Probing Preferences between Six Designs of Interactive Sonifications for Recreational Sports, Health and Fitness

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ABSTRACT

This pilot study investigates six interactive sonifications of accelerometer data in the context of outdoor sports activities. The designs investigate different techniques and theories of sonification. Through this study we also trial and develop mobile technologies for interactive sonification, and a 'technology probe' methodology for research in outdoor sporting situations. The sonifications were synthesised in realtime on an Apple iPod touch from the onboard accelerometers. The selections between sonifications were automatically recorded on the device during usage in trial sessions. Participants were not given any specific tasks and used it in activities that included walking, jogging, martial arts, yoga and dance moves. The participants were interviewed about the experience to find out how they could imagine using it, their suggestions for improvements, and their preferences for different designs. The general preference for the musical and the sinusoidal sonifications agrees with the data about selections collected by the probe. However the interviews also indicate that two of the most preferred designs are also among the least preferred. The results provide inspiration and guidance for the design of further interactive sonifications for sports, health and fitness activities.

1. INTRODUCTION

"Let's get physical, let me hear your body talk" were lyrics from Olivia Newton-John's hit pop-song that optimised the dance aerobics exercise fad that swept the world in the 1980's [1]. This fad firmly established popular music as part of health and fitness activities at the gymnasium. The music added to the enjoyment of group exercise, motivated people to keep up the pace, and helped in learning and coordination of routines. Today it is common to see people wearing headphones at the gym and listening to their own choice of music during individual workouts with weights and exercise machines. Digital music technologies are small and robust enough that walkers and joggers can listen to music outside the gym well. The Nike sports shoe company has tapped into the mobile sports music phenomenon with an accelerometer inserted in a sports shoe that transmits data wirelessly to an Apple iPod touch. The product allows you to "hear how you run" by providing voice feedback about pace, distance and calories burnt during the exercise session. A "Power Song" that has been flagged in your personal sports music play-list can be triggered to "motivate you mile after mile" [2].

The second generation Apple iPod touch has acceleration sensors built-in, and enough computational power to synthesise sounds in realtime for games. These capabilities have also led to the development of musical games and new forms of interactive music. For example "Little Boots is a reactive remixer that transforms your world into the three Little Boots hits Remedy, New In Town and Meddle. Your movements and sounds create a unique realtime remix each time you listen. If you are already a fan of Little Boots, this is a completely new way to listen to your favorite tracks. It's a new way to experience music" [3].

These capabilities also enable interactive sonifications of the accelerometer in the Apple iPod touch that could provide much more detailed continuous feedback than a voice synthesiser. However sonifications of digital data do not usually sound like the beat driven dance or emotive rock and roll that people typically listen to while jogging or at the gym. In early studies of sonification in swimming and rowing Effenberg observed that "if possible, the targeted person's musical taste has to be accommodated for" [4]. Following on from this work Henkelmann noted that the sine-tone based sonification of 4 sensors on a rowing machine soon became irritating with repetitive use. In his Master's thesis on aesthetics of sonification he explored computer music techniques such as Phase Aligned Formants synthesis in an effort to develop more pleasant sounding sonifications for more general audiences outside the science lab [5]. These prior works on the aesthetics of sonification in sports motivated a further exploration of techniques, approaches and theories of sonification at a COST-SID workshop in Berlin in 2009 [6]. Nina Schaffert provided acceleration data recorded from a four-man rowing skull from her study with elite rowers in Germany [7]. In this study coaches and athletes who listened to a sine-wave sonification of this data said they could hear useful information about the phases of the rowing stroke that they thought could improve rowing performance. The sonifications of this data produced during the COST-SID workshop included a repetition of the previous sine-wave (*sinification*) pattern, a midi-based sonification (*midification*), a repetition of the Phase Aligned Formants technique from Henkelmann, a metaphorical design that used water and impact sounds, a soundscape listening approach, and a techno music inspired design. The sonified soundtracks were synced to a video of the rowing trial and are online at [8]. After the workshop Nina showed these videos to elite rowers after they had tried the sine-wave *sinification* in on-water trials. These rowers all expressed a preference for the *sinification* over any of the other designs [6]. This finding is in contrast to Henkelmann's observations that a *sinification* became irritating in trials at the gym, and the efforts to produce more aesthetic sounding sonifications during the COST-SID workshop. Does the actual usage in a physical activity change the appreciation and enjoyment of sonifications? What is the effect of the competitive level of athletes on preferences in sporting sonifications? Does the way a sonification sounds affect the acceptance, enjoyment and usage? How can function and aesthetics both be designed into a sonification? Should sonifications of the same data sound different for different sporting activities? Do different sonifications induce different kinds of activities? Do they inspire new activities?

