New Type of auditory progress bar: exploration, design and evaluation

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Abstract. In this paper, we focus on the method to explore a different type of auditory progress bar by analyzing the characteristics of the visual progress bar and contexts of auditory application. A scenario of bearing in the forward/reverse modes of digital compass is selected to implement the auditory progress bar. The auditory cues play an interactive role in the bearing that they are altered according to the user's operating behavior. Composed of sound signal and silent pause, the auditory cues are generated from a formula based on the warm/cold metaphor. A method incorporating the foreground/ background sounds is also designed to provide different ranges of progress information/progress update expressed through auditory cues. In this report four versions of auditory cues are presented as the solution to the interactive auditory progress bar and a pilot study is evaluated.

Keywords: Auditory progress bar, sound design.

1 Introduction

Progress bars are typical widgets in graphical user interfaces; the objective of the progress bar is to provide the user with information concerning the achievement of a task; primarily the information is about the task time. The study of Conn[2] indicated eight task properties to provide good time affordance for the progress bar in the graphical user interface. Progress bars vary between different applications; for example, a vending machine for hot drinks. The progress bar presents a simple process of making coffee. Other customary examples in computer user interface are shown in Fig.1, where the progress bar expresses more detailed information during the process of downloads. Previous studies [1][3][7] have proved that the auditory cues could be an alternative option to support visual feedback. Concerning the effectiveness of adding sounds to the progress bar, Crease and Brewster [3] developed an auditory progress bar composed of four musical tones referring to the different status' of a file transmission. Another study [9] is the application of the auditory

progress bar in the telephone system, whereby the auditory progress bar indicates the waiting time on telephone lines.

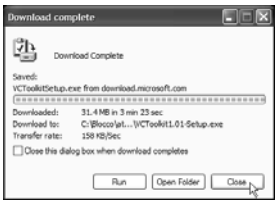

Fig.1. The progress bar from the interface of downloads.

2 Method

Progress bars are applied in various ways for different uses; they differ either from their forms or from the contents of messages. To discover other types of auditory progress bars, a systematic method is executed to explore possible applications. Firstly, two factors are used to analyze the visual progress bars: the external characteristics in visual presentation and the internal contents in transmitted information. Secondly, a cross table is adopted to generate all possible results composed by the two former factors. Finally, in order to choose the prospective application for the auditory progress bar, the interactivity, the contexts of auditory feedback and user scenarios are also considered.

2.1 Investigation of the Visual Progress Bar

The first step of investigating progress bars focuses on the external characteristics. By looking at the mode of usage of the visual progress bar, the evolution of visual presentation can be categorized as follows:

(1)The monotone and non-monotone bars: From the viewpoint of interactivity, the visual presentation of progress bars relates to the nature of the task. In the non-interactive tasks, the monotone progress bar indicates the progress of the task which can't manipulated by the user's operation; therefore, the progress bar performs regularly in a route from a starting point to an end point, as the example in Fig.1 shows. In the case of interactive tasks, its progress is represented by a non-monotone progress bar which acts in a repeated back and forth motion due to interaction between users and the interface.

(2)The continuous and discreet bars: Without additional measurement of the progress, visual presentation is one of the possibilities available for users to perceive the progress that the progress bar has made, either in the continuous or discreet form. In contrast to the transforming form of the continuous bar, the discreet bar is accumulated by certain sections equal to each other in size. Both examples are shown in Fig.2.

(3) The gradual and non-gradual bars: another way to display the progress of the task is how the progress bar works with a graduated scale to produce measured indications. The gradual progress bar in Fig.3 is defined by the measure to indicate the progress while a non-gradual progress bar has no scale.

Fig.2. The example of continuous and discreet progress bar.

Fig.3. The example of gradual and non gradual progress bar.

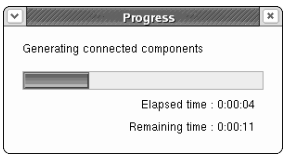

Fig.4. The progress bar presents the value of ongoing time.

