affected children face different challenges in their perception and processing of information, it is important to provide them with appropriate tools to train their vision skills and related competencies. To address this need, we designed a tangible and illuminated dice, which wirelessly communicates with a game running on a tablet (dice and game together form LightSight). This concept should provide a playful way for the children to train their vision and a range of related motor and cognitive skills (e.g. manipulating the device with their hands, learning shapes etc.). Understanding this interactive toy is simple enough for children who are below the age of 6 years. The paper concludes by discussing the system's design motivations and observations from field deployments.

Author Keywords
Perception; tangible; low vision; interactive toy; children; cerebral visual impairment; CVI;

ACM Classification Keywords
• Human-centered computing~User studies • Human-centered computing~Field studies

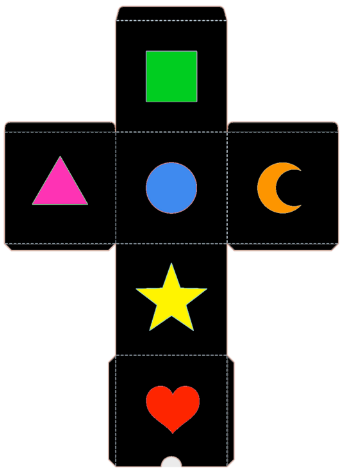

Figure 1: The surface of LightSight 'unfolded'. To make this toy **perceivable** for children with **impaired vision**, it is important to use high-contrast colors or even active illumination as implemented in the prototype of LightSight.

LightSight was conceived in particular for:

- Training vision
- Learning colors
- Learning shapes
- Training cognitive skills like matching shapes, understanding sequences of action and reaction
- Practicing patience, regulating emotions
- Exercising motor skills
- 'Having a good time'

Introduction

During the last decade, vision loss caused by damage to the brain (CVI) has become the fastest growing type of visual impairment diagnosed in children [2]. The symptoms that come along with this impairment are very diverse and can vary from child to child, from day to day. They are often associated with comorbidities like Cerebral Palsy or cognitive disabilities, because of general underlying neurological problems. According to this diversity in disabilities it is important to offer each kid suitable support for their special needs. If appropriate interventions are undertaken early on, it is possible to counteract the effects of CVI (at least to some extent) and help the kids improve their vision and related competencies, for example, hand-eye coordination.

So far, however, there is little research on CVI from an interaction design perspective. In order to help fill this gap and support children in training their vision and related skills we decided to design a game. To this end, we carefully elaborated requirements and affordances from fieldwork involving ten children (aged 3-6) with CVI, four therapists (psychologists and educators) specialized in CVI, and one ophthalmologist. The resulting game "LightSight" relies on a dice, which has distinct, illuminated shapes on each side to make it perceivable and simple enough for young children with low vision and cognitive delays. This dice is wirelessly connected to a tablet, which challenges the children to interact with the dice in a playful way. The illuminated surface of the dice is illustrated in Figure 1, and the concept of the overall game is visualized in Figure 2. In this paper, we focus on the design and underlying motivation of LightSight, but also give a brief insight into how the system is used in the field by therapists.

Figure 2: LightSight consists of an illuminated high-contrast dice and an accompanying tablet app. The child or player has to match patterns as displayed by the app.

Background & Interaction Design Concept

CVI is not a specific diagnosis but rather an umbrella term. Patients with CVI develop a diverse variety of symptoms, such as troubled vision, shape and color recognition, impaired motor skills, problems with hand-eye coordination, and cognitive impairments [1; 4]. Those conditions can be treated or supported with the targeted therapy assigned by the doctors individually. For example, affected young children get exposed to bright visual stimuli in the hope to improve their vision due to neuroplasticity [1]. Complementary, they are trained to make best use of their remaining (low) vision. In short, CVI treatments are holistic and as diverse as the characteristics of the affected people [3].

Unfortunately, it's hard for young children with delayed development to keep interest in therapy, because exercising can be repetitive and boring (e.g., having to look at bright visual cues over and over again). Naturally, there is a commercial market with therapeutic toys and tools, which try to make things more interesting for the kids; however, there is still

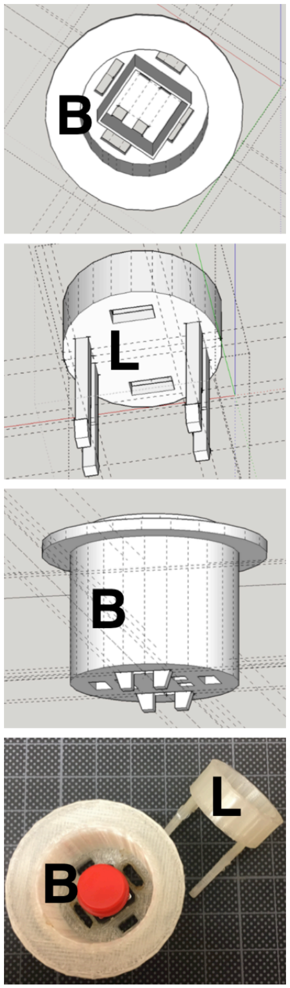

Figure 3: Detailed views of the illuminated push button mechanism, which constitutes an important design element. It took a series of tests to find a solution robust and bright enough. We can see mounting spots for pushbutton (B) and ultra-bright LED (L).

tremendous potential for the scientific study of such CVI related toys. Most importantly, we see great potential for 'interactivity' and interaction design to improve the quality of these products and consequently therapy. One of the rare exceptions was proposed by Waddington et al. [5] who targeted people aged 15-18 years and designed a therapeutic 'CVI video game'.