In this pilot study we introduce a 'technology probe' methodology that allows us to move from the design of sonified soundtracks of recorded data to the design of interactive sonifications in real world sporting activities. The following section introduces the methodology and the technology that was developed to support it. The following section then describes the sonifications that were developed in the study. The data from the trial sessions is plotted and analysed for preferences and activity. The results are compared with comments in post trial interviews. The final section summarises the findings and suggests further work.

2. PILOT STUDY

The pilot study investigates six different sonifications of the accelerometer data. Through this study we aim to explore and open up the space of sonification designs, and the space of sporting applications. The study also trials and develops new mobile technologies for interactive sonification, and explores a methodology for research in-situ in outdoor sporting situations.

2.1. Methodology

Studies in sports science are often carried out through simulations on gym equipment such as jogging and rowing machines. Video recordings are also used to capture information from actual sporting events outdoors. Mobile technologies such as the Nike+iPod now make it possible to capture acceleration data in an actual running session that can be uploaded afterwards to an online journal for analysis.
Mobile technologies open up the opportunity to trial the 'technology probe' methodology that has been developed in Human Computer Interaction. "Technology probes are simple, flexible, adaptable technologies with three interdisciplinary goals: the social science goal of understanding the needs and desires of users in a real-world setting, the engineering goal of field- testing the technology, and the design goal of inspiring users and researchers to think about new technologies" [9].

Probes are a design-oriented approach aims to open up the space of possible solutions rather than moving towards a single solution or product [10]. Probes allow studies to move outside the laboratory as the primary site for interactions between designers and those who might be affected by their activities. Probes are expected to change the behaviour of those that interact with them. While the original probes collected information about behavioural responses from the participants through creative exercises such as taking photographs or writing postcards, a technology probe can automatically collect and store data about its use over time for later retrieval. We hope that this methodology will provide a foundation for the study of how people really use an interactive sonification in outdoor sporting activities.

2.2. Apparatus

"On the engineering side, technology probes must work in a real-world setting. They are not demonstrations, in which minor details can be finessed. Therefore, the main technological problems must be solved for the technology probes to serve their purpose" [9].

The probe developed in this study is a mobile device that synthesises six different interactive sonifications of acceleration. The interface consists of six large coloured radio-buttons, shown in Figure 1, that select between the six different sonifications. The device records data from the onboard 3D accelerometer along with the timing of selections of different sonifications. The audio output can also be recorded for later playback. The probe is built with an Apple iPod touch equipped with a 3-axis accelerometer that has a nominal update rate of 100Hz. There is a touch screen interface and a stereo-audio headphone socket. The probe can be worn strapped to an armband designed for sporting activities such as walking, jogging, and aerobics. A waterproof housing and headphones also potentially allow kayaking, rowing, swimming and other water sports.

Figure 1. *The Sweatsonics technology probe for interactive sonification in sports*

The sonifications are implemented with the RjDj software [11] that allows sound synthesizer programs to be programmed in the Pure Data visual programming language for synthesis on an Apple iPod touch [12]. The x,y,z acceleration values are written as floating point numbers to a new ascii file at a rate of once per second. The naming convention for the file encodes the session ID, time since start of session in seconds, and the current sonification selection in the form

<sessionID>-<time-in-seconds>-<currentselection>.txt

The update rate of the 3D acceleration in these files is typically 20 Hz when the sonification algorithms are running.

The six sonifications, listed in Table 1, are iterations of prototypes that were developed during the COST-SID sonification workshop in Berlin in June 2009 [8]. Each sonification sounds distinctly different even though they are all audio representations of the same underlying data. You can listen to examples of each online at [13]. This range of designs is not definitive but serves to illustrate a variety of sonification theories and to open the space of designs that are possible even in the sonification of a single data variable.

