EXPLORING SOUND TO ENHANCE LEARNING OF ABSTRACT SCIENCE CONCEPTS

Taciana Pontual Falcão
London Knowledge Lab - Institute of Education
23-29 Emerald Street, WC1N 3QS, London UK
t.pontual@ioe.ac.uk

Sara Price
London Knowledge Lab - Institute of Education
23-29 Emerald Street, WC1N 3QS, London UK
s.price@ioe.ac.uk

ABSTRACT
Auditory feedback plays an important role for many educational technologies. This work is part of an on-going study that aims to explore whether the aggregation of sound to visuals on a tabletop may enhance users' interaction and be beneficial for the learning of abstract science concepts. In this paper, we present findings from our initial study in which a number of sounds were elicited, and their mappings to scientific concepts were explored and verified, both with and without visuals. Issues were raised regarding attributes (like pitch), levels of abstraction, duration and continuity of sounds, as well as connection between sounds and visuals.

Author Keywords
Auditory feedback, tangible learning environments, science concepts.

ACM Classification Keywords
H5.2. Information interfaces and presentation: User interfaces. K.3.m Computers and education: Miscellaneous.

CONTEXT
This study is part of an ongoing project investigating how tangible environments affect the way that learners interact with and understand scientific ideas [6]. Tangibles offer the opportunity to augment everyday interaction with the world, combining digital information, in the form of sound, narration, images, text or animation, with concrete objects. As part of this research a tabletop environment has been built. A first application allows for the exploration of physical processes like light absorption, reflection and transmission. Although the visual mode is often a predominant form of representation, the potential for audio and tactile modes in tangible computing requires a broader understanding of their role for learning. Auditory feedback is an important part of many educational technologies. In learning contexts sound has been used to: produce sound patterns through body movement [1]; assist the visually impaired in exploring graphical interfaces [8] or spatial information [5]; mediate understanding of large amounts of abstract data [3]; show progress in task solving activities [4]; and help conveying invisible concepts [7]. Physics of light is particularly challenging, as its behaviour cannot be naturally perceived (eg. specific frequencies of light being reflected or absorbed by a surface). Although visual augmentation can convey some aspects of invisible processes, the role of sound for supporting learning of abstract scientific phenomena is under-researched.

STUDY DESIGN
The main goal of this study was to inform the use of sound in the design of a tangible environment, allowing future investigation of its role in promoting learning. Although it is relatively easy to design sounds for referents that have direct mappings, presenting absolute data with sound is difficult [2]. In order to use sound in the context of the physics of light, types of sounds to represent light phenomena were first elicited (Phase 1). Next, the mappings of chosen sounds with the desired concepts were verified, with and without visuals (Phase 2).

Phase 1: Each participant from group 1 was asked for a verbal description about the "quality" [9] that a sound should have when representing reflection, absorption and transmission of light. Such qualities could include concepts of continuity, bouncing off, or prohibition. Each participant then selected sounds from a set of samples to associate with each of the phenomena being investigated, e.g. whistle (transmission), brake (absorption) and hitting a hard surface (reflection). The aim of Phase 1 was to elicit general descriptions for types of sounds people would a priori link to the concepts involving light, as well as mappings between specific sound samples and the phenomena.

Phase 2: Participants from group 2 listened to the sounds selected in Phase 1 and reported which phenomenon (reflection, absorption or transmission) they would associate to which sound. The aim of this task was to check if the sounds could evoke the expected phenomena. This is particularly important when considering the use of the system by the visually impaired. Participants from group 2 then worked with the tabletop, exploring the interface with and without the sounds chosen in Phase 1, to investigate the effect of combined sound and visuals on interaction.

RESULTS AND DISCUSSION
Preliminary studies were performed with 8 children aged between 7 and 16, to enable exploration of age-related issues to inform future studies. . The flexibility of the tangible environment allows for a wide age range, as different levels of complexity can be explored for similar activities, according to the forms of representation used. Verbal descriptions of qualities of sounds given in Phase 1

were quite uniform. Reflection was associated with the ideas of hitting and bouncing off; transmission was linked to passing or forcing through, in a continuous manner; absorption evoked ideas of evaporating, gathering, unclear mixture of sounds, or changes in pitch and volume. Sounds chosen in the next task generally matched verbal descriptions. For reflection, popular sounds were: cymbal, gunshot and spring bouncing. For transmission, continuous sounds of whistle, cars passing by, and laser swords were chosen. For absorption, chosen sounds, in general, were abstract and continuously changing pitch, except for a chimes sound chosen by the younger children. A number of interesting themes emerged from the studies:

Familiarity with concepts: sounds chosen for reflection had more similarities among participants. In Phase 2 children correctly identified which sound represented reflection. For absorption and transmission, choices were more varied and children did not easily associate the sounds to the expected phenomenon. It may be that children are more familiar with the concept of reflection (e.g. through mirrors) from school and everyday life, as even older children were unfamiliar with the concept of transmission.

Age differences: when chosen sounds were played with the visuals, younger children classified it as a good matching, while the older ones rejected some sounds they had chosen. They justified their reaction declaring that sounds needed to be more abstract, so that they would not be recognized as something concrete (like a doorbell), or evoke associations with real-world things not related to the concepts. Older children tended to go for varying pitches in sounds, which matched their preference for abstraction.

Duration, continuity and inference: short sound samples were used in the study, and participants sometimes took the duration of the sound into consideration, although the focus was on the type of sound. For example, sounds for transmission were supposed to be long, in their opinion. In addition, the visuals run continuously, whereas the sound samples were played for a very short time. When choosing a spring sound for reflection, participants were thinking of the idea of bouncing. However, the sound did not match the visual representation of reflection that consisted of the light beam reaching an object and arrows or ripples continuously coming off it. For absorption, children approved their choice, as they actually wanted a sound that would stop, as a way of showing light had been absorbed. This shows children had in mind a sequence in time to represent the phenomena, i.e., light travels from the source, then it reaches the object, then it is, say, absorbed, and finally the process “finishes”. However, processes related to light rather occur in a continuous manner, and are represented in that way in our visual application. Exploring the use of sounds therefore called attention to a learning aspect that had previously gone unnoticed when only considering visuals.

FUTURE WORK

The preliminary findings presented here will be further investigated to define a set of sounds to be added to the visual application, considering characteristics like pitch, volume, duration, continuity, annoyance, and level of abstraction. Future studies could involve parallel (rather than disconnected) choice of visuals and sounds, aiming to find a proper match. An accurate mapping between sounds and visuals can also enable the use of the interface by the visually impaired, following the principles of universal design. As for these users auditory feedback may replace visuals (although the idea is not to design a solely audio-based system, which would have different implications), it is extremely important to find the most intuitive set of sounds to represent the concepts. Studies with blind children may be needed to verify the effectiveness of sounds in this context. Integration of sounds and visuals will then be more deeply analyzed concerning its effect on children’s awareness, attention, interaction with information and understanding of science concepts.

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