Design motivations

Therefore, we decided to develop an engaging interactive toy for the kids, which would keep their interest for a longer time. Additional objectives are enumerated in the text box on the previous page. The design of LightSight is targeting several elements to reach this goal, which are based on field observations and literature. As evident from Figures 4 and 5, the dice has high-contrast colors, where each side features illuminated shapes. These shapes act like buttons, since we carefully designed a robust push mechanism as shown in Figure 3. When one of the shapes is pressed, a signal is transferred wirelessly to a self-contained tablet screen. The tablet has a game running on it, and can be manipulated by the dice. Considering the children's age and cognitive challenges, we designed it very simple for most of the kids being able to understand it. In detail, the concept of the game is the following: at the beginning of the game, a randomized shape out of the set of six, which are also on the dice, appears on the screen and the player has to find the matching shape on the dice and press it. If the wrong shape on the dice is pressed, the shape appears on the screen along with a sad *emoji*. In contrast, a cheerful *emoji* appears along with a cheering sound and a new randomly chosen shape appears on screen, should the kid identify and press the correct shape. We deliberately avoided text and restricted the number of elements in the interface of the game due to the visual and cognitive challenges of the children. Hence, the interface of the game on the tablet contains only three self-explanatory symbols.

Since our dice is, as already mentioned before, wirelessly connected with the tablet, the kids can freely rotate and play with the dice without having any cables in the way. For the outer surface of the dice we consciously decided to use black foam rubber, because it makes the edges of the dice smooth and hence avoids possible injuries. Further physical requirements are listed in the text box on the next page.

Implementation

The cube of LightSight consists of one outer and one smaller inner dice. Both dices are made of thin wooden panels. We used a laser cutter to cut the wooden panels into squared pieces and to cut out the shapes on the outer dice. The inner dice is needed to stabilize the buttons and LEDs. On each side it contains a 3D-printed button/LED placeholder (see Figure 3). For each side of the outer shape we created a different 3D-printed shape, for example, rectangle and triangle. All buttons, ultra-bright multi-color LEDs and a radio (sender) are connected to a microcontroller including batteries, which is placed in the inner dice. The setup also includes a gyroscope for advanced games, which takes the orientation of LightSight into consideration and uses it as a game mechanic (e.g., 'all LEDs get switched off except the top surface', or 'dice must be placed correctly before pressing the button will lead to success'). The corresponding tablet game was developed with *Processing*. In order to enable the wireless communication between the 'smart' dice and the tablet, we developed and connected a dongle

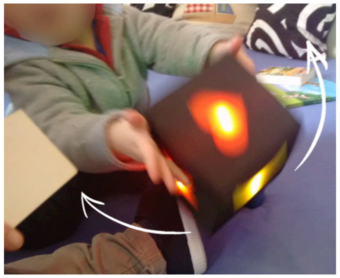

Figure 4: As evident from this snapshot, the design choice of coating LightSight in soft foam rubber was appropriate. In this image, we can see a child (aged 3 years) who found great delight in testing LightSight's flight capabilities.

In sum, we carefully took the following **physical requirements** into consideration:

- High-contrast colors
- Light emitting
- Good for small hands
- Soft surface
- Robust button mechanisms
- Low-risk batteries (no LiPo accumulators etc.)
- Rechargeable
- Portable (home visits)

(microcontroller including a radio receiver) to the tablet. Whenever one of the shapes/buttons of LightSight is selected the information is sent via radio connection to the dongle and tablet.

LightSight in the Field

We are currently conducting *field observations* of LightSight in daily therapeutic practice and *interviews* with therapists and parents. Throughout the observations the defined role of the LightSight showed to be very well understood among the children. The therapists stated that after short explanation the kids knew what they had to do and enjoyed the interaction with device and game (see e.g. Figure 5). They also noted that the kids really enjoyed the cheerful feedback. Most importantly, the black color provided good contrast and allowed the kids an easy perception of the shapes and ensured that typical low-vision problems did not occur. The illumination was equally supportive. The LEDs did not only make the shapes more distinguishable and the lights more explicit, but also attracted the attention of the younger children.

It should also be noted, that LightSight is not a game to be played without therapists or parents. The children were guided and actively prompted to deal with the dice and tablet application. This is however to little surprise. Indeed, all interventions with young children with CVI are based on trained adults that moderate play and therapy [3]. Here (and so far), LightSight proved to be an appropriate therapeutic tool to be incorporated into play-mediated dialogues between therapist and children to support their development and personal growth. Of course, the children were also allowed to take the initiative and make up their own games using LightSight as captured in Figure 4.

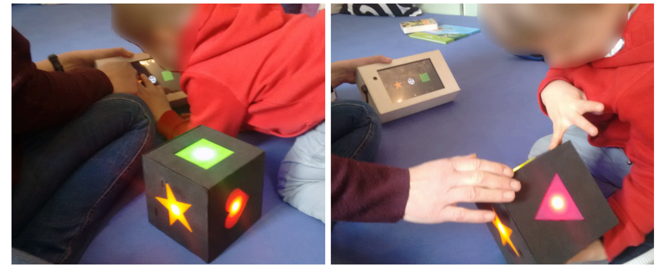

Figure 5: Child with CVI (aged 6 years) closely investigating the shapes as displayed by the tablet (left) and then identifying the corresponding shape on the dice (right).

Acknowledgements

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