The second step of the analysis is to find out what kind of information is conveyed by progress bars. Four types of information are presented: (1) the process: the progress bar represents the process of achievement for an ongoing task. (2) The value of the transmitted task: the progress bar can be used to present the value of the progress in the ongoing task as the example in Fig.4 demonstrates. (3) The change of status: The process of executing a task can be divided into different sections to indicate the progress status as shown in example Fig.5. (4) The variation of the evolution: in the non-monotone progress bar, users are aware of fluctuation of the progress in real time from the progress bar as shown in Fig.6.

Fig.5. The progress bar presents the change of status in the video game Athens 2004.

2.2 Generating Possible Progress Bar

The following stage is to explore the possible types of progress bar based on the analysis of the progress bar. Like the external characteristics, the modes of usage are

defined in eight categories as listed in the rows on the left hand side of Table.1. Four kinds of internal information featured in a progress bar are shown at the top of the four columns in Table.1. A column with a star means that certain sort of usage possesses the attributes of one particular piece of information (Process, value, status, variation). In Table.1, two types of progress bar don't match either column from the transmitted information. These two progress bars don't exist due to their incompatible elements (non-gradual and discreet). The results from Table.1 can be listed as six types of progress bar.

Fig.6. The progress bar presents the variation of the motion from the player in the video game of Torino 2006.

Table 1. Table composed of two types of characteristics. (M: Monotone, NM: Non monotone, G: Gradual, NG: Non gradual, C: Continuous, D: Discreet)

Mode of usage \ Information			Process	Value	Status	Variation
M	G	C	*	*	*	
		D	*	*	*	
	NG	C	*			
		D				
NM	G	C	*	*	*	*
		D	*	*	*	*
	NG	C	*			*
		D				

2.3 Parameters Concerning the Auditory Progress Bar

To explore the possible application of an auditory progress bar from the generated results, six criterions based on the study of Edworthy [5] will be considered: (1) The concentration of vision and multi-tasking: when the working environment isn't visually simple, the auditory feedback would be a possible solution to visual overloads from tasks. (2) The characteristics of tasks**:** the use of feedbacks from different modalities depends on the task's characteristics. Three conditions are

discussed by three circles from the same center; the first inner circle proposes that the user performs tasks in a fixed place where feedbacks are easy to access. Factors which can possibly stir the annoyance of users due to being highly exposed to auditory messages are also taken into consideration. The extended middle circle shows that the operation in a mobile condition will intensify the priority to adopt the auditory feedback because of the visual feedback's inefficiency during the process. The outer circle shows a condition where visual feedbacks from the ongoing tasks are totally inaccessible for users; auditory feedback is transmitted from one end to the other in an operation carried out over a certain distance. (3) The duration of a task: the indication of the progress via auditory feedback can easily become annoying with the long duration of the task. (4) Various sources of sound from the surrounding environment could affect the use of auditory feedback. (5) Audio-only or audio-visual feedbacks: the auditory feedback could be an alternative option to replace the visual feedback, or it could play a role to enhance the effect of the visual feedback in the case that the visual and auditory feedbacks exist simultaneously. (6) Different conditions in vision: the use of auditory feedback will benefit various levels of sensory difficulties of vision. People with normal sensory abilities may experience different levels of sensory difficulties. For example, the modality of vision may not function well when overloaded or when there is low visibility underwater.

2.4 The Prospective Application for Auditory Progress Bar

In contrast to the study of Crease and Brewster[3] concerning the effectiveness of adding sounds to the visual progress bar, we aim to implement an auditory progress bar without any visual feedback. From analysis on the visual progress bar, we found that the parameter of variation in non-monotone progress bar showed an interactive condition between users and interface; such a parameter was considered to be an important factor in implementing a new type of auditory progress bar, which is most commonly found in video games. Beyond the domain of entertainment, a prospective non-gaming application was found in the electronic compass where it provided the modes of forward/reverse bearing; that is, according to the bearing relative to the target, whereby the user can trace the correct direction of the target without knowing the current bearing. This process of finding the target in this type of scenario can be regarded as a non-monotone progress bar because the status of the progress is manipulated by users according to the search conditions. In such a scenario of bearing, the auditory cue benefited bearing tasks where users could fully concentrate on the upcoming events, instead of being distracted by the visual feedback from the electronic compass.

