The Cuebe: Facilitating Playful Early Intervention for the Visually Impaired

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TEI '18, March 18–21, 2018, Stockholm, Sweden

ACM ISBN 978-1-4503-5568-1/18/03.
https://doi.org/10.1145/3173225.3173263

Abstract
Cortical Visual Impairment in children is a severe issue caused by prenatal injury of the brain affecting timely development during childhood. Therapists work with affected children to foster general development, to improve their learning, and to train sensory skills. In order to support effective and playful practices in Early Intervention we designed *The Cuebe* and present a working prototype. It is a tangible device that can detect and project colors, allowing therapists to "magnify" those colors and creating a vast variety of playful interactions for and with children suffering from low vision. The exploration of the design domain and the iterative development of *The Cuebe* were driven by a co-design approach involving four therapists and 12 affected children. We describe use-cases from the field, illustrate *The Cuebe's* potential in Early Intervention sessions and discuss further improvements and directions of future developments.

Author Keywords
Therapeutic toys; children; disabilities; CVI; stimulation; playful approach

ACM Classification Keywords
• *Human-centered computing ~ Field studies* • *Human-centered computing ~ Participatory design*

Introduction

In this work-in-progress paper we present the design and exploration of *The Cuebe*, a working prototype from a one-year research project ('Schaukasten') involving 12 children with Cortical Visual Impairment (CVI) and their four Early Intervention specialists. The project's objective is to support affected children with innovative therapeutic toys (see also [3]), which fit with Early Intervention strategies.

Our main challenge in formulating fitting design proposals stems from the heterogeneity of the group of affected children and their diverging developmental goals. In order to uncover obvious and hidden needs in this challenging design space we follow a design-driven approach similar to Research through Design (e.g., [11]). Thus, we aim to add to existing Early Intervention practices by iteratively formulating design proposals, *The Cuebe* being one of them.

In this paper we focus on the design and underlying motivation of *The Cuebe*, a stand-alone tangible toy for children that "magnifies" (amplifies) visual cues, supporting play activities guided by therapists. *The Cuebe* is capable of detecting colors and projecting them onto its surface in a bright "magnified" fashion (see Figure 1).

In this way, *The Cuebe* makes visual stimuli "graspable" and thereby invites children to explore, experience, and experiment with visual cues in a playful fashion. In the following, we briefly provide background information before we describe the design process of *The Cuebe* and a preliminary field study.

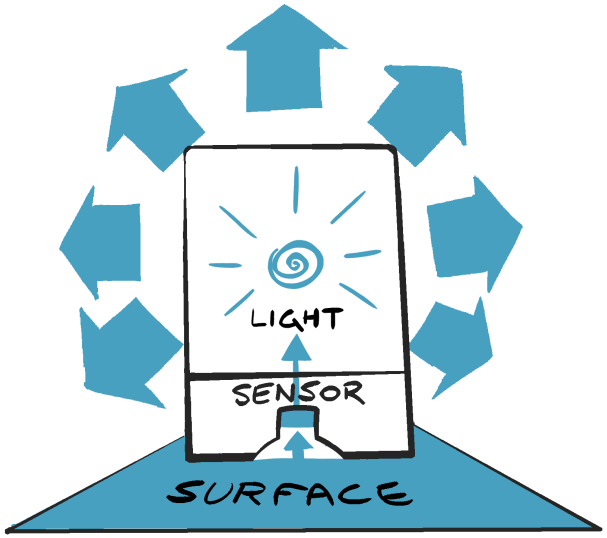

Figure 1: Concept sketch of *The Cuebe* - The sensor at the bottom detects the color of the underlying surface. The detected color is electronically amplified and the whole upper body of *The Cuebe* lights up in that color.

Background & Related Work

The term Cortical Visual Impairment (CVI) encompasses neurological impairments related to low vision. Children suffering from such impairments are not only handicapped in their development regarding visual factors, they are often also affected in their motoric and cognitive skills (like hand-eye coordination or attention and learning capabilities) [2; 7]. Hence, children with CVI suffer from a complex variety of individual symptoms, increasing the challenges for therapeutic intervention.

CVI – symptoms and support

CVI is an umbrella term for a broad variety of vision-related impairments relating to poor visual acuity, restricted field of vision, problems in visual cognition, issues with hand-eye coordination, etc. [7]

Early Intervention Services usually support affected children by offering training with special materials and toys painted with saturated colors and high-contrast patterns. In this way, children can exercise their vision in a playful fashion. At the same time, in this example, their motor system is addressed in physically playing the game (for example, throwing a yellow ball into a blue ball-run) training their hand-eye coordination. However, the number of toys that are both suitable and fun for the children is limited; thus in this paper we explore *The Cuebe,* a tangible for providing appropriate visual cues and interesting physical affordances.

