Pick, Place, And Follow: A Ball Run for Visually Impaired Children

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Abstract
Conventional ball runs are usually made from wood and used with marbles. Their easy handling and comprehensible principle of action and reaction – a marble placed into it will run down the slope – make them a popular therapeutic toy among occupational therapists and related professionals when exercising with impaired children. However, traditional ball runs are often too fast paced and not perceivable for children with low vision, making it impossible to fixate the moving ball with their eyes. We created a virtual ball run with tangible elements to extend it with properties only the digital can afford, for example, magnification of the marbles or change of color or physical behavior of the ball run in order to support visually impaired children in tracking them with their eyes. We report how we conceived the concept in a participatory design process involving four therapists, three children with visual impairment, and one ophthalmologist.

Author Keywords
Visual disability; CVI; children; ball run;

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

Cortical Visual Impairment (CVI)

The term CVI encompasses neurological impairments related to low vision. Children suffering from such impairments are often not only handicapped in their development regarding vision, they can also be affected in their motoric and cognitive skills [1; 3].

In order to stimulate and foster development, therapists (in our study, primarily psychologists and educators) create playful experiences for affected children to catch their attention and engage them with (visual) cues or stimuli.

The therapists assess and successively build up the children's individual capabilities, e.g., by training vision and motor control. They often draw on special toys to account for their clients' age and disability, and to make exercising motivating and entertaining. Due to the impairments, stimuli or visual cues often need to be quite intense or vivid to provoke interaction.

Introduction and Medical Background

The reasons for visual impairment are manifold and consequently many people are affected by this kind of disability [1]. According to the World Health Organization (WHO) there are an estimated 253 million people who have to cope with vision impairment including 19 million children [1;13].

In this work-in-progress paper we focus on children aged 0-6 years who suffer from Cortical Visual Impairment (CVI), which is an umbrella term for a variety of vision-related impairments relating to poor visual acuity, restricted field of vision, problems in visual cognition, issues with hand-eye coordination, and related problems [9] (see left column for a brief summary). Given the complex and diffuse clinical picture of CVI, young children are supported in many countries by specialized therapists, for example, occupational therapists or early intervention therapists, who conduct exercises according to the children's specific needs. These exercises target primarily vision, however also the training of related skills and competencies like hand-eye-coordination or body perception. Recurring tasks during a training session include *following objects with the eye* or *picking certain objects* and *throwing/placing them* into an open can etc. These objects are often of strong colors and high contrasts against the background to compensate low vision, making them perceivable for the children. In principal, therapists make up or design a whole variety of exercises to holistically address whatever is needed at the particular state of development of a child.

A great many of children without disabilities are fascinated by ball runs, and so are children with CVI despite their restricted vision. Hence, a lot of support institutions draw on conventional marble runs to facilitate therapy. Marble or ball runs have many appropriate features, for example, they naturally encourage children to pick and place marbles (training of motor skills and hand-eye-coordination), but also to track the ball as it moves downs the slope (eye control, fixation). In addition, marble runs are fun and most children are intrinsically motivated to engage with them for longer durations in time. This is of crucial importance as keeping the child engaged is a key factor during training sessions.

Related Work

There is a growing body of literature in HCI on how to support children with disabilities by means of interaction design. Tangible artifacts and interactions have been described as being generally promising when supporting learning and developing skills in children [8]. However, the amount of research in HCI addressing specifically CVI or vision impairment in children is quite limited to date, in particular research on *vision rehabilitation training* [12].

