The Accessible Aquarium: Identifying and Evaluating Salient Creature Features for Sonification

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ABSTRACT
Informal learning environments (e.g., aquaria, zoos, science centers) are often inaccessible to the visually impaired. Sonification can make such environments more accessible while also adding to the experience of sighted visitors. This study was to determine the salient features of moving creatures in the sort of dynamic display typically found in such environments and to evaluate the efficacy of sonification in improving the experience of viewing such displays by sighted research participants.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: Social Issues – *assistive technologies for persons with disabilities, handicapped persons/special needs*

General Terms
Human Factors, Design, Performance.

Keywords
Sonification, Dynamic Displays, Visual Impairment, Assistive Technology, Accessibility, Informal Learning Environments, Self Actualization, Hierarchy of Needs

1. INTRODUCTION
The Accessible Aquarium is an effort to satisfy cognitive and aesthetic needs of visually impaired visitors to Informal Learning Environments like aquaria. Although the Accessible Aquarium was conceptualized with the visually impaired visitor in mind, it can be universally applied to make dynamic exhibits more informative and appealing to the general audience as well.

2. THE ACCESSIBLE AQUARIUM DESIGN AND IMPLEMENTATION
The GT Accessible Aquarium project is currently developing the infrastructure to track fish, code their behaviors, and then generate music from those data. The study discussed here is an effort to determine exactly what kinds of data the system needs to obtain. Once we determine what attributes of the exhibit (fish shape, size, speed, location, etc.) to communicate to the listener, we can design the computer vision system to obtain those data. Our investigation was based on an initial sound design that was created to take advantage of the listeners' mental models that correlate certain properties of music with specific behaviors and moods [e.g., 3-5]. For example, high-pitched sounds may be associated with smaller sizes, and low-pitched sounds may be associated with larger sizes. Similarly, fast paced music is associated with quick movements, whereas music with a low tempo is mapped to slow heavy motion. We utilized these kinds of mappings to represent the movement of animals (fish and also ants) with music. Stereo panning has naturally been used to indicate direction of motion along the left-to-right axis [2].

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RESEARCH METHOD
To date, the creature characteristics that have been sonified (including in the three videos used here) [1] have been decided on by the intuitive deduction of the composers. However, we need to obtain empirical evidence of the relevance of these characteristics. What is it that sighted visitors perceive to be the most important in a dynamic exhibit, i.e. what features do they notice the most? and, Can users make associations between the music and what they are seeing in the sonified demo videos (i.e., does the music actually help them experience the aquarium?).

A total of 13 sighted university students saw three videos each with an accompanying soundtrack designed in prior research [1]. The videos included a real aquarium, a simulated fish video, created by computer animation, and an ant video. Each was shown to the users via high definition projection, about 8 feet by 6 feet, viewed from a distance of approximately 10 feet.

2.1 Procedure
Evaluations were divided into two parts, one focused on each of the research questions discussed earlier. The order of parts was randomized between subjects. Also, the order of the videos presented within each part was randomized. The entire process was recorded for subsequent quantitative and qualitative analysis. In the first part the participant was asked to watch the videos without sound and "think aloud" about what was seen as the video progressed. Sonified videos were shown in the second part with no "think aloud" to minimize distraction. Both sessions were followed by a short semi-structured interview.

3. RESULTS AND DISCUSSION
3.1 Analysis of "Think-Aloud" Comments
The videotape for each participant was coded for references to features, comments, and other information. For each video, the mean number of times a feature was mentioned, over all participants, was then calculated (see Table 1). From this, a few features emerged as more important than the others. The data in Table 1 are sorted by overall salience of a feature (as measured by references and mentions). Also of interest was whether the features differed in their importance across the different videos. To determine this, a repeated-measures ANOVA was performed

Table 1. Mean number of mentions of Creature Features.