Children with CVI find support in Early Intervention Services where trained professionals assess and successively build up their capabilities, for example, by exercising vision and motor control. Early Intervention Service is most effective when it supports affected children from birth on and during crucial phases of their development [2; 5]. To this end, the trained specialists accompany the children up to the age of 6 years [5]. As play is of crucial importance in a child´s development [4], Early Intervention specialists (in our case, primarily psychologists and educators by training) create playful experiences for the children. Playful interaction also offers the chance to capture a child's attention during (potentially) exhaustive intervention sessions. The info box on the left side provides more detailed information about CVI.

As children with multiple disabilities are described to play "differently", design-work should acknowledge these circumstances in order to be suitable [1]. Thus, stimuli or visual cues need to be more intense and vivid for affected children to provoke interaction. Especially tangible artifacts and interactions are promising when supporting learning and developing skills in children [6]. From the large body of literature about tangible toys we present two examples, IO-Brush [8] and Polipo [9].

IO-Brush [8] is a tangible device for children, which is capable to scan color and texture of real world objects, e.g. the favorite stuffed animal of a child. The scanned colors can then to be used as digital paint on a screen. The brush-shaped IO-Brush invites children to explore their surroundings as if it was a palette for painting and picking up colors.

Polipo [9], on the other hand, aims to improve motor skills of children in a therapeutic context. As a playful artifact Polipo allows a therapist to customize exercises for the children by offering different interactions for motor training by attaching different knobs and handles to Polipo to provide different affordances. If a child performs an exercise correctly, Polipo rewards the child by playing audio clips and light animations. The knobs and handles as well as the rewards can be customized and adapted to best fit a therapist's goal.

In contrast to the IO-Brush [8], *The Cuebe* is a standalone tangible device that is designed to be employed together with (existing) materials and equipment from the therapists. And while the Polipo [9] addresses the training of fine motor skills, *The Cuebe* targets visual exercising. *The Cuebe* is specifically designed to the requirements of our participants as a toy-like supplementary artifact supporting playful therapeutic activities (going beyond conventional interventions or games for CVI that are often just screen-based [10]).

Research Approach and User Needs

The Cuebe prototype resulted from an ongoing collaborative one-year project between the authors (experts in interaction design) and Early Intervention specialists (experts in working with children suffering visual impairment or CVI).

Initially, we explored and gathered information about the domain of Early Intervention by conducting four in-depth interviews lasting 1 to 2 hours each. Additionally, we made 18 in-situ observations of Early Intervention sessions at 12 children's homes lasting 1 hour each. Hence, we familiarized ourselves with the daily work of

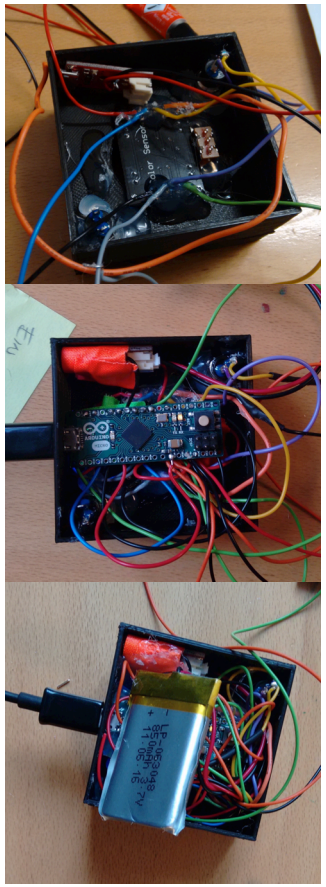

Figure 2: From top to bottom: The opaque basis of *The Cuebe* housing a
a) color sensor facing down
b) Arduino Micro and
c) LiPo Battery: 3.7V 850 mAh.

our partners and their therapeutic efforts, goals and practices. In addition to the fieldwork, we held an initial design workshop, lasting about 2 hours, with the four Early Intervention specialists in order to establish common ground for further discussions and to collaboratively generate ideas.