Selection	*Sonification*
red	*Algorithmic music*
yellow	*Sinification*
green	*Weather metaphor*
cyan	*formants*
blue	*musicification*
magenta	*stream-based*

Table 1. *Selection Colour by Sonification Design*

The red button selects algorithmic music in which the acceleration in the x,y,z axes controls sounds generated by three FM synthesis instruments – one for each dimension. The sonification sounds like esoteric, generative or improvisational ambient electronic music. However there is a many to many mapping between the data variables and synthesis parameters that has been designed for musical effect. The music is influenced by the data but the informational content is not necessarily clear.

The yellow button is a parameter mapping of a continuous data variable to the pitch of a sine tone. This design has been used many times in sonifications of different kinds of data, and has been shown to improve sports performance in recent studies with elite rowers [6]. The repetition and success of this design qualifies it as an example of a sonification design pattern [14], which we have called a *sinification*.

The green button selects a *weather metaphor* that aids the interpretation by using familiar everyday sounds that vary in expected ways. In this metaphorical design y-axis acceleration is represented by the sound of the wind blowing. A lack of acceleration is heard by a lack of wind, which is something that you can't hear in the *sinification*. The *weather metaphor* design maps the same data to both the brightness and loudness of a band-passed noise. Additional information about jerkiness is analysed from rate of change in acceleration and is conveyed by a roll of thunder triggered by threshold.

The cyan button selects the *formants* design that maps 3D acceleration in x,y,z directions into the 3D timbre space of a speech formant synthesizer. Different vowel-like sounds distinguish different directions so that positive acceleration in the y-axis produces a different vowel than a negative acceleration. This design has the advantage that positive acceleration sounds different from negative acceleration.

The blue button is the *musification* which is a more complex example of algorithmic music that includes some narrative and compositional structure. Real-time analysis of turning points, zero crossings, and derivatives of the acceleration influence the synthesis and sequencing of six FM instruments that include a drum-machine.

The magenta button selects the *stream-based* sonification uses the theory of auditory scene analysis to draw listening attention to repeating patterns in the acceleration over time using figure/ground gestalt [15]. This approach highlights rhythmic or repetitive actions, and may help with synchronization between team-mates.

2.3. Participants

The participants were attendees at the Human Communications Science (HSCnet) annual national symposium in Sydney 2009 [16]. Participants were recruited through a demonstration of the technology probe during a poster session at the conference. The subjects (*N*=15) were postgraduate researchers (males and females) from 20 to 60 years of age. They volunteered and were not compensated for their participation in any way. No information that could allow the identification of individual subjects was collected during the experiment. All data recorded with the technology probe was anonymous.

The trial began with an interview in which the participant was introduced to the general idea of sonification in sports, and shown how to use the technology probe. They were told about the logging of the data and asked for their consent to take part. They were then asked about their sporting activities, whether they listen to music during these activities, and any previous experience of sonification. The probe was fitted to the upper arm and the headphones were then fitted and tested. The participant then tried some test selections with the interface buttons to make sure everything was working. They were then free to take the probe out for a trial session. They were not given specific tasks or activities to perform, and were not given any time constraints. When they returned, the device was removed and there was a post-session interview to gather overall impressions, preferences, and suggestions of applications and improvements.

3. RESULTS

A data log from an individual trial session (ID95) is shown in Figure 2. The plot shows the acceleration in the x,y,z directions in units of (g's) on the vertical axis over time (seconds) on the horizontal axis,. This session was 600 seconds (10 minutes) in duration. The acceleration plots are coloured by the selection button colour on the interface according to the colour key in Table 1. For example, *sinification* is yellow while *algorithmic music* is red.

