**Implementation of an Auditory Task in THEATER**

**Background:** The purpose of this task is to add an audio component to the current version of the THEATER task in order to study the interaction between memory and hearing loss/disability. Here, I describe the implementation of a simple auditory task to measure speech-in-noise ability. Specifically, below is a description of the implementation of a digit-in-noise task, also known as the digit triplet task (DTT), in bWell. The DTT consists of identifying sets of three digits (e.g., 5, 4, 8) in the presence of noise presented at different intensities. This task was originally designed to be used in a telephone interview to measure hearing ability (Smits et al., 2004) and has been revised for use as web-based task (Smits et al., 2006), and later as a lab task (Smits et al., 2013), which has recently been adapted for the Canadian population in both French and English (Giguère et al., 2020). Currently, there is no virtual reality version of this task. Since our daily activities are often accompanied by noise, it would be interesting to integrate this aspect into virtual reality environment.

**Interesting literature related to the task:** Several studies have shown that the DTT is a reliable task to measure hearing sensitivity, with the performance at the task being moderately to highly correlated with hearing thresholds as measured with pure-tone audiometry (e.g., Armstrong et al., 2020; Jansen et al., 2010; Koole et al., 2016; Smits et al., 2004).The DTT has been shown to be sensitive in cognitive impairment and dementia. Specifically, a recent study using the DTT has observed that individuals with high risk factors for Alzheimer’s disease had lower speech-in-noise ability (Brenowitz et al., 2020). Another study has observed that better performance at the DTT task is associated with better cognitive ability in tasks assessing fluid intelligence, speech processing, prospective memory, working memory and visual memory (Moore et al., 2014).

All sound files and scripts that may help to implement the task in bWell can be found here: <https://github.com/mperron8/DTT_VRversion.git> . The files have been created or selected from: https://www.ee.columbia.edu/~dpwe/sounds/, and have been adapted to the purpose of the task.

**Stimuli:** The stimuli consist of all digits between 0 and 9, with the 0 and 7 excluded in English to keep monosyllabic words. Participants should be unaware of the absence of these two digits. Sets of three digits (e.g., 5, 4, 8) will be created by randomly selecting three digits from the list. A set of digits should not be repeated over the course of the task, and the position at which the digits appear in the sets should be balanced over the session. The number of possible sets of digits is then 336. Some authors have removed all country codes (e.g., Giguère et al., 2020), but I do not think it makes much difference. If you consider that country codes should be removed: a list of all Canadian codes can be found here: https://countrycode.org/canada/. Each set of stimuli needs to have a silent interval of 500 ms before the first digit and after the last digit, with an additional random interval of ± 50 ms to add uncertainty. A silent interval of 150 ms needs to be included between each digit. Stimuli can be computer-generated or selected from: https://www.ee.columbia.edu/~dpwe/sounds/tidigits/, where a male and female version is available. The gender of the speaker could be an interesting option to add in the bWell settings. The speech level is fixed at 65 dB and the noise level should vary during the session. All sets of digits are presented in presence of noise, using an adaptive procedure according to participants' accuracy.

**Noise:** Traditionally, the digits are presented in presence of speech-shaped steady-state noise, which targets speech by interfering with the peripheral encoding of sound. This noise is an energetic noise which is more auditory than cognitive demanding. Here, I generated a speech-shaped noise using Praat, by combining the spectral properties of all selected digit stimuli. One sound was generated for each speaker (i.e., one for the female voice and one for the male voice). I also proposed to add in the bWell setting the possibility to change the noise to more ecological/informative noises, such as babbling noise and street noise. Different sounds are suggested and were taken from: https://www.ee.columbia.edu/~dpwe/sounds/noise/, where the description of the recording is provided. The use of different sounds would allow for the study of different aspects of listening ability, but I suggest keeping the speech-shaped noise as the default, as it allows for the study of a very pure listening ability with low cognitive demand. By default, each noise will be presented using an adaptive 1-up, 1-down procedure with a 2 dB step. The starting sound level needs to be set to 65 dB, resulting in a starting signal-to-noise ratio of 0 dB. The clinician could change this setting and use a specific signal-to-noise ratio.

**Procedure:** Immediately after a set of digits is presented, the numbers 0-9 will be presented in the field of view all at the same time to minimize the demand on working memory, and participants will be asked to click on the numbers they heard using the VR controllers. Participants will have 5 seconds to respond. One trial will be presented after each trial of the THEATER task, resulting in the same number of trials for the DTT and the THEATER task. In the original version of the DTT, 24 trials are presented, and performance is defined as the speech reception threshold, which examines at which level the patient can repeat 50% of the speech material, based on the 20 last trials. In the case of a VR task, trials will also be presented during the practice of the THEATER task, and the speech reception threshold will be based on all trials of the actual version of the THEATER task. A triplet of digits will only be considered correct when all digits are correctly identified. The speech reception threshold will be calculated by averaging the signal-to-noise ratios of all trials, except for the practice trials. The percentage of correct responses and the reaction time can also be calculated.

**Short Summary**

Stimuli:

* The stimuli consist of the digits 1, 2, 3, 4, 5, 6, 8, 9, with 0 and 7 excluded in English to keep the words monosyllabic. Sets of three digits will be created by randomly selecting three digits from the list. The number of possible sets is 336.
* One set should not be repeated during the task and the position at which the numbers appear in the sets should be balanced.
* The stimuli will be presented using VR.
* Each set of stimuli will have a silent interval of 500 ms before the first digit and after the last digit, with an additional random interval of ± 50 ms to add uncertainty. A silent interval of 150 ms will be included between each digit.
* The stimuli are selected from: <https://www.ee.columbia.edu/~dpwe/sounds/>
* The stimuli could be presented in a male or female voice.
* The speech level will be fixed at 65 dBA.

Noise:

* The sets of digits will be presented in noise. We can use different types of noise, but the most commonly used is steady-state speech noise.
* A steady-state speech noise will be created using Praat. The noise is created by combining the sound files of each digit.
* The noise will be presented with an adaptive procedure. Specifically, a 1-up, 1-down adaptive procedure with a step size of 2 dB will be used.
* The starting sound level will be fixed at 65 dB, providing a starting signal-to-noise ratio of 0 dB.

Procedure:

* After the presentation of a set of digits, the numbers 0 to 9 will be presented in the field of view, and participants will have to click, using the VR controllers, on the numbers they believe were presented.
* The number of trials will correspond to the number of trials in the theater task.
* The performance will be defined as the speech reception threshold (SRT), accuracy and average reaction time.

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