Stemming from the analysis of these data we generated sketches and design proposals of artifacts, including the concept of *The Cuebe*. In a second workshop, again lasting about 2 hours, with the four Early Intervention specialists we discussed the sketches and selected the most promising ideas. Then we further detailed the chosen concepts and brainstormed practice-oriented interactions and use-cases.

The most promising ideas included the enhancement of visual stimuli by means of colored lights. These kind of optical cues play a central role in training visual perception and learning the colors' names. We also aimed to improve opportunities to establish play activities as we identified playing as a key motivator and often-used strategy to sustain attention and to increase training time and intensity.

To this end, visual cues and (versatile) elements of play were the most important factors in the design process for *The Cuebe*, a toy for experiencing and playing with colors and chromatic light.

The Cuebe: Design & Development

The Cuebe aims to provide a toy design that supports the goals of Early Intervention specialists and fits the needs of the visually (and often multiple) impaired children. The major goals our design pursues are:

a) **to deliver stimuli appropriate for therapeutic training** in the context of Early Intervention and b) to support Early Intervention specialists with a **toy to inspire the creation of play activities in order to uphold motivation.**

The main function of *The Cuebe* is to detect color from an underlying surface and to replicate the color through an array of RGB LED-lights. In analogy to a "reading stone" that magnifies text, *The Cuebe* intensifies the color it reads. For example, the surface of a red toy car will be "magnified" by self-emitted red light projected onto the cap of the device, which again produces visually perceivable stimuli for children with low vision who hardly can perceive the color of the original toy car (c.f., major goal a).

The latest working prototype of *The Cuebe* is a physical handheld artifact resembling a cubic shape measuring 6x6x7 centimeters fitting the hands of children of the target group well.

The bottom of *The Cuebe* acts as a button as its surface is mounted on springs and can be pushed inwards (2mm). Children can use the device by placing their hands on top of *The Cuebe*, pushing it, and thereby "updating" *The Cuebe's* color by activating the color sensor, which is located at the bottom's surface (see Figure 2). It is reading the color continuously, as long as *The Cuebe* gets pushed down. After a child releases his or her hands *The Cuebe* keeps glowing with the same color until the next push.

The top of *The Cuebe* is made of translucent material and houses an array of RGB-LEDs. When a new color is read, an Arduino microprocessor board processes the

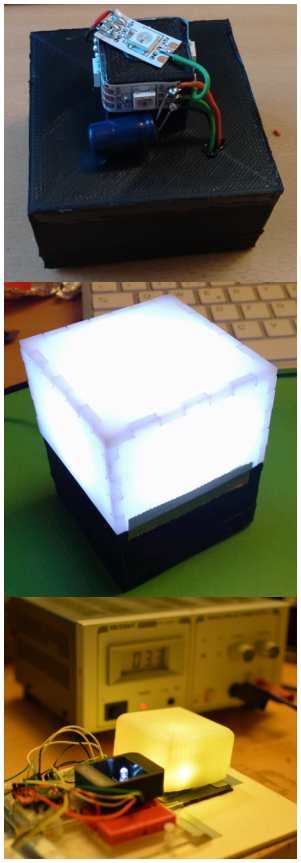

Figure 3: From top to bottom:
a) 5 Adafruit-Neopixel LEDs attached on top of the basis
b) the translucent cap made of acrylic glass, diffusing the emitted light and
c) an alternative 3D printed cap made of semi transparent PLA material (in a test-setup).

signal, maps the electrical signal to a color and subsequently activates the array of RGB-LEDs. The cap then lights up, replicating the (read) color in bright light (see Figure 3).

Similar to frosted glass, the cap diffuses the light homogenously. This is important for many children with CVI to correctly perceive and understand the shape of *The Cuebe* as a whole. Unevenly lit parts could create an incoherent perception of the colored surface and make a correct interpretation of the shape of the cap more difficult. Figure 3c depicts the development of an alternative cap for the current iteration of *The Cuebe* with improved light diffusion.

According to the Early Intervention specialists and our observations the children can be supported in their perception by two different modalities: constant light and blinking light. These are *The Cuebe's* two basic "play modes". We go on to describe how *The Cuebe* supports Early Intervention specialists creating play with children in the field (c.f., major goal b).

Field Study & Play

In order to evaluate the design of our prototype and to gain insights for further design iterations, we observed how each of the specialists used *The Cuebe* in the field. Six of the 18 total observations (each lasting approx. 1 hour) included *The Cuebe* as a toy offered to five different children. Beside its basic functionality we provided no instructions for *The Cuebe* to minimize influence on genuine interactions. We go on and describe three exemplary cases, illustrating play scenarios we observed during different Early Intervention sessions. The names of the children are altered for anonymity.