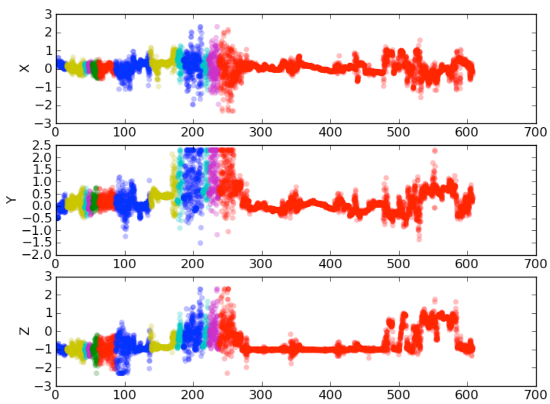

Figure 2. *Acceleration in x,y,z (g's) over time (seconds), coloured by selection for session ID95*

The plot of this session shows several distinct stages of behaviour with the probe. In the first stage the probe is shaken while all the sonification selections are explored, some of them several times. In the next stage there are longer explorations of 30-50 seconds with *algorithmic music*, then *musification* then *sinification*. In the third stage, from approximately 200-300 seconds, the sonifications are explored in more extreme conditions by shaking the probe vigorously, while scanning through five of the six selections, skipping the *weather metaphor*. In the final stage, from approximately 300-600 seconds, the selection choice is fixed on *algorithmic music*

while the acceleration trace shows a range of different events and levels of activity.
The time the subject spent listening to each selection during this session is summarised in Figure 3.

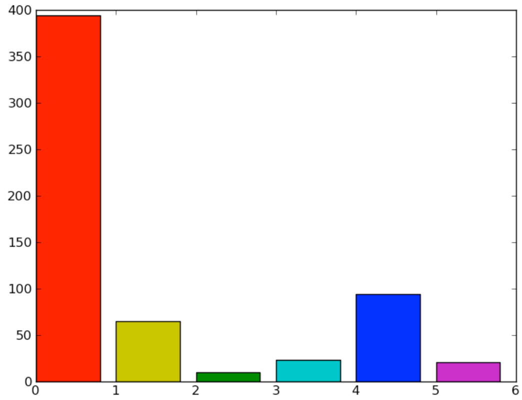

Figure 3. *Time (seconds) by selection for session ID95*

More time (394s / 65%) was spent with *algorithmic music*, than all the other selections together (213s / 35%). The *musification* (94s / 15%) and the *sinification* (65s / 11%) take up most of the rest of the time. The other sonifications received much less listening time with *stream-based* (23s / 4%), *formants* (21s / 3%) and *weather metaphor* (10s / 2%).

The overall selection times across all the subject sessions is shown in Table 2. The duration of the sessions varied from 120 seconds (2 minutes) to 1200 seconds (20 minutes) with the average being 441 seconds (7.35 minutes). Overall these results show that most time was spent with *algorithmic music* followed by *sinification* and *musification*.

Selection	Total (seconds)	Average (seconds)	Percentage Time
algorithmic music	1903	127	29
sinification	1262	84	19
musification	1213	81	18
stream-based	911	61	14
formants	702	47	11
weather metaphor	613	41	9

Table 2. *Time (seconds) by selection for all sessions*

A bar-chart of the time in each selection across all sessions is shown in Figure 4. The overall pattern of preferences is not uniform (Chi-squared test, p<<0.01) and is similar to the pattern of individual preferences in Figure 3. Nevertheless many of the other individual plots vary considerably from this pattern.

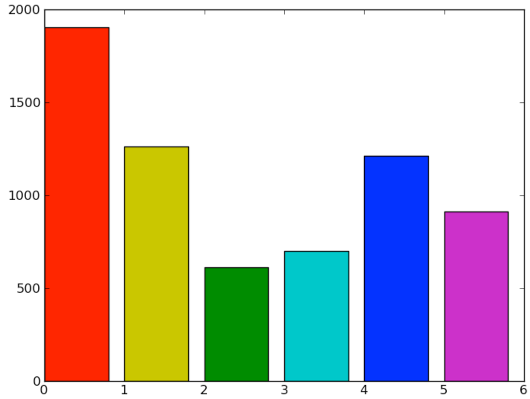

Figure 4. *Time (seconds) by selection for all sessions*

3.1. Interviews

The participants listed their sporting activities as walking, jogging, running, cycling, canoeing, triathlon, swimming, gym, martial arts, yoga, dancing and aerobics. They engaged in these activities daily, 3x per week, weekly, monthly, or irregularly. Although we began with the hypothesis that music is now a common part of recreational sports activities most of the participants in this study did not choose to listen to music during these activities. One listened to dance music because it “takes your mind of the pain”. All were familiar with the touch-screen interface to the Apple iPod touch/iPhone. Although the participants were attendees at a International Conference on Music Communication Science it was surprising to find that only three of the 15 had any previous experience listening to a sonification.

