Experimentally Derived Guidelines for the Creation of Earcons

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ABSTRACT
There is a lack of guidelines for designers to use when creating sounds for their interfaces. This paper proposes a set of general guidelines for the creation of earcons based upon six experiments we have performed. Using them a designer will be able to create effective earcons.

KEYWORDS
Earcons, auditory interfaces, multimodal interfaces, sonification, guidelines

INTRODUCTION
Arons & Mynatt [1] have suggested one problem in the creation of auditory interfaces (p 44):

> "…the lack of design guidelines that are common for the creation of graphical interfaces has plagued interfaces designers who want to effectively build on previous research in auditory interfaces".

To try and overcome this problem we propose a set of guidelines for the creation of *earcons* [4]. These are abstract, synthetic sounds that can be used in structured combinations to create sound messages to represent parts of an interface. They have been used to sonify several interfaces and shown to be effective at communicating complex information in sound (see Brewster [5] for a review). We conducted two detailed exploratory experiments into earcons [8] and since then have conducted four more experiments using them. One experiment tested *parallel earcons* (where two earcons were played at the same time) [10] and the other three used earcons to correct usability errors with graphical widgets [5, 6, 9]. We showed that, for example, by sonifying buttons and scrollbars the time to recover from errors, the time taken to complete tasks and workload could all be reduced without making the interface more annoying [5]. From these experiments we have gained detailed knowledge of designing with earcons. This paper proposes a set of guidelines for the creation of earcons based on these experiments.

GUIDELINES
The creation of a set of earcons to sonify an interface depends on the interface and what the application behind it does. However, some general guidelines can be given. Some of these may appear obvious but as yet there are few examples of effective earcons so we thought it necessary to make all aspects of earcon design explicit. This is a list of guidelines, references will be given to the work from which they come because there is not enough space here to give details of all the experiments.

When designing a family of earcons start with timbre, register and rhythm [5]. These can be used to create the basic structure. For example, each family of earcons might have a different timbre and default register. This would differentiate it from other families of earcons. Each family could also be given a different spatial location. Rhythm can then be used to create the major sub-groups within each family. To further differentiate the sub-groups pitch, intensity, chords or effects such as chorus or delay can be used. Care must be taken to make sure that the earcons are recognisably different.

If listeners must recognise each earcon without reference to any other, i.e. make absolute judgements, then there must be big differences between them. If listeners are able to make relative judgements then differences can be smaller. Each of the different parameters that can be manipulated to differentiate earcons will now be described.

Timbre
Use musical instrument timbres, simple tones such as sinewaves or square waves are not effective [5]. Where possible use timbres with multiple harmonics as this helps perception and can avoid masking. Timbres that are subjectively easy to tell apart should be used. For example, on a musical instrument synthesiser use 'brass' and 'organ' rather than 'brass1' and 'brass2'. However, instruments that sound different in real life may not when played on a synthesiser, so care should

be taken when choosing timbres. Using multiple timbres per earcon may confer advantages when using compound earcons [5].

Register

If listeners are to make absolute judgements of earcons then pitch/register should not be used [2, 7]. A combination of register and another parameter would give better rates of recall. If register alone must be used then there should be large differences between earcons but even then it may not be effective. Two or three octaves difference give better recall. Much smaller differences can be used if relative judgements are to be made.

Pitch

Complex intra-earcon pitch structures are effective in differentiating earcons if used along with rhythm or another parameter. The maximum pitch used should be no higher than 5kHz (four octaves above C_3) and no lower than 125Hz-150Hz (the octave of C_4) so that the sounds are not easily masked and are within the hearing range of most listeners [14].

Take care that the pitches used are possible given the chosen synthesised timbre; not all instruments can play all pitches. For example, a violin may not sound good if played at very low frequencies. If a wide range of pitches is needed then timbres such as organs or pianos are effective.

Rhythm, duration and tempo

Make rhythms as different as possible. Putting different numbers of notes in each rhythm is very effective [5]. Patterson [14] says that sounds are likely to be confused if the rhythms are similar even if there are large spectral differences. Small note lengths might not be noticed so do not use notes less than 0.0825 sec. However, if the earcon is very simple (one or two notes) then notes as short as 0.03 sec. can be used [6].

Earcons should be kept as short as possible so that they can keep up with interactions in the interface being sonified. Two earcons can be played in parallel to speed up presentation [10]. Earcons with up to six notes played in one second have been shown to be usable. In order to make each earcon sound like a complete rhythmic unit the first note should be accented (played slightly louder) and the last note should be slightly longer [13]. Changing the tempo, speeding up or slowing down the sounds, is another effective method for differentiating earcons.

Intensity

Great care must be taken over the use of intensity because it is the main cause of annoyance due to sound [3]. The overall sound level will be under the control of the user (in the form of a volume knob). Earcons should be kept within a narrow intensity range so that if the user turns down the volume no sound will be lost or turns it up then no one earcon will stand out and be annoying.

Listeners are not good at making absolute intensity judgements [11]. Therefore, intensity should not be used on its own for differentiating earcons. If it must be used in this way then there should be large differences between the intensities used. This may lead to annoyance on the part of the user because it contravenes the previous guideline. Some suggested ranges [14] are: Maximum: 20dB above threshold and minimum: 10dB above threshold.

One of the main concerns of potential users of auditory interfaces is annoyance due to sound pollution. If intensity is controlled in the ways suggested here then these problems will be greatly reduced [5].

Spatial location

This may be stereo position or full three-dimensions if extra spatialisation hardware is available. This is very useful for differentiating parallel earcons playing simultaneously [10]. It can also be used with serial earcons, for example each family of earcons might have a different location.

Making earcons attention-grabbing

In many cases earcon designers want their sounds to capture the listener’s attention. This can be achieved in different ways. It can be done by using intensity. This is crude but effective (and very common). However, it is potentially annoying for the primary user and others nearby so we recommend other methods. Rhythm or pitch can be used (perhaps combined with lower intensity), for example, because the human auditory system is very good at detecting dynamic stimuli. If a new sound is played, even at a low intensity, it is likely to grab a listener’s attention (but not that of a colleague nearby). As another example, if the rhythm of an earcon is changed (perhaps speeding up or slowing down) this will also demand attention.

Other techniques for making sounds attention-grabbing are to use: High pitch, a wide pitch range, rapid onset and offset times, irregular harmonics and atonal or arrhythmic sounds (for more see [12]). The opposites of most of these can be used to make sounds avoidable but in this case the main parameters are low intensity and regular rhythm.

Compound earcons

When playing serial earcons one after another use a 0.1 second gap between them so that users can tell where one finishes and the other starts [7]. If the above guidelines are followed for each of the earcons that is to be combined then recall rates will be high.

CONCLUSIONS

This set of guidelines will allow an interface designer to use earcons effectively. The designer will not have to deal with problems that we faced in designing the earcons for our experiments. Using them an he/she can create a set of usable earcons for a multimodal interface. The earcons will communicate their messages effectively and be easily recognisable and distinguishable by listeners.

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