IMPOVING THE EFFICACY OF AUDITORY ALARMS IN MEDICAL DEVICES BY EXPLORING THE EFFECT OF AMPLITUDE ENVELOPE ON LEARNING AND RETENTION

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ABSTRACT

Despite strong interest in designing auditory alarms in medical devices, learning and retention of these alarms remains problematic. Based on our previous work exploring learning and retention of associations between sounds and objects, we suspect that some of the problems might in fact stem from the types of sounds used. Several of our previous studies demonstrate improvements in memory associations when using sounds with "percussive" (i.e. decaying) envelopes vs. those with "flat" (i.e. artificial sounding) envelopes – the standard structure generally used in many current alarms. Here, we attempt to extend our previous findings on the effects of temporal structure on the learning and memory. Unfortunately, we did not find evidence of any such benefit in the current study. However, several interesting patterns are emerging with respect to "confusions" – the times when one alarm was confused with another. We believe this paradigm and way of thinking about alarms (i.e. attention to temporal structure) could provide insight on ways to improve auditory alarms, thereby prevent injuries and saving lives in hospitals. We welcome the chance to gather feedback on our approaches and thoughts as to why our current attempts (which we believe are based on a solid theoretical basis) have not yet led to our hoped-for improvements.

1. INTRODUCTION

Medical alarms are designed to alert medical staff immediately when there is a problem with a patient. Despite their ability to grab attention, the current design of medical alarms is ineffective and results in several deaths and injuries among patients each year [1]. This could be attributed, in part, to the poor learning and high rates of confusion seen in empirical tests of alarm learning [2,3].

Confusions among alarms can arise from a variety of factors such as acoustic similarity, functional similarity or difficulty forming associations [1,4]. The current study aims to investigate a more subtle change to the current acoustical design of medical alarms. Previous studies in the lab have focused on the ecological validity of sound and its effect on associative memory abilities. The main manipulation in these studies was the shape of a sound over time; or more technically known as the 'amplitude envelope'. Two types of amplitude envelopes were investigated: flat and percussive (as shown in Figure 1A). A percussive envelope is representative of impact sounds, which we hear on a regular basis. A flat envelope, on the other hand, is man-made and is heard significantly less often than percussive sounds. Therefore we hypothesized that percussive sounds could be learned and recalled much easier than flat sounds due to our extensive experience with them. This hypothesis was supported in several object-melody association experiments [5], where it took significantly fewer trials to learn the associations when percussive melodies were used compared to flat melodies. Here, we will investigate the role of amplitude envelope as it applies to the learning and memory of medical alarms.

2. METHOD

2.1 Participants

Participants consisted of 48 undergraduate students (16 Male, 31 Female, 1 Transgendered) ranging in age from 17 to 26 (M = 19.06, SD = 1.80) recruited from the undergraduate psychology and linguistics pools

2.2 Stimuli and Apparatus

We selected eight tone sequences from a set used in a previous study [5]. In order to create both flat and percussive versions of the tone sequences, SuperCollider[1] was used to shape pure tones (i.e. sine waves) into flat and percussive envelopes to create individual tones. These individual tones were then arranged into sequences using Audacity[2] - a free sound editing program. All tone sequences consisted of four one-second sound clips that were either all percussive or all flat concatenated together to make a four-second track. Percussive tones were approximately 800ms in length and were separated by 150ms. Flat tones were 745ms in length and were separated by 200ms. Each of the tone sequences were labeled with a number from 1 to 8 and are shown in Figure 1B.

Tone sequences were stored on an iMac computer and presented over Sennheiser HDA 200 headphones at a comfortable listening level, which was held constant.