3 Design of Auditory Progress Bar in Electronic Compass

There were several examples of using sound to indicate the bearing. Verbal sound such as speech was used to indicate the exact degrees of bearing in the auditory compass Tacktick[12]. In Smith-Kettlewell's project [6], the dynamic auditory cues of “beep-beep” and “ding-ding” were created to express the bearing of veering from a

travel path. Another design aimed at finding the target via auditory cues can be found in AudioGPS[8]; different repeated tones were used for panning the direction, and the warm/cold metaphor was used in composing auditory cues to indicate the relative distance to the target. The manner in which to perceive the verbal sound was different from that to non-verbal sound. The verbal sounds conveyed more emotional and complex messages than non-verbal messages do. We decided to choose non-verbal sound to simplify and to eliminate cognitive factors about verbal language. Moreover, the non-verbal sounds are also more appropriate than the verbal sounds when aiming to express the relative progress of bearing without giving information concerning the four cardinal points or exact degree measurements.

3.1 Indication of the Progress in Finding Target

In the scenario of panning the target toward a 2-dimension space using an electronic compass, the process of bearing in a circular path can be transformed into a linear progress bar where auditory cues convey relative bearing. To design the auditory cues, we have two principles as followed: firstly, a "warm/cold" metaphor is used to express the progress of the ongoing task. Secondly, to feature the non-monotone progress bar, the content of the auditory cues has to express the message of variation during the task of searching for the target. Moreover, three sound parameters are adopted to generate the auditory cues: (1) the continuous and discrete sounds are used to indicate the process of reaching a target. (2) The stereo sound of the auditory cues indicates the relative position to the target (whether the user had passed the target or is approaching it). (3) Different duration from the sound signal and the silent pause: auditory cues composed by different durations of sound signal and silent pause would be created to express the progress.

3.2 Generation of the Auditory Cues

A mathematical equation based on the warm/cold metaphor is generated when we calculate the relative distance between the target (Xref) and the current heading(X) which is considered as two points on the circle of 360^o. The relative distance (D) between Xref and X is calculated every 10 degrees from 0^o to 360^o. The result for each D is distributed as a hyperbolic curve as one example demonstrates in Fig.7. The output data of the equation from 0^o to 360^o is used to determine the duration for sound signal and silent pause in order to generate the auditory cues.

$$D = \frac{\left|1 + Sin\left(90 + \left|X - Xref\right|\right)\right|}{10\left|Sin\left(\left|X - Xref\right|\right)\right|} \qquad (1)$$

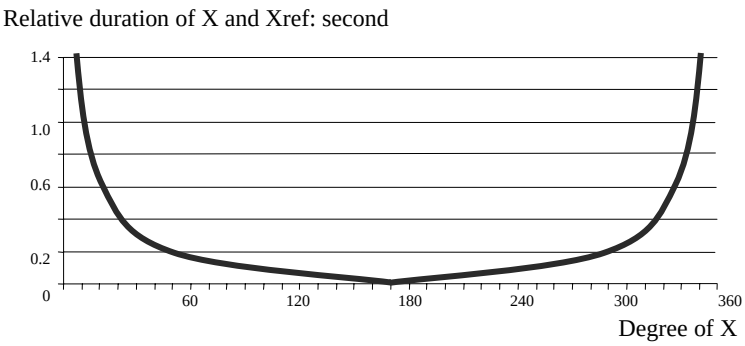

Fig.7 The distribution of the curve D when Xref =0

We designed four versions of the auditory cues by using the polarity (increasing and decreasing) of the duration for sound signal and silent pause; four versions are shown in Table.2. A beep sound (350Hz) was used as the basic unit for the sound signal.

