Sensory Substitution Training for Users Who Are Blind with Dynamic Stimuli, Games and Virtual Environments

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ABSTRACT
Sensory Substitution Devices (SSDs) offer people who are blind access to visual information via other senses. One of the main bottlenecks to widespread adoption of sensory substitution is the difficulty of learning to use these devices – both mastering the device and learning to properly interpret visual information. We have recently upgraded the training offered in our lab to congenitally blind EyeMusic users from a static training paradigm to an interactive dynamic one in an attempt to address both challenges mentioned above. This offered us a unique opportunity to explore the effect of this change on both the users and on their sighted personal instructors. We explored users' ability to play simple interactive games and learn visual principles, and explored the feelings and opinions of both the users and instructors during the shift. We found that all users were able to successfully complete these tasks utilizing visual principles such as depth-size, reported a high level of enjoyment and satisfaction for them, viewed these sessions as more effective and highlighted their feelings of a higher sense of independence and control. The instructors were enthusiastic as well, mirrored the users' answers and especially highlighted the flexibility advantage.

Categories and Subject Descriptors
H.1.2 User/Machine Systems; H.5.2 User Interfaces: Auditory (non-speech) feedback;

General Terms
Performance, Experimentation, Human Factors, Standardization

Keywords
Sensory Substitution; training; visual rehabilitation; gamification; Universal access; blind; Auditory Interfaces;

1. Introduction
Imagine a simple game in which a player, target and obstacle are displayed on your screen. Bringing the player to the target without touching the obstacle is typically not a difficult task – as long as you can see. Without vision, identifying the objects and relative spatial layout and tracking their positions as you move is nearly impossible. Even using standard accessibility tools, such as screen readers, would not improve the situation by much – you may be able to "tab" between the objects, if the programmer pre-programmed it, but spatial layout and movement are not typically supported.

Sensory Substitution Devices (SSDs) offer us a tool for transforming visual information into other senses and offering it to people who are blind [1-4,6]. SSDs such as EyeMusic can capture the entire scene and sonify it, enabling users to perceive the visual information in their environment and perform tasks such as object recognition or navigation. Importantly, by sonifying the on-screen information they can do so without need for in-game pre-programming, and can utilize skills from other tasks for dealing with new ones such as the game detailed above.

However, despite recent advances which boost SSD availability and practicality beyond past failures, SSDs are still only in very limited use (For a review exploring these reasons and new mitigating factors in depth see [3]). One of the main causes for this is the bottleneck formed by the long and arduous training required. SSDs are notoriously difficult to learn and require long repetitive simple tasks to master, especially when starting out, leading to user frustration and abandonment of the technology. Furthermore, even once mastered users who are congenitally blind report difficulty in processing the visual information they are offered, such as being confused by occlusion, change of shape and size from different angles and distances etc.

One potential approach is using more dynamic gamified tasks [3,6], recently showing success in many other similar training situations [5,7]. In this work I explore the use of dynamic stimuli and games as a training paradigm for SSDs, specifically as a training paradigm for EyeMusic. We test the ability of a pool of 7 participants who are congenitally totally blind and who had previously trained with EyeMusic via static lessons to perform these dynamic tasks and explore their opinion of the different training sessions via behavioral challenges, surveys & interviews at several time-points. We wanted to explore if they could indeed perform these tasks successfully, how enjoyable and effective they feel it is, and in general gather their thoughts regarding such training games. We also addressed the same survey and interview to their instructors to explore the shift from their perspective.

2. The dynamic training & games
There were three types of additions to the training program (fig 1). All were controlled via keyboard (Arrow, Enter & Space keys).

The first was using dynamic stimuli instead of static ones. Specifically, instead of using many files of different shapes in different colors and locations, we used dynamic objects that could be manipulated by the user or instructor via the keyboard. Beyond saving the tedious work of stimuli creation, it enabled more interesting ad-hoc tasks and enabled sensorimotor perception. This was not a game, but rather a training tool building upon the importance of closing the sensory-motor loop during perception

The second were simple 2D games focused on deepening users' control of EyeMusic, with emphasis on parsing the visual scene for shapes, colors & locations.

The third type was virtual environments experienced from a 1st person perspective. Completing tasks in these environments requires the ability to understand the changes in the visual scene

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caused by user and vantage point movement and different dedicated tasks were focused on different visual principles.

