Review of Pitch-Match and Ear-Training Methods used for Tinnitus Treatments

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TINNET Short Term Scientific Mission (STSM) - Final Report
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1. PURPOSE OF THE STSM

Among the tinnitus therapies that are based on auditory stimulation, some rely on a precise initial pitch matching process. Incorrect matches may fail to bring into play the principles of the therapies. More often than not, patients experience difficulties in performing an accurate pitch match. A few studies have approached this problem by proposing ear training for the tinnitus patients in order to improve their matches, among which, we can refer to [1] [2]. This STSM involved interaction with researchers who participated in those studies.

2. DESCRIPTION OF THE WORK CARRIED OUT DURING THE MISSION

This STSM allowed the possibility to exchange knowledge between the TINNET investigator and the Auditory Perception Group at University of Cambridge. Both parts learned new techniques and gained access to specific instruments and methods not available in their own institutions.

On the first week, the TINNET investigator gave a presentation about his acoustic tinnitus therapy to members of the Department of Psychology. They, in turn, provided a substantial amount of feedback. Subsequently, the head of the group, being also the first STSM supervisor, learned about the therapy in more detail and provided more specific comments and advice for future studies.

Regarding ear training, the first STSM supervisor explained the approach used in [1]. That study included ear training to minimise octave confusions. The tinnitus patients were informed on the similarity that exists between two sounds forming an octave interval. For the tests, the patients were allowed to switch between a sound at the frequency that they initially matched to their tinnitus and alternative sounds that were one octave higher or lower. That possibility allowed the patients to compare and be surer about which was the correct octave before answering. After the training, the tinnitus pitch matches tended to be lower than before the ear training.

The main work carried out by the TINNET investigator is described below, focusing on: a literature review, algorithm development and experimental work.

2.1 LITERATURE REVIEW

A literature review on the area of pitch matching methods was carried out. The objective was to learn about the precision afforded by the following two general types of methods: Forced Choice methods and Methods of Adjustment. The papers reviewed (see “References” section) indicated there is an abundance of variations just for forced-choice methods. For example, as far back as in the 80’s, considerable progress had been already made in the development of forced-choice adaptive methods [3]. Nowadays, new variations are still being developed [4]. Thus, such a vast literature review was out of the scope of this short-term stay (officially from 3rd to 25th of August 2015).

Regarding the main interest of the review, i.e. the precision of the procedures, given that it is possible to adjust, on both types of methods, the step size to as little as we wish, suggests that both types of methods can provide a high level of precision. In that case, one could think that the patient's aural skills play an important role when it comes to precision. In the 60s, Cardozo evaluated one method of adjustment [5]. From a theoretical study the conclusion was that the method of adjustment "would seem inadequate indeed". However from the experimental test of the model (and even with all the technical limitations at that time) the conclusion was that "It yields fairly accurate results if certain conditions are fulfilled". Among these conditions we could include the patient's aural skills, as the paper mentions at some point: "If the subject shows good ability" (in the listening tests). This reinforces our approach, mentioned in the first section, of improving patient's aural skills with ear-training programs.

After the literature review we conducted an experimental study to compare a method of adjustment and a forced choice method. As the therapy of the TINNET investigator currently uses a method of adjustment it was necessary to implement the forced choice method, and some adaptations to the method of adjustment.

2.2 ALGORITHM DEVELOPMENT

A forced-choice double-staircase adaptive method (FCDS) was implemented in Matlab, based on [3] [6]. The role of the double staircase is to minimise habituation or sequential bias by using randomly interleaved staircases, each using the same decision rule [3]. Thus, "successive stimuli are not presented in a predictable monotonic sequence" [6].

Once the test starts, the reference tone (or virtual tinnitus) is presented first, followed by the comparison sound. Then, the subject has to indicate which of those tones was higher in pitch. Additionally, the graphical user interface (GUI) of the Matlab algorithm provides visual stimuli on the screen for each sound. After the user input, the rules are applied and these steps are iterated until the end of the process.

The GUI has only a few buttons because it is a basic application. More time would be needed to develop a more complete app, and that is outside the scope of this STSM. Therefore, the parameters that cannot be changed from the GUI have to be changed directly from the code. The top two buttons of the GUI are for establishing the initial frequency values of the two staircases, or sequences. Sequence A should start clearly below the frequency of reference, Fr (or tinnitus frequency). Similarly, the initial value for Sequence B has to be set clearly above Fr.

The abovementioned rules were implemented following the version of Levitt [7], 2up-1down. Thus, for the ascending staircase, or Sequence A, two consecutive responses for the reference tone make the frequency of the comparison stimulus increase. One single response for the comparison stimulus makes its frequency decrease. Sequence B implements the inverse rules.

As Jesteadt explains: "The procedure can be terminated either after a fixed number of trials in each sequence or after a specified number of reversals in the direction of the changes in level within each sequence" [3]. For each sequence, the final frequency value will be obtained by averaging a fixed number of the last reversals' values. At that point, the screen shows the frequency values corresponding to: Sequence A, Sequence B and the average of the two sequences. Also one button allows for plotting the two staircases.

