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Enhancing selective attention: Oticon Opn S™ new evidence

ABSTRACT

The ability to selectively attend to what is important and relevant is essential for us as listeners to navigate through the complexities of sound environments throughout the day. This ability is important for successful speech communication and social participation and is restricted in individuals with a hearing impairment.

This whitepaper starts by introducing the concept of selective attention. It then moves on to discuss a novel technique to assess selective attention using electroencephalography (EEG), which can measure the brain's ability to track speech that the listener is attending to over time.

We present a research study using this new technique to assess benefits of an advanced technology in hearing aids for the first time. Evidence shows that OpenSound Navigator (OSN) in the Oticon Opn S hearing aid significantly enhances the brain's tracking of the speaker of interest, allowing listeners to better organize different sound sources. This suggests that the improved audibility of and access to speech details provided by OSN contributes to the successful use of selective attention in challenging listening situations.

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Try to picture yourself with your friends and family. You are at a restaurant, surrounded by other people enjoying their time there as well. Under the cacophony of laughter and clanging cookery, you converse with your close friend who is sitting opposite to you. The conversation, filled with joy and laughter, draws the attention of your cousin. Your cousin joins in on the conversation to share their part of the story, so you are intrigued and may decide to direct your attention to your cousin. Sometimes the topic is about the food, other times it was about that one time you did something embarrassing. Your attention switches rapidly between the two of them such that you can follow the conversation.

Such a dynamic situation may be thrilling for people with normal hearing. But those with hearing loss often find such a scenario daunting (Noble, 2006). One of the reasons for this discrepancy is due to differing levels of the ability to selectively attend to a speaker (Shinn-Cunningham & Best, 2008).

Selective Attention

Selective attention can be loosely defined as the ability to focus on a single desired source while suppressing competing sources over time by organizing the sounds around you. It is the process that allows us to prioritize the processing of relevant over irrelevant information. Ideally, selective attention is rapid and steerable. It is an ability to naturally focus and refocus (switching attention) on different sound sources of interest. In the above scenario, it would be organizing the sounds in a complex environment (mixture of sounds from your cousin, friend and restaurant noise) and prioritizing your cousin's speech.

This is an ability that listeners with normal hearing may take for granted but can be challenging for those with hearing loss to achieve. The underlying mechanisms are complex but largely surrounds the idea of the perception of "auditory objects" (Shinn-Cunningham & Best, 2008). Briefly put, for the brain to make sense of a complex auditory scene, it must first organize sounds into distinct auditory objects, then analyze them in a way that it achieves some ultimate goal of a listener (such as wanting to understand your cousin such that you can come up with a valid response).

It is known that our brains like to organize and group these auditory objects according to the sound features, such as differences in pitch, loudness and spatial position as well as familiarity and expectations (Bregman, 1990). When we develop a hearing loss, the distortion factor (Plomp, 1978) causes us to lose our sensitivity to acoustic cues such as spectral resolution (Moore, 2007) and temporal resolution (Nelson & Freyman, 1987) which are crucial for identifying those features. As a result, these distinguishing features become blurry and may merge, creating an object that is far too complex for the brain to decipher. This also interferes with the ability to filter out sound sources. A visual concept is illustrated in Figure 1.

One way to compensate for hearing loss is the usage of hearing aids. In addition to providing audibility of sounds at frequencies that people with hearing loss cannot hear, noise-reduction schemes aim to reduce the level of background noise and improve the signal-noise-ratio (SNR). When background noise is reduced, the brain has access to a clearer speech signal, including the acoustic cues mentioned above. This makes speech more salient and to be more easily picked out from a sound mixture. This allows the listener to selectively attend to a sound source more easily.

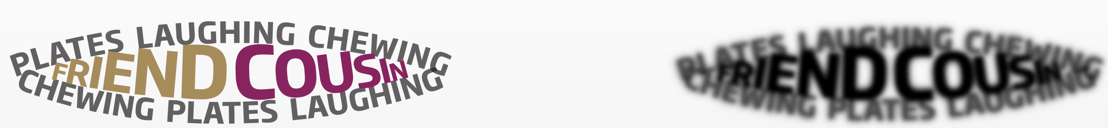

Figure 1. A schematic illustration of the concept of auditory objects and how it is represented in an individual with normal hearing or with hearing loss. The left diagram shows what would likely happen if one had normal hearing, the sharp text shows a clear classification of the individual sound sources. In addition to that, the different colors for "friend" and "cousin" shows a clear distinction between the two sources of interest, and that the listener's ability to separate and selectively attend to them; In contrast, the right diagram shows what would likely happen if one had hearing loss, the blurred text shows that with a degraded sound mixture, it is not only harder to focus on any one of those objects, it is also harder to distinguish between them. This eventually causes these objects to "look" similar and merge as one complex mass that is challenging to decipher. Illustration inspired from concept of Shinn-Cunningham and Best (2008).