Figure 4: Mario playing with *The Cuebe*, using a dice (arrow on the left) and a prepared set of colored discs with different shapes & colors.

Case A: Kyle was invited by one of the specialists to explore the room and find a certain color to pick with *The Cuebe*: "Will you pick something *green* for me?" Kyle was carefully navigating in the room, examining different colors.

Case B: Tim was challenged to pick colors from a colored wooden disk located inside an empty metal can. The reflective steel mirrored the emitted light and the can lit up strongly. Tim was putting the head close to the top, observing the change of color curiously. He took pride in picking colors and in putting *The Cuebe* into the can and taking it out again.

Case C: An Early Intervention specialist was setting up a board game-like play activity, combining *The Cuebe* with other common materials in therapy (see Figure 4). Colored disks and planes were spread out on a flat surface. Mario was throwing a dice with differently colored surfaces. He was then asked to find the corresponding disk. The child had to say a "magic spell"

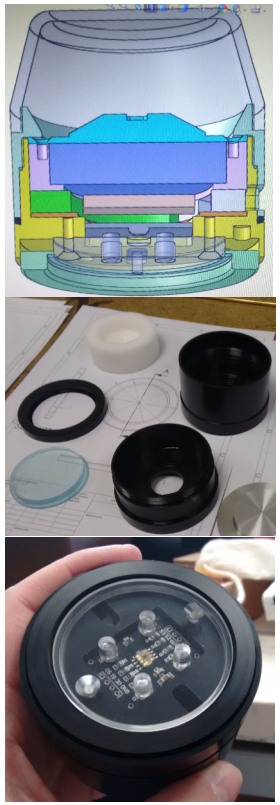

Figure 5: Currently under development (from top to bottom):
a) cross section of the next design iteration,
b) schematics and extruded parts from robust plastics and
c) bottom-view of the new iteration's mockup including the color sensor behind protective acrylic glass.

including the color's name and then pick it with *The Cuebe* to complete the task. The spell was part of the specialist's narrative or play strategy to make the game more engaging.

These cases illustrate three different play ideas inspired by *The Cuebe*. The trained specialists seamlessly integrated the device in their sessions in various ways, highlighting its potential for creating play.

Discussion & Further Development

Throughout the field tests *The Cuebe* showed the potential to fulfill the roles it was initially designed for. It was interesting to observe how the specialists used supplementary materials (colored planes, discs and old cans) to extend *The Cuebe's* functionality.

The creation of play activities included make-believe aspects or narratives like "magic spells" to foster interaction and to connect therapeutic goals with play. The therapeutic goals/challenges integrated into those play activities demanded a variety of skills from the children, such as various ranges of vision (close to distant) and different motor-skills (fine to gross). Games like the mentioned "board-game" or the "I-spy-with-my-little-eye"-like exploration game supported different kinds of such therapeutic challenges through different gameplay experiences.

However, regarding *user needs* we also found areas for improvement covering affordances, electrical components, and product safety.

Adjustable brightness: Some children are susceptible to glaring effects, even though their visual acuity is low.

Complexity and shape: Some children did not understand that picking the color requires using a distinct side of *The Cuebe* (the bottom-one with the sensor) leading to confusion and discouragement.

Additional modalities: Vibro-tactile or auditive feedback, as well as different color mappings may add more opportunities to create meaningful play activities.

Product safety: Replacing the potentially hazardous lithium polymer battery (LiPo battery) with another type of accumulator.

Hygiene: As children tend to put toys into their mouths, the next iteration of *The Cuebe* must be easier to clean.

Finally, *The Cuebe* has to be more *robust*. The structural integrity of the last prototype was easily brought to its limits, when a child smashed it forcefully and repeatedly against a table´s surface. The resulting destruction of *The Cuebe* ultimately concluded the evaluation of the current prototype in a 'spectacular way', allowing us to proceed to the next iteration.

For the next iteration, which is not yet in a working state, we will consider the items listed above. We will extrude the device from solid plastics to improve robustness and hygiene. We will also continue the exploration of different functionalities and form factors, for example, using a cylindrical shape (see Figure 5).

Acknowledgements

This research was funded by "Gemeinsame Gesundheitsziele aus dem Rahmen-Pharmavertrag, eine Kooperation von österreichischer Pharmawirtschaft und Sozialversicherung".

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