A) B)

[1] http://supercollider.sourceforge.net
[2] http://audacity.sourceforge.net

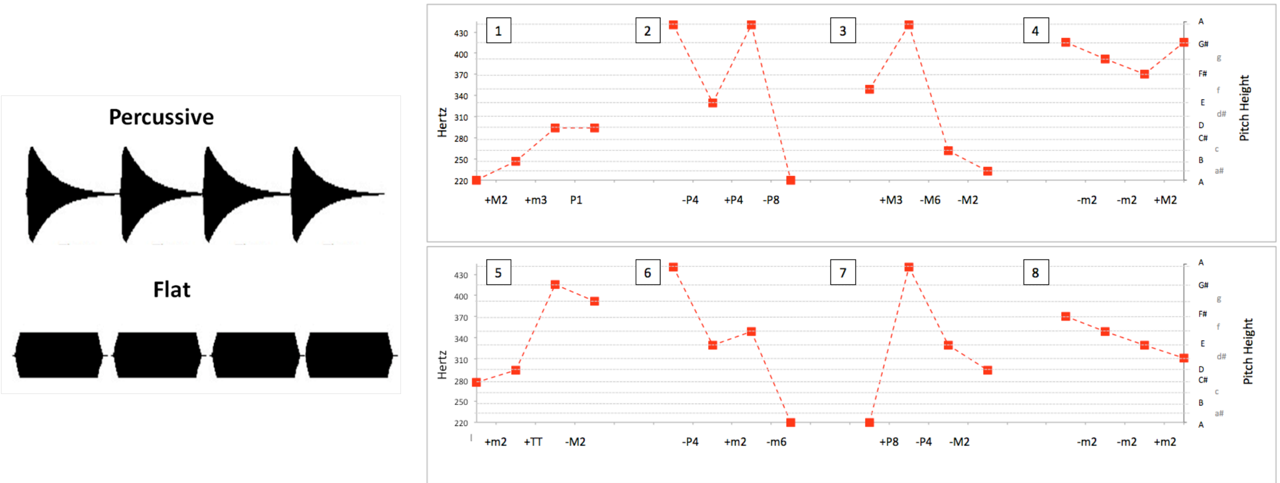

Figure 1 – Percussive and flat waveforms (A) and the contours of the 8 melodies used in the Experiment (B).
M = Major, m = Minor, P = Perfect, TT = Tritone, + = Ascending, - = Descending.

Participants filled out a short survey that included questions regarding demographics, musical training and musical practice and listening behaviours prior to beginning the experiment.

2.3 Procedure

To control for differences I musical training, participants heard alarm sets that contained four flat and four percussive tone sequences. The pairings tone sequences and alarm labels were randomized for each participant.

The experiment consisted of four phases: Study, Training, Break and Evaluation. During the Study phase, participants heard each of the 8 alarms twice and were told its correct alarm association. In the Training Phase, we presented participants with each of the tone sequences once (in a random order) and asked participants to identify the correct alarm association. Participants were given feedback on their correctness, played back each of the sequences and were told the correct alarm association regardless of their answer. Participants heard all 8 melodies, which made up a block of training. These blocks were repeated until participants could correctly identify 7 out of 8 tone sequences in 2 consecutive blocks, or reached a maximum of 10 blocks. Once the Training phase was complete, subjects took a five-minute Break to play a mini-golf game on a computer. The sound was turned off to ensure the game sound effects did not interfere with our evaluation of learning and retention of the tone sequences. During the Evaluation phase, participants were randomly presented with each of the 8 tone sequences and were asked to identify the correct alarm association. Participants received their final score upon completion. This paradigm is a hybrid pairing of one used in previous studies [5], and what is currently used in medical alarm research [2,3].

3. RESULTS AND DISCUSSION

Performance on flat and percussive alarm associations in the Evaluation phase was compared using a pair-wise sample T-test and yielded no significant difference ($p = 0.554$).

We are currently examining the patterns of confusion and suspect amplitude envelope, timbre and tonality play significant roles. To our knowledge, no studies have looked at alarm confusions based on these aspects and think this might provide some insight on ways to improve auditory alarms.

Given the importance of alarms in a medical setting, the design of sounds that can easily be associated with their intended meaning is a pressing and timely issue. Therefore, we are very interested in any comments and feedback on the research presented in this extended abstract.

4. ACKNOWLEDGMENT

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