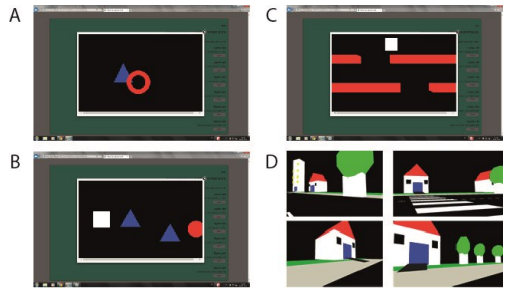

Figure 1 – Game screenshots: (A) Dynamic objects users could manipulate (move, rotate, change shape and color etc.). (B) Navigate to target – Bring the player (white square) to the target (red circle) while avoiding the obstacles (blue triangles). (C) Maze – Bring the player (white square) to the screen's other end while avoiding contact with the red flaming walls. (D) Screenshots from one of the virtual environments

2.1 EyeMusic

EyeMusic is a visual-to-auditory SSD conveying whole scene visual information including shape, location and color (fig 2). It is described in detail in [1] and was previously used for various tasks (e.g. [3] among many others). It is also freely available on iTunes and Google Play. Importantly, EyeMusic can capture the on-screen image and offer the user the visual information from a game without the need for any hardware beyond standard audio output (speakers/headphone). While here we used EyeMusic, it is only one of many auditory-to-visual SSDs currently available, such as The vOICe [4]. We do not claim here any advantages and indeed suggest our results can be generalized for to them as well.

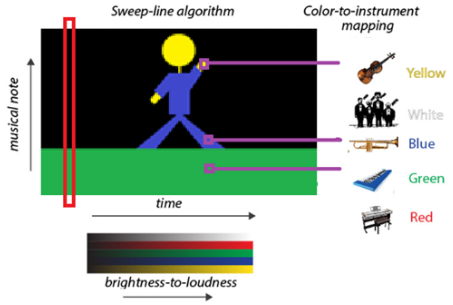

Figure 2. EyeMusic transformation. Left-to-right Sweep-line codes X-value to time, brightness as loudness, Y-Value coded as musical notes and color as different musical instruments.

3. Initial results - performance

All users were able to complete all tasks successfully, and both by self-report and by instructor report did so generally at ease.

The instructors reported frequent returning to the dynamic object trainer for short focused sessions ("I can have a lesson planned and then he has a lot of difficulty with some side point. So I can just stop and focus on that"." I9) and subconscious learning by the users ("when playing she could get around concepts she didn't get when I tried to teach directly. Especially angles and space, but also colors. She just got it by playing without noticing" I8).

4. Initial results - usability

All but one user recommended restructuring their training around the interactive dynamic additions, though both participants and instructors recommended using both types of training.

The interview and survey revealed that participants found the dynamic additions to be more enjoyable, less tiring and more efficient than the static training sessions. Nearly all participants reported that the main advantages of the dynamic session were in their increased feelings of control and independence ("In the dynamic sessions I can work by myself and make new shapes, the shapes that I want." P1, "The big advantage is the feedback I can interpret myself" P7) and enjoyment ("well, you know, the static is kind of boring. Not a lot of variance. The games are more challenging, more creative." P2. "It's just plain more fun." P3).

Instructors' replies mirrored those of the participants (verified by 2-tailed unpaired t-tests, corrected for multiple comparisons). They highlighted higher user engagement and independence ("It makes the training nicer for my participants; they become more active and engaged when they can move the shape themselves". I3 "the main difference between the two types of sessions is how involved, how much agency, the participant has.")

5. Conclusion & Future work

We found that that all participants were able to complete these tasks, utilize visual principles, reported a high level of enjoyment, satisfaction & preference for it and that they viewed these sessions as more effective. The participants highlighted an increased feeling of independence and control. Instructors were enthusiastic as well and highlighted its advantages in terms of flexibility.

This research is only a start in the direction of using structured interactive SSD training and is still far from a final training program. The next main steps are integrating more complex games, optimizing training based on the logged behavioral data from these sessions, comparatively exploring the effects of different games, and exploring generalization across different devices and visual rehabilitation approaches. Beyond training, another interesting aspect is the increase in accessibility of games in general via SSD. While the games presented here are relatively simple, participants saw the potential for future steps and made many suggestions for future games, with recurring requests for games that would enable practicing for the real world such as simulated environments of real-world locations.

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