DATA SET SELECTION FOR A CONSTRAINED SIMPLE SONIFICATION

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ABSTRACT

Previous work on the production and test of various sonifications has shown that adding a sonification to an interface can assist the execution of a variety of operator tasks [1,2,3]. However, it has also shown that in some cases sonifications can have little benefit and may reduce performance in some areas [4]. This implies that choosing the information to encode and the type of sonification to employ are important steps when seeking to produce a successful application [4]. Within this paper one approach to the problem of data selection for sonification is described and the results presented. The objective of the work is to produce a new audio interface for short range air-to-air missiles. Features of this task are a small specialist user group and a constrained choice of sonification schemes. Structured interviews were used to produce repertory grids based on the sounds heard and information required in current and ideal cases. This was followed up with a broader survey of system users. The results showed that the views of designers and users are often fundamentally different and that care is required to achieve a satisfactory result.

1. INTRODUCTION

Throughout the world short-range air-to-air missiles produce audio tones used by the pilot to assess the status of the missile before committing to launch. After launch these missiles are entirely autonomous and no further inputs can be made to improve their chance of success. Legacy missiles provide tones to the pilot interface as an enhanced by-product of their analogue signal processing. In effect the pilot is "listening in" on the missile analogue electronics. The tones produced by the most recent versions of these analogue missiles are highly informative to practiced pilots. New missiles use digital signal processing and have no equivalent output that can be filtered and presented to the pilots. However, these missiles possess a much greater array of information, albeit in digital form, which can be presented visually or audibly. The current study is centered on the sonification to be used with a modern digital missile on an F/A-18 aircraft. This kind of missile uses an imaging seeker (camera) to detect targets. The information possessed by the missile and potentially available to the pilot includes the operating status of the missile and all the usual information that can be extracted from a series of images. Of particular relevance are; infrared detector cooling status, target parameters, background parameters, signal to noise ratio and the number of potential targets in the scene. During this study it has been assumed that most of the information will be presented in the audio channel for two reasons. One is that information overload in the visual channel is a long-standing problem for pilots of single seat fighter aircraft and additions to the existing visual displays can be dangerous [5,6]. The other is that changes to the missile audio may be carried out independently of the aircraft by using the aircraft's existing audio systems.

The first problem to be solved is the selection of data to be encoded into the new missile tone scheme, *i.e*. what information is of sufficient value to the pilot to be encoded into the tone scheme. Opinion on this topic varies greatly among those involved in such missile projects, noticeably as a function of their role and views on typical engagement scenarios. Further, opinion among the end users (military pilots) is often strongly divided [7], and it can be quite difficult for researchers to gain access to significant numbers of these people. There is a risk that work carried out on the perceived advice of one or two pilots may not be well received by others.

Once the data has been selected, a tone scheme must be developed within several constraints;

- Sounds produced must not interfere with the numerous alerts, warnings and alarms that are already in use in the F/A-18 fighter aircraft.
- Information must be continuously displayed with as little latency as possible.
- The tone scheme must be simple and not require the pilot to focus attention on it to the detriment of other tasks being executed simultaneously. (Flying the aeroplane in combat.)
- Voice communications (Radio) must still be possible while listening to the missile tones.

2. STRUCTURED INTERVIEWS AND REPERTORY GRIDS

Other workers in DSTO (Defence Science and Technology Organisation) have found that eliciting repertory grids can give good results with a small sample. The Repertory grid was developed by George Kelly as an element of Personal Construct Theory [8,9]. Repertory grids are used to elicit a model of the way in which people understand the world around them. Their use with a structured interview technique assists in the reduction of observer bias and can give a deeper understanding than would usually be achieved with a single questionnaire.

Three experienced pilots (RAAF test pilots) were interviewed and repertory grids were constructed focused on the audio tones produced by short-range missiles. Each session took about an hour. Repertory grids were produced during the course of the interview using the PC Pack Rep Grid tool version R2.11 (by Epistemics Ltd), on a laptop computer.