Assessing selective attention

There are different ways to measure selective attention. Subjective or self-reported measures are one of the most common ways to do so, where listeners are asked to rate how well they are able to selectively attend to the desired sound source. However, one drawback is that people may have a different perceptive "threshold" as to what makes them think they can attend to it. Behavioral tests are another way to assess selective attention. This can be done by testing a listener's ability to track a desired sound source such as speech while simultaneously presenting competing speech streams. In recent years, there has been a surge in interest within the field of selective attention using human neuroimaging (Alickovic et al., 2019; Lee et al., 2014). Studies have demonstrated that by using for instance, electroencephalography (EEG), magnetoencephalography (MEG), electrocorticography (ECoG), it was possible to determine the primary interest of a listener in a multi-talker environment (Alickovic et al., 2019; Ding & Simon, 2013; Mesgarani & Chang, 2012; O'Sullivan et al., 2015; Power et al., 2012). In other words, these techniques allow us to measure how well the brain tracks speech that the listener is attending to over time.

EEG is a non-invasive, objective, electrophysiological method that can be used to measure electrical activity generated by the brain. It is recorded by electrodes placed on the scalp and mounted in an elastic cap in order to ensure that the recordings are collected from identical positions across test participants.

A more familiar EEG based measurement technique to audiologists may be the auditory brainstem response (ABR). It measures, on the scalp, the electrophysiologic response to rapid auditory stimuli, such as clicks or tone-bursts, originating from the brainstem. In clinical practice, it is used to estimate hearing thresholds and detect auditory dysfunction in clients who are unable or unwilling to participate in the traditional behavioral hearing testing.

In contrast, the EEG technique used in recent selective attention studies examined the selective enhancement of cortical responses to attended speech over unattended speech during active listening. Typically, these studies record cortical responses as raw data by directing a listener to pay attention to an attended speaker (desired source) while simultaneously ignoring any competing sources (competing talker and background speech babble). In the case of EEG, the methodology, as shown in Figure 2, for the corresponding steps typically involves:

1) Present the sounds from two target speakers simultaneously to the listener, instructing the listener to pay attention to the desired source, which is one of the target speakers, while ignoring other sources. EEG signals are typically recorded by wet scalp electrodes as raw data.
2) Then the EEG signals go through an amplifier as the signals are typically very weak relative to electric signals generated by muscle movements.

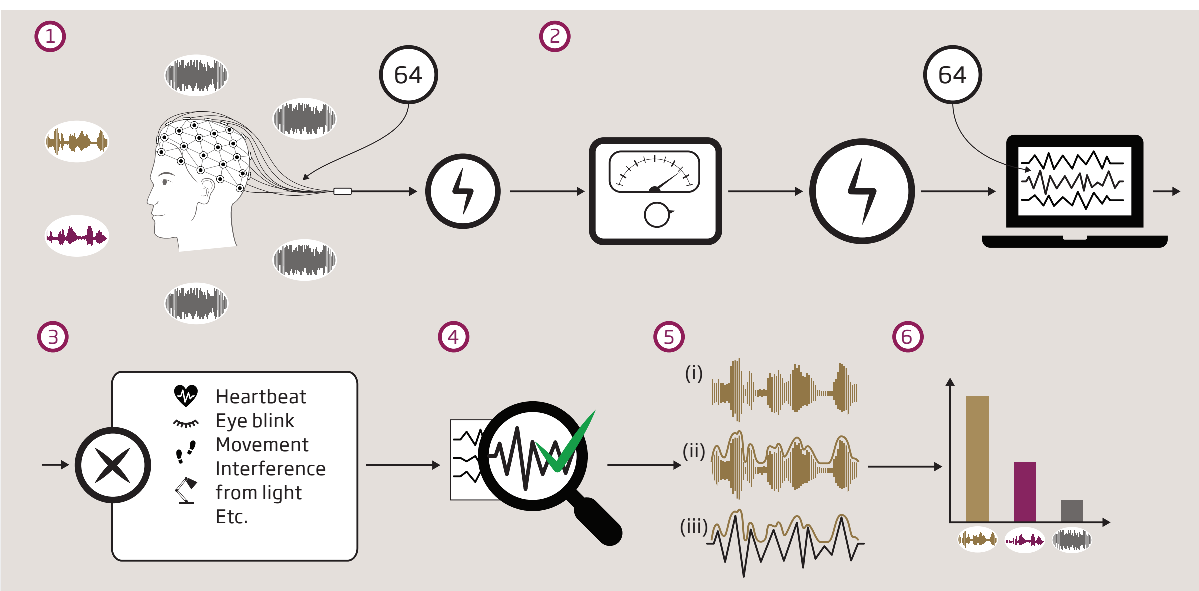

Figure 2. This flowchart describes the general procedure of measuring selective attention in a multi-talker environment with two target speakers.