Recently, we [4-6] proposed a set of open-ended toys to be incorporated by therapists in their work with children with CVI. Our particular idea was to provide a set of tangibles that can be triggered remotely to make sounds, light up or vibrate. The work exhibits how vision therapists made use of these tangibles to address various senses (vision, hearing, feeling, bodily experiences, etc.) to foster the competencies of children with CVI in responding to or interacting with their environment. The therapists showed a great amount of creativity in their work with the children, an observation that was also made by Metatla [10]. His field research into inclusive education pointed to a certain hands-on and maker attitude among professionals working with children with visual

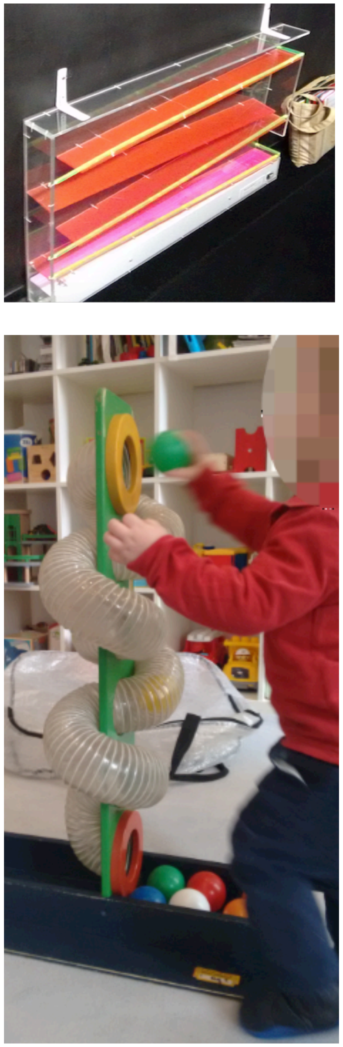

Figure 1: Acrylic ball run that can be illuminated in the dark to support children with CVI in perceiving it visually (top). Conventional ball run without illumination (bottom).

impairments. This do-it-yourself attitude reflects the requirement to individually address the children's needs as briefly explained in the text box on the previous page.

Polipo by Tam et al. [11] constitutes a playful and recent tangible prototype that aims at improving motor skills and hand-eye-coordination by offering a device with customizable knobs and handles to be manipulated by the children. Linehan et al. [7] and Waddington et al. [12], on the other hand, specifically focused on visual perception in their screen-based application. They created computer games that were optimized for low vision (e.g., high contrast, appropriate shapes) to be used in therapy.

The design that we will present in the next section – a *virtual* ball run – combines screen based interaction with tangible elements. To the best of our knowledge, there is no similar ball run as a therapeutic toy or device.

Virtual Ball Run – Background & Design

The virtual ball run is currently under development as part of a one-year research project. The design process of this particular prototype involved 3 children with CVI (4-6 years of age), four therapists specialized in CVI, and one ophthalmologist. In the course of the project, we visited a total of 12 children in their homes on several occasions (n= 25 observations) or at the support center (n = 3) together with one therapist at a time and one or two parents. We maintained a strict ethical conduct and used techniques like observation, interviewing, some photo/video-recording (when appropriate), and qualitative data analysis.

In particular, we were interested in developing design ideas for supporting the children with interesting *stimuli* and technologies [4-6]. On multiple occasions, we observed the therapists making use of conventional ball runs. For example, Figure 1 (top) shows one illuminated ball run, which was permanently installed at one of the support centers operated by the therapists. Figure 1 (bottom) displays another track without illumination. This conventional ball run, however, is not appropriate for many children with CVI as they cannot follow the ball with their eyes (e.g., it is too slow or covered by the plastic tube shown in Figure 1 bottom).

Based on this and similar observations we developed the idea of the *virtual* ball run (see Figure 2 and 3), combing advantages of both the physical and the digital world. For one thing, it allows controlling the physical properties of the toy. That is, the size and velocity of the balls can be changed. In addition, color and contrast can be optimized according to the children's needs by pushing different option keys. For another, the virtual ball run still features physical properties that are important for motor training and other competencies that are integral part to a holistic

Figure 2: Virtual ball run prototype at one of the children's home. Plastic balls of different colors can be thrown into or placed inside the funnel (arrow). A color sensor detects these balls and displays them as virtual balls of corresponding colors immediately. A servo motor releases the balls as soon as they arrive at the end of the virtual ball run. (Note, currently we support the synchronized release of one ball at a time, only.)