The pilots were asked to list the real word objects that can generate current missile tones or tone changes. Particular emphasis was placed on the tracking tones and some examples were given such “fast jets” and “clouds”. Pilot responses were entered as elements in the grid. For each of these elements identifying features of the sound produced were listed as constructs in the grid. Each element was given a rating against each construct. Examination and refinement of the completed grid clarifies which differences in tone are readily perceived. A nine point scale was used in all cases with the poles chosen by the subject. The subjects were free to develop the grid to their satisfaction.

A second grid was then constructed for an ideal missile. Example elements given were target infrared intensity and target angular size. The pilots selected their own set of elements as shown in figure 1 below. The nature of the tone produced by the ideal missile was only superficially addressed as this is going to be developed later in the project. Hence the list of constructs is somewhat arbitrary. In the grid shown in figure 1 “relative change” has poles of no change to rapid change, “Pitch” has poles of growl to clean and “volume” has poles of minimum and maximum. Hence having a steady track on a target should be indicated by “no change” in a tone with a clean pitch and maximum volume.

At this point it is worth noting that the opinion of scientific staff (including the author) had already been sampled and a clear consensus was emerging. We agreed that the minimum information needed was to indicate that; the missile detector was (or was not) cooled and electronics working correctly, and that the missile was tracking a target (or not). Further information that would be of use was the angular size of the target, the brightness of the target, the presence of multiple targets, the presence of countermeasures and an indication of an adverse background. This can be readily achieved by varying the pitch (size) and volume (brightness) of the tone representing the target and then superimposing as required a second set of distinct tones to indicate the other conditions including background when appropriate. A normal tracking tone would immediately indicate the missile was both functioning correctly and tracking and would instantly give relevant information on the target that is valuable in confirming a high quality track on the desired target. With a little practice pilots would become used to the sounds presented in response to typical targets under typical conditions. Other parameters such as target line of sight rate might also be worthy of encoding but their relative merits should be established by consultation with the pilots.

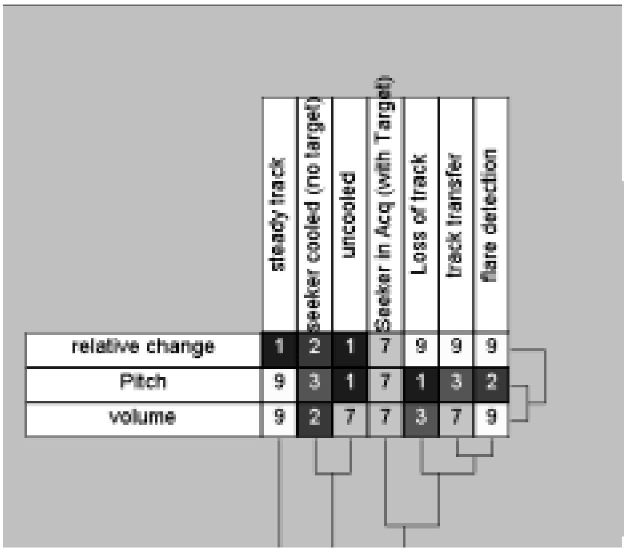

Figure 1. *One of the repertory grids produced during the interview process.*

The results of the sessions show a distinct contrast with the consensus found among the technical staff. The pilots desired the following information:

1. **missile seeker status (cooling),**
2. **seeker can detect a target (designate / track),**
3. **quality of track,**
4. **loss of track ,**
5. target within LAR (Launch acceptability region)
6. target track co-incident with Radar track,
7. countermeasure (flare) detection
8. track transfer or a sudden change in the target.

A further stipulation was that the tones should be both simple and non-intrusive allowing warnings to be heard and voice communications via radio to continue.