3) The raw EEG data is passed through a filter that excludes unwanted artefacts and noise that are internal (heart beats, eye blinks, head movements etc.) as well as external (interference from light source). This results in a cleaner signal allowing for more convenient analysis.
4) Initial inspection of the acquired data to confirm that it is suitable for analysis.
5) This step examines how well the brain tracks or synchronizes with the attended and unattended speech by comparing the EEG signals and original speech signals. To achieve this,
   a) First, from the original acoustic signal (i), we extract the speech envelope (ii).
   b) Then, we need to transform the EEG signals into a format that can be compared with the speech envelope. This is achieved with a decoder, its purpose is to best approximate (or reconstruct) the original acoustical signals based on the EEG signal as input. This process is called stimulus reconstruction.
   c) We compare the envelope of the reconstructed stimuli and the envelope of the original speech signals by calculating the correlation between them (iii). A higher correlation value can be interpreted as a better ability for the brain to track the speech signal (referred to as "strength of EEG tracking" in Figure 5).
6) Finally, the correlation values are compared between the reconstructed stimuli of the attended and unattended conditions.

In certain cases, in order to ensure that the listener is actively engaged in the task, experimenters will also require the listener to answer questions that are relevant to the attended speech.

New evidence on selective attention

Noise reduction schemes are designed to improve speech intelligibility by reducing the level of background noise, hence raising the SNR for the listener. BrainHearing technologies such as OpenSound Navigator (OSN) (See Le Goff et al., 2016) are designed to help hearing aid users in complex acoustic environments by reducing the cognitive load and facilitating the organization of complex sound scenes, thereby helping the brain to focus on the source of interest.

OSN is an improvement from conventional noise reduction schemes as noise is more precisely processed, allowing more effective and rapid attenuation of these sources. A significant improvement in speech understanding over two conventional hearing aid technologies, directionality and narrow directionality, was demonstrated (Le Goff & Beck, 2017). The benefits of OSN are not just limited to speech understanding. We have also shown a significant reduction in listening effort with the help of OSN using pupillometry and a significantly improved performance in a memory recall task (Juul Jensen, 2019). This shows that OSN was able to free up cognitive resources by facilitating the encoding of words into long-term memory, which is crucial for speech communication.

The purpose of the current study was to investigate one's ability to selectively attend to or track different speakers in background noise using the auditory attention detection techniques described above to investigate whether OSN enhances selective attention. In this whitepaper, we present a brief summary of part of a larger study conducted at Eriksholm Research Centre (Alickovic et al., submitted).

Figure 3. Test setup with a total of six loudspeakers. There are two target speakers in the front (in blue and red, at +/- 22 degrees). Each of the remaining four loudspeakers (in black, at +/- 90 degrees and +/- 150 degrees) presents a 4-talker babble, resulting in a 16-talker babble. All loudspeakers are placed 141 cm from the participant.

Methods

Twenty-two experienced hearing aid users (average age 67 years) with mild to moderate hearing loss took part in the study. Oticon Opn S 1 miniRITE hearing aids were used, and amplification based on individual audiometric thresholds was prescribed using the Voice Aligned Compression (VAC) formula (Le Goff, 2015). To assess the benefit of OSN, two experimental conditions were used - OSN ON and OSN OFF.

Participants were seated in a listening booth. Figure 3 illustrates the test setup. There were two target speakers (one female and one male) and four loudspeakers presenting noise. The presentation level of each of the target speakers was fixed at 62 dB SPL and the overall level of noise, which is a 16-talker babble, was fixed at 59 dB SPL. The SNR was always kept at +3dB, mimicking a realistic noisy environment. The presentation order of the gender of the target speakers (male/female) and the direction (left/right) was randomized.

The participants were instructed at the beginning of each trial which speaker to attend to while ignoring the other competing sound sources. Each test trial began with the 16-talker babble. Five seconds later, two different news clips were played separately from the attended and unattended speakers in front together with the babble noise for the remaining duration (33 seconds). The news clips were all taken from Danish news broadcasts, therefore allowing a realistic speech stream for the participants to follow. At the end of the news clip, a 2-choice question was presented on a computer monitor for the participants to answer. The purpose of this was to maintain engagement of the participants on the task. This is illustrated in Figure 4. Twenty trials were used for each test condition.

EEG signals were recorded by 64 wet scalp electrodes and two linked mastoid external electrodes. Unwanted noise and artefacts were filtered out.

Results

In the OSN OFF condition (see Figure 5, left panel), there was a clear distinction in terms of brain tracking between the attended speech and the unattended speech, which demonstrates how the brain organizes sounds or auditory objects based on relevance. Firstly, the strength of EEG tracking was the highest for the attended speaker. This means that the brain naturally amplified the strength of the tracking of the attended speech, even when it had the same presentation level as the unattended speech (62 dB SPL). This is in agreement with results reported by Petersen et al. (2017) and Das et al. (2018), which showed weaker brain tracking of the unattended speech than that of the attended speech. The ability to track the unattended speaker and background babble was very similar. This suggests that it could be hard for the listeners to distinguish between the two sound sources.

Statistical analysis showed that with OSN ON (see Figure 5, right panel) the brain tracking of both attended and unattended speech significantly improved ($p < 0.05$), while the tracking of background babble significantly suppressed ($p < 0.05$). This is in line with the results reported by Das et al. (2018) that better SNRs generally enhances brain tracking of the attended speech. The results also