Creature	Grand	Std	Real	Sim	Real	F	p	
Location	4.05	0.50	5.46	3.92	2.77	6.951	0.006	*
Color	3.69	0.37	2.00	8.62	0.46	56.671	0.001	*
Size	2.74	0.38	5.92	1.85	0.46	25.557	0.001	*
Species	2.28	0.55	2.85	3.92	0.08	5.679	0.017	*
Enter/exit	2.18	0.38	2.46	1.08	3.00	4.361	0.029	*
Direction	1.90	0.38	1.92	3.00	0.77	6.584	0.014	*
Behavior	1.85	0.36	0.69	2.46	2.39	3.120	0.080	~
Background	1.59	0.31	2.00	2.00	0.77	3.361	0.053	~
Interacting	1.10	0.12	0.69	0.92	1.69	3.852	0.055	~
Grouping	0.87	0.13	2.15	0.08	0.39	17.818	0.001	*
Speed	0.69	0.20	0.85	1.00	0.23	2.383	0.121	
Liveliness	0.44	0.22	0.23	1.00	0.08	2.362	0.145	
Surround	0.39	0.15	0.77	0.23	0.15	3.369	0.075	~
Shape	0.26	0.11	0.54	0.15	0.08	4.326	0.051	~
Feeding	0.18	0.06	0.23	0.15	0.15	0.103	0.896	
Sound	0.08	0.06	0.00	0.15	0.08	1.565	0.233	
Acceleration	0.00	0.00	0.00	0.00	0.00	-	-	

with video-type as a grouping variable. Some of the variables were considered more or less important in some videos than in the others. The results (*F* and *p*) are listed in Table 1 (the two rightmost columns). Significant results (indicated with an asterisk, *) and marginally significant results (indicated with a tilde, ~) indicate that the features had reliably different saliences in the different videos.

3.2 Qualitative Analysis of Interviews

The open coding technique was used to analyze responses to semi-structured interviews. The first section in this analysis covers the viewers' perception about, and interest in, the exhibit and the points of interest during the viewing session, while the second half covers the same for the sonified videos.

3.2.1 Perceptions and Points of Interest

Color was the primary characteristic of interest with the **Simulated Fish video**, with a number of people also commenting about the fast *speed* and the *variations in speed* of the different fish. A number of the fish had erratic *motions* that were noticed by a majority of the participants. The viewers also showed interest in what they thought to be *interaction* among the fish and often made up little "explanations" for them. When questioned about their favorite fish, participants usually chose the *most brightly colored* fish, or one that somehow triggered a "*personal connection*" with the viewer. The **Real Fish video** did not have as much color differentiation and hence the fish were primarily distinguishable by *size* and *shape*. Viewers liked the whale shark due to its large size, fast speed and instant *recognizability*. Viewers also expressed interest at *interactive behavior*. Perceptions of the **Ant video** were different due to the limited number of creatures on screen (never more than three) as well as the absence of any distinguishing characteristics between the ants. The high point of interest for most viewers was the hole in the center and they enjoyed watching the entries and exits. A number of viewers expressing a desire to know more about where the ants were and what they were doing.

Viewers were most attracted to creatures that they know more about, or to which they could associate a past experience, often involving a feature film (e.g, "Jaws", "Finding Nemo"). Participants also tended to make up stories to support what they saw, often hoping and expecting to view an exciting culmination to the ongoing events. Most viewers paid attention to a single creature for 4-5 sec. then attended to another creature, either because it came closer or made a sudden movement. Viewers most often focused their attention on the center of the screen. An event that attracted a viewer's attention was often a 'grand' entry or exit, especially the whale shark in the Real Fish video and the hole-based interactions in the Ant video. Most viewers claimed they paid attention to one creature at a time unless a larger number were grouped together and interacting.

3.2.2 Visual Features-to-Sound Mapping

Most said that sonification added to the experience. There was some variation in whether the participants felt that the qualities of the sound matched the visuals. Some commented on how the low-pitched tones used for the sharks were evocative of the music in the film "Jaws" (this was somewhat intentional). Likewise, the music corresponding to one of the other fish was described as being "regal." On the other hand, some participants commented that they liked the music, but that it didn't seem to "fit." Similarly, the sounds were seen by some to correlate with the movements and behaviors of the fish, while others did not see such correlations. Interestingly, those who were told in advance the nature of the mappings (e.g., higher pitch for a fish higher up in the display) did not always notice the correlations. Likewise, those who weren't told the correlations sometimes grasped them, and other times formed their own spontaneous associations. Several participants felt that the music added to the overall experience. Several also noted that the music called attention to things that they hadn't noticed when they watched the video the first time.

4. CONCLUSIONS

Location, color, size, species, entering/exiting, direction, behavior, background/environment, and interaction were universally considered to be important to observers. Thus, any system for sonifying the movement of such creatures in an aquarium would need to provide information on those qualities, regardless of the vision level of the visitors. Also, if there is considerable color variation in an exhibit, then color seems to be more salient. If creatures suddenly enter or exit, or make rapid changes in direction, then those features are salient. Thus, a consideration of the type of exhibit, and the specific attributes of the creatures within the exhibit, need to be considered in sonification.

5. REFERENCES

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