Table 2. The 4 versions of auditory cues with different durations in the sound signal and the silent pause

Version	Duration of the sound	Duration of the silent pause
1		
2		
3		
4		

3.3 Progress Sounds from the Different Grounds

Like the visual design of units on a ruler, different sizes of actual measurement markings are used to distinguish different levels of measuring. Therefore, we decided to apply two layers of auditory cues, foreground and background sounds, to express the progress in a different sense. The foreground progress sound generated by the equation presents the progress in details. The background process sound expresses the progress using a wide range of sounds, comprising a mixture of four pitches in total (D_2-9 73Hz, $A^{\#}_1$+32 59Hz, $C^{\#}_2$-7 69Hz, D_2+12 73Hz). Both layers of progress sound are dealt with increasing volume.

3.4 Sounds concerning the Target

When the target is found, a continuous beep sound (2100Hz) is launched. If the user misses the target and passes it by, the auditory cues in stereo sound will help the user to distinguish the relative position of the target.

4 Experimental Design

A prototype of the electronic compass' interface was simulated in Macromedia Flash 8. Target finding tasks were executed via the laptop computer's headset. Subjects used the right and left keys on the external keyboard to simulate turning the compass without any visual feedback from the screen. The aim of this experiment was to determine if the designed auditory progress bars were able to enhance the awareness of the progress of the target orientation tasks. Four versions of auditory progress bar were implemented in four stages and each stage contained four tasks of finding targets in cardinal points without description in advance. A five-minute warm-up was provided for each subject at the beginning of each stage before starting the formal tasks; there were also five-minute breaks between each task. Moreover, the method of counterbalancing was used to even out carryout effects. An interview took place at the end of the tasks to collect subjects' opinions. A pilot study was carried out involving fourteen subjects, consisting of seven female and seven male students.

4.1 Results

From Fig.8, we found that the average time taken by subjects in version1 and version4 was less than that in version2 and version3. The average task time for male subjects was less than that for female subjects. We can refer to Table.2 when discussing this result, where the auditory progress bars were designed with decreasing duration of sound signal in version1 and version4, whilst the increasing duration of sound signal was used in version2 and version3. That is, subjects are used to the warm/cold metaphor in version1 and version4 when perceiving progress made from the auditory cues. Moreover, subjects expressed their preferences towards the four versions; four subjects preferred version1, version2 was preferred by two subjects, one subject preferred version3 and four subjects preferred version4. Three subjects made no comment.

With regard to the two-layer auditory progress bar's performance, ten subjects expressed that they couldn't identify its function while two subjects found the background sound was not evident. Furthermore, two other subjects even considered the auditory cues from the two layers progress to be incompatible and annoying. Ten of the fourteen subjects perceived the progress by using the foreground sound (different durations of sound signals and silent pauses) and the other four subjects followed the same method by using the background sound (different pitch of sound). One reason why we failed to receive positive response for the two-layer progress sound was due to the fact that the subjects had already established their personal preferences when faced with the priority of detecting and ignoring auditory stimuli.

Thus, this caused the subjects to choose one dominating factor to perceive the progress and to screen the therefore redundant auditory messages. This situation could possibly be what the theory of gestalt in psychology describes.

In the process of finding targets, eight out of fourteen subjects considered the volume as the dominant factor in conveying much clearer messages of progress, while the duration of the sound signal was regarded as the crucial factor by four subjects; another two subjects considered both the volume and the duration to be equally important. The auditory cues were composed by different duration of sound signal and silent pause to convey the progress information. Nevertheless, it is only natural that subjects needed to spend more time to distinguish the differences between the duration and the volume, especially when they encountered several auditory cues simultaneously.

Certain interesting findings were also discovered about the subjects' behavior when perceiving the progress made. There were two principal types of navigation methods adopted by the subjects: monotone navigation and non-monotone navigation. In adopting the first method, subjects moved the compass in one single direction (either clockwise or counterclockwise) to perceive the difference between the auditory cues. Using the other method, subjects took advantage of the different indications provided by the auditory cues when they changed their direction. Moreover, certain subjects carefully listened to each section of the auditory cues so that they could be sure of the differences between the auditory feedbacks, whereas some subjects preferred to speed up the bearing progress by skimming through some sections of the auditory cues. However, this finding could be accounted for, when taking into account the simulated control of the keyboard; subjects might not have had the same control behavior when holding a real compass.