Items 5 and 6 on this list are information produced by the aircraft and need to be addressed via the aircraft audio system. This information is commonly presented visually to the pilot on their heads up display, so a sonification would be a re-enforcement. Items 7 and 8 were requested by only one of the three pilots. Two of the pilots specifically stated that they did not want any indication that countermeasures were present unless the countermeasures reduced the quality of track. They felt having the missile tone respond to countermeasures might unnecessarily reduce operator confidence. The other test pilot felt the information that an opponent was using flares added to his situational awareness and was therefore desirable. This leaves items 1 to 4 as the core information requested by all three pilots from the missile. The missile seeker status and an indication of track were regarded as essential. Quality of track was regarded as the next most important item of information followed by the indication that the target was within LAR. A target that is within LAR can be physically reached by the missile as it is within both the missile’s range and manoeuvre capabilities.

Note that there is no mention of target angular size, target intensity or adverse backgrounds. All these parameters are wrapped up in a quality of track indication. This would reduce pilot workload and training time. After the initial grids had been produced, each pilot listened to a brief demonstration of a tone changing in volume in response to target intensity changes and rejected the notion entirely.

3. QUESTIONNAIRES

The results of the interviews and the repertory grid analyses were used to formulate a questionnaire. The questionnaire consisted of 4 pages and took between 10 and 20 minutes to complete. It asked the pilots about the information they received via the audio tone from a current missile and what information they would like from an ideal tone on a new missile. An importance rating was requested for each piece of information. The level of resolution currently achieved using the current missile and that preferred for the new missile was also requested. Eleven pieces of information were listed with space for comments on each individual parameter. Extra space was provided to allow the pilots to request new information .

RAAF Williamtown provided a group of 10 pilots available to fill out the questionnaire. These were less senior, but still experienced operational pilots. Two pilots with a higher level of seniority (instructors) were also given the survey. The instructor's results were very similar to the preferences of the test pilots referred to early in the paper. Both the instructors included a suggested design solution in their comments.

The survey results from the group of 10 pilots were quite different from the more senior pilots. The reason for this generational divide is not clear and is beyond the scope of this paper. Primary differences were that the less senior pilots wanted a tone that changes with target infrared intensity as well as a discrete indication when the target is deploying countermeasures. The majority were also in favour of an alert when multiple targets were detected during the acquisition phase, allowing more care to be taken when selecting a target under these conditions. Opinion was divided on including an indication of when the target is within LAR with only 6 pilots in favour of the idea and 4 against it. Like the instructor level pilots, this group gave the quality of track the highest priority. They indicated that background interference, sudden changes in the target characteristics and success in rejecting countermeasures should be incorporated into the quality of track feature. They were in agreement that target angular size was not desirable information to encode in the tone.

The most innovative suggestion was a change from the traditional audio method of indicating the seeker cooling status. When using this method the pilot selects a missile and assesses its' cooling and operational status by listening to the audio tone. It was suggested that this information be displayed on the stores page of a heads down display. A pilot could then know the missile status before selecting it. This information is only available when using new missiles equipped with a digital interface. No additional parameters for encoding into the tone were suggested.

4. CONCLUSIONS

Structured interviews were used to elicit repertory grids focused on the audio interface of short range air-to-air missiles. This process successfully highlighted the information of interest for sonification, as demonstrated by a lack of new information appearing in the questionnaire results. During the interviews a completely new issue was raised in using audio to indicate information not directly related to the missile seeker. *i.e.* Indicating the target is within LAR.

The interviews were conducted with only three pilots, each with a similar level of experience and outlook, resulting in a narrow body of opinion on the issues arising. However, a genuine user opinion was developed that was very different to the expected result.

A questionnaire was developed using the results of the interviews and was used with a larger group of pilots. This proved to be a time efficient method for gathering a wider range of opinion. This wider consultation resulted in a more diverse set of opinions. The open portion of the survey resulted in some very innovative suggestions on how to present various pieces of information.

The result of this two stage structured consultation process is a user opinion that is fundamentally different to researcher expectations. It also allowed for a deeper understanding of the reasons for the user opinion.

Moving on to the next stage will require the development and assessment of multiple sonification schemes. As it will be impossible to objectively measure performance in the operating environment, testing will be carried out under simulated conditions.

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