Afterwards the participants were asked the following questions.

Can you describe your experience with the sonifications?
“it motivated me to move.”
“I played with the different sounds: one was more musical; one more like wind.”
“I preferred the left side (hard beat). You were able to keep the beat.”
“it is easy to get into a rhythm.”
“it gave me biofeedback.”
“I kept walking faster to see what happened”
“it could be good for generating music, movement and sound art performances”
“individual use, dance with yourself, maintaining a steady beat, and playing music”
“movement related music performance”
“jogging in sync”
“train yourself to move, coordinate movements, entertainment”

Which selection did you prefer the most?
“red - more variety, more interesting, more sensitive to speed”
“red is minimal electronic synthesiser, subtle, more musical”
“red and yellow - they reinforced your pace”
“yellow provides squishy sounding movements”
“green– it was nice and mellow”
“green - fitted with the environment”
“green - the sound of it, insects flying and going faster when you go faster”

"green – wind sound - it was quieter; but also blue and red – more musical."
"cyan – no annoying disco crap"
"cyan and yellow because I'm a fan of glitch music"
"blue and red - just interesting with the relationship, moving faster sounds faster, and gives feedback"
"blue and red – both had a beat and rhythm"
"blue - has most going on, generally more musical"
"blue – more beat and rhythm"
"blue – most going on, generally more musical"

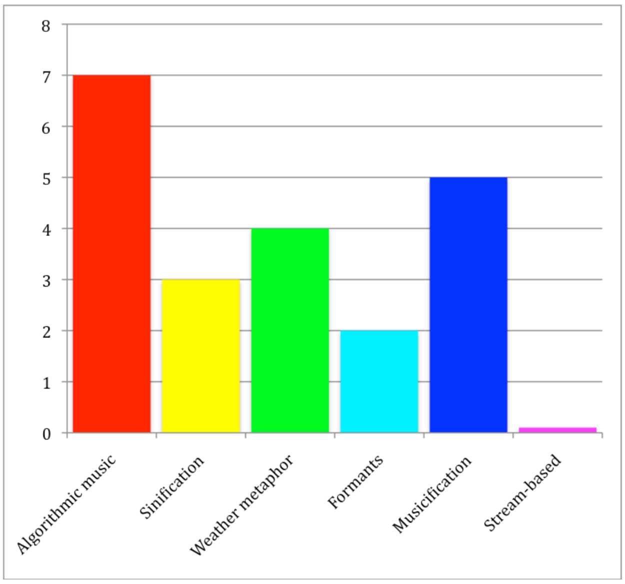

Figure 5. *Number of nominations for most liked*

Question: Which selection did you prefer the least?
"yellow - really weeeooo weooo - can't do anything"
"yellow – too UFO scifi like"
"yellow - too synthetic"
"yellow, has no rhythm, would have been good with a beat"
"green – didn't change"
"cyan - sounded techno, didn't like it"
"cyan – too constructed"
"cyan - too high pitched"
"cyan"
"blue wasn't synced to movements"
"blue – not interesting"
"blue - noisy and distracting"
"blue – too disco"
"blue - the rhythm changes are too obvious"
"magenta - too staccato and not enough variation"
"magenta is distorted sounding"
"magenta – boring, ticking, too little going on"