The Matlab files are available at: http://www.mathworks.com/matlabcentral/fileexchange/53129

2.3 EXPERIMENTAL WORK

The objective was to collect quantitative data to compare levels of precision and time required to perform a pitch match with the two methods: the FCDS and the method of adjustment (MOA). Additionally, the subjects were asked for qualitative feedback about preferences between the two methods.

As mentioned above, we simulated the tinnitus with an external stimulus consisting of a pure tone. The comparison sound was also a pure tone. The number of trials per subject was 10 per method. The sequential order of the 20 trials was randomised.

For each subject we chose a frequency band in which the subject could perfectly perceive the simulated tinnitus tone. This is to ensure that any hearing loss or real tinnitus did not mask the reference tones (or simulated tinnitus). The range of the reference tones was 400 – 2000 Hz in order to prevent the FCDS last more than 4 or 5 minutes. The MOA was also limited in frequency, accordingly.

For each trial, the reference tone was different to avoid the fact that some subjects try to remember their previous matches [8]. Thus, each reference tone had a frequency at random within a range of 10% above and below the frequency chosen to represent the above frequency band.

Each method was explained to the subject, who did a training match with the two methods before the test. As shown in the next section, after the matches we computed the ratio between the reference frequency (Fr) and the matched frequency (Fm). This ratio would ideally be 1 for a perfect match. We also kept record of the time required for each match.

3. DESCRIPTION OF THE MAIN RESULTS OBTAINED

We conducted the experiments with three subjects. They were all male with a mean age of 66. Despite the low number of participants, and the fact that all of them were experienced psychoacousticians, we obtained an interesting variability of results. For example, with the FCDS algorithm only Subject 3 could perform accurate matches consistently. As we can see in Figure 1, for the other two subjects the frequency ratios deviated more from 1 and the standard deviations were larger. Additionally, worth mentioning is the fact that averaging the two staircases sometimes can "improve" or “hide” a poor match. To illustrate this effect let us consider the following case of one of the subjects. The frequency of the reference was 1621.8 Hz, the ascending staircase resulted in a frequency match of 1133.8 Hz and the descending staircase yielded 2176.8 Hz. These are really distant matches but then, when averaging the two staircases, the final result is 1655.3, which is really close to the frequency of the reference.

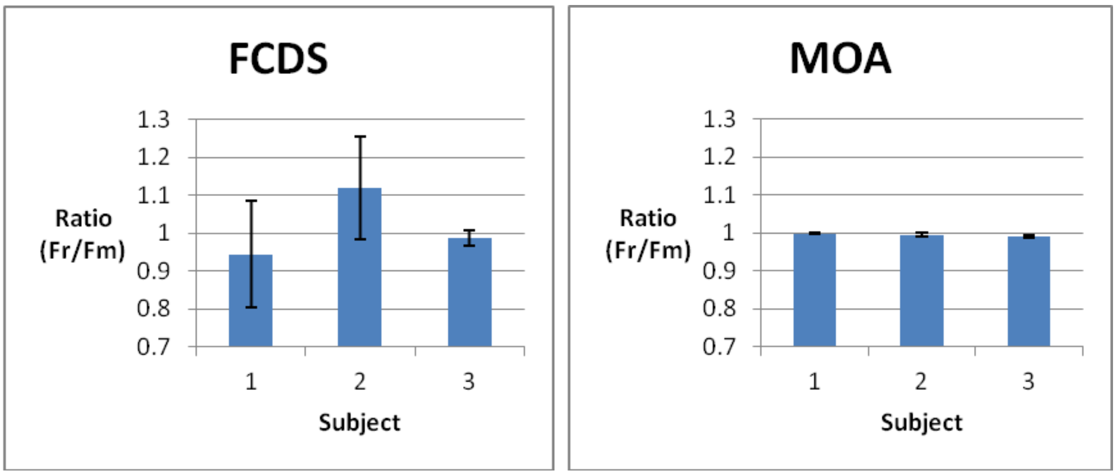

Figure 1: Statistic data analysis.

Regarding the MOA method, Figure 1 clearly shows that the matches were consistently more accurate for all the subjects. (Note that for Subject 2, one match (out of ten) was excluded from the data analysis. This is because its value was considerably distant from the rest of the matches, perhaps because it was the first match and the subject was not totally familiar with the procedure). Additionally, it should be mentioned that matching two pure tones that are identical in timbre, is easier than a real tinnitus match. Therefore, we cannot expect the MOA to afford the same accuracy for real tinnitus cases.

These results suggest that both methods can allow for very accurate matches, but the FCDS method does not give accurate matches for some subjects, the aural skills of the subject being a determining factor. This is demonstrated by the results of Subject 3, who was the only one that matched very accurately and consistently with the two methods.

In relation to the time required for the matches, the MOA stands out with an overall mean, i.e. averaging across all the subjects, of 0.7 minutes (SD = 0.25 min). The FCDS required an overall mean of 4.7 minutes (SD = 0.71 min).

The qualitative assessment of the two methods was unanimous; all the subjects preferred the MOA method.

4. CONFIRMATION BY THE HOST INSTITUTION OF THE EXECUTION OF THE STSM

A letter by the host institution is attached to this report.

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