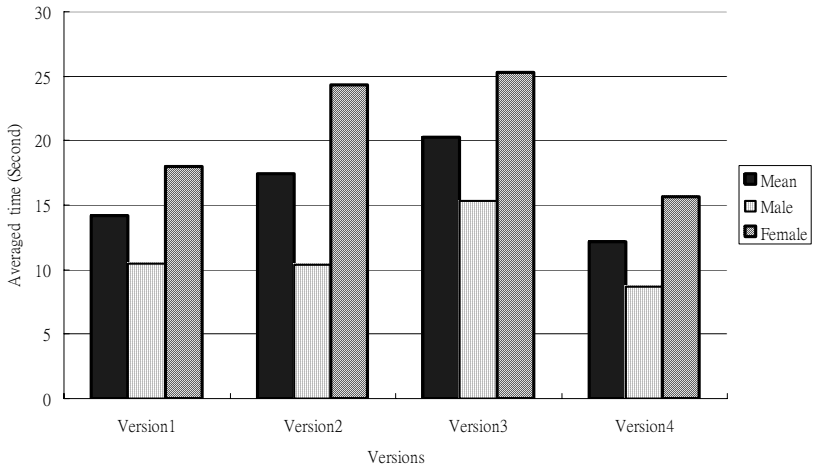

Fig.8. Average time taken by subjects (male and female) for each version

5 Conclusions

The study aims at exploring the new type of auditory progress bar by using a systematic method. The coding of non-verbal sounds in the auditory progress bar can be regarded as one kind of earcon which conveys different messages to express the status of progress. Future work will continue to explore different applications in the audiovisual context where the auditory interface plays an essential role in enhancing usability and providing parallel feedback to support the visual interface.

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References

1. Blattner, M., Sumikawa, D. & Greenberg, R.: Earcons and Icons: Their Structure And Common Design Principles. Human Computer Interaction, Vol.4. (1989) 11-44
2. Conn, A., P.: Time affordances: the time factor in diagnostic usability heuristics. Proceedings of the SIGCHI conference on Human factors in computing systems(1995)
3. Crease, M.G., Brewster, S.A.: Making Progress with Sounds - The Design and Evaluation of An Audio Progress Bar. Proceedings of ICAD, British Computer Society(1998)
4. Deneen, B., J.: Electronic Compass for the Blind. <http://nsf-pad.bme.uconn.edu/1991/chapter_7.pdf>
5. Edworthy, J.: Does sound help us to work better with machines?. Interacting with Computers, Vol.10(1998)401-409
6. Flux-gate auditory compass <http://www.ski.org/rerc/5yrReport/General/IV.html#anchor151824 >
7. Gaver, W.W.: Auditory Icons: Using Sound In Computer Interfaces. Human-Computer Interaction, Vol.2.(1986) 167-177
8. Holland, S., Morse, D. R., Gedenryd, H.: Audio GPS: Spatial Audio in a minimal attention interface. in 3rd International Workshop on HCI with Mobile Devices, 2001.
9. Kortum, P., Peres, S. C., Knott, B., Bushey, B.: The Effects of Auditory Progress Bars on Consumer's Estimation of Telephone Wait Time. Proceedings of the 49th Annual Human Factors and Ergonomics Society. Orlando, FL(2005)
10. Leplâtre, G., Brewster, S.A.: Designing non-speech sounds to support navigation in mobile menus. Proceedings of ICAD(2000)
11. Norman, D., A.: Affordance, conventions, and design. interactions, Vol.6(3)(1999)
12. The Tacktick <http://www.blindsailing.org>
13. Wogalter, M., S. (ed.) “Handbook of Warnings”, Lawrence erlbaum associates, Mahwah New Jersey London (2006)