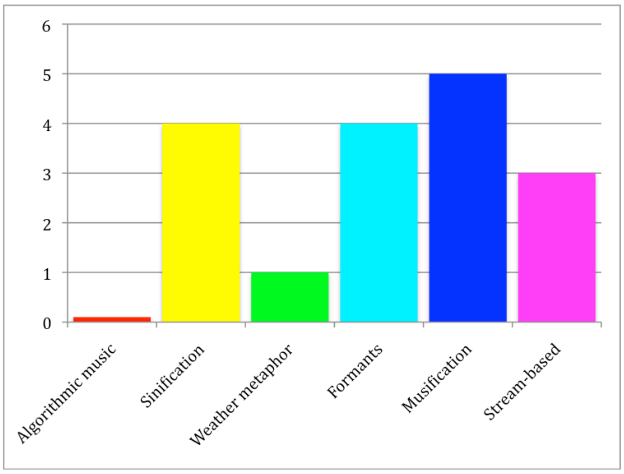

Figure 6. *Number of nominations for least-liked*

Can you imagine ways it could be used, or do you have any suggestions for improvements?
"make one that sounds like the seashore"
"good for jogging on a busy road to zone out, to concentrate
"too bulky, headphones get in the way"
"it would be good for meditation"
"needs more catchy riffs; or make it sound like pink floyd; dark side of the moon"
"feedback for cadence-rotation in cycling, or running-pace"
"needs to be smaller and lighter for the gym"
"it would be good to block out surrounding noise at the gym or use it on an airplane –"
"more bass"
"feed to speakers for indoor activities where more than one person could enjoy, and it would keep people rhythmic"

4. DISCUSSION

Four kinds of exploration behaviour with the technology probe were interpreted from the plot of acceleration coloured by selection in Figure 1. combined with the bar-chart of time spent in each selection in Figure 2.

* *overview* in which the user explores the entire range of selections that are available, spending short amounts of time with each.
* *narrowing* in which the user trials to a subset of the most preferred selections for longer periods.
* *testing* in which the user trials most of the available selections again for shorter periods under more extreme conditions, but leaving out the least preferred selections.
* *choice* of the most preferred sonification for extended usage in a sporting activity.

Applying this interpretation to session ID95 the final *choice* is *algorithmic music*, and the least preferred sonification is the *weather metaphor*. This interpretation is supported by the bar-plot of time spent with each selection which also shows more time spent with the *sinification* and the *musification* that were the other two main selections during the *narrowing* phase.

The aggregate plot of time spent with each selection across all 15 sessions follows a similar pattern of overall preference for *algorithmic music*, followed by *sinification* and *musification*, and then lower levels of preference for *stream-based*, *formants* and *weather metaphor*. The preferences interpreted from the data gathered with the probe correspond with the most preferred sonifications in the post-experiment interviews. The *algorithmic music* is most preferred and is not nominated among the least preferred. However the plot of least-preferred selections is not a simple inversion of most-preferred. The *sinification* and *musification* are both among the most preferred and the least preferred. *Weather metaphor* was moderately preferred and was not among the least preferred, whilst *formants* was weakly preferred and moderately least preferred. *Stream-based* was not nominated among the preferred and was moderately ranked among the least-preferred.

5. CONCLUSIONS

This pilot study developed a 'technology probe' method and device to investigate preferences between six different interactive sonifications in recreational sporting activities. The technology probe was used to capture acceleration data and user selections from subjects engaged in outdoor physical activities that are difficult to simulate in a laboratory. An analysis of the combination of acceleration and selection data allowed us to understand four initial phases of exploration behaviour with the probe that we called *overview, narrowing, testing* and *choice*. There was a general pattern of preference for *algorithmic music*, followed by *sinification* and *musification*. However the post trial interviews indicate that the *sinification* and the *musification* also ranked as the least preferred sonifications. These initial results indicate that there are subgroups with different aesthetic and functional requirements. Some subjects may prefer the more conventional listening experience of a musical sounding sonification, while others may prefer more distinctly informational sonic feedback. These differences may be influenced by competiveness, previous experience with music and sonifications in sports, and the kind of sporting activity. There was a general agreement between the analysis of preference from the technology probe, and the preferences expressed in interviews. This correspondence indicates that the technology probe has potential for future studies of sonification with athletes of different levels of competitiveness in authentic sporting contexts.

6. FUTURE WORK

This study has identified aesthetics and functionality as aspects of sonification in sporting activities. In future work we aim to tease apart these aspects of the sonification design in sports. Do recreational sports have different aesthetic and functional requirements than competitive sports? Does the functional design of the sonification of accelerometer data differ in different sports? What other phases of interaction occur with longer experience with the probe? Does the duration of experience with the sonifications influence the final choice? How can functionality be designed to support team sports? Does the design need to be changed for different environmental contexts? The future work will involve further development of the technology, methodology and sonification designs that have been explored in this pilot study.

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