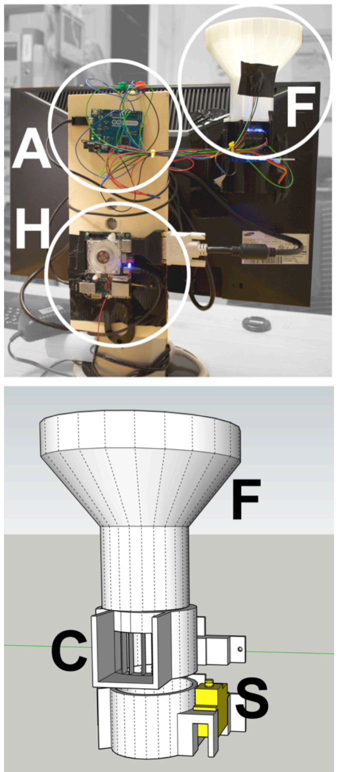

Figure 3: Virtual ball run prototype from behind (top). A small single-board computer by Hardkernel (H) hosts our software implemented in Unity3D and controls a peripheral color sensor and servo motor via an additional Arduino micro-controller board (A). The mounting spot for the color sensor (C) and servo motor (S) at the funnel (F) are displayed in the bottom image.

therapy. Picking the ball and placing it in the funnel, for example, targets at *hand-eye coordination* or the understanding of *spatial relationships*.

First Impressions from the Field

As evident from Figure 2 and 3, we interpret *design* as an iterative process, which is initialized by deploying 'affordable' prototypes to collect user feedback to then gradually progress the design [2]. Hence, we are currently conducting field studies with our first fully interactive prototype and have demonstrated it to one ophthalmologist and one family (c.f. Figure 2) by now.

The ophthalmologist is involved in the yearly examination of children with CVI on a regular basis. In response to the ball run, he was especially underlining the potential of this toy as a diagnostic tool in combination with eye-tracking. According to this expert, one could assess the field of vision of children by displaying digital elements close to the focus of vision (e.g. the moving ball) and additional salient objects in the periphery. Should the child not perceive the peripheral elements, there might be a problem. In this way, ophthalmologists could measure viewing-angles etc.: "*You could test at which point the child is stopping to follow the ball or whatever is displayed. And next year, to monitor progress, you could check if the child can follow a faster ball*" (Ophthalmologist).

While our prototype does not feature eye-tracking, a therapist was nevertheless able to clearly observe behavior induced by a restricted field of vision. The child of Figure 2 was lowering his head to be able to see the virtual ball running down the track: *"This makes it [the ball run] not only good for assessing vision, but the track is also an appropriate toy for learning alternative strategies for scanning the environment to make best use of the remaining sight the children have. … And the throwing of the real ball into the funnel seems to be a hell of a fun for the kids while exercising their motor skills"* (Therapist).

Conclusion and Future Work

We presented a prototype from a participatory design process involving therapists and children with CVI. At its current state, we employed an interactive and lo-fi implementation of the ball run (see Figure 2 and 3) to test the overall acceptance of the concept with children and to gather feedback from ophthalmologists. As the preliminary results were encouraging, we will go on to implement different ball run tracks and additional effects (game elements with different modalities, etc.), supporting additional therapeutic goals. Motivated by the ophthalmologist, we will also research into the feasibility of supporting visual tests by offering specific ball-run elements and setups, able to test certain examination goals (e.g., peripheral vision).

For the evaluation of the next design iteration, we aim at long-term field deployments in the children's homes to gain holistic insights of how the ball run is perceived by different children with different needs. We will pay particular attention to potential pitfalls of mixed reality (e.g., potential irritations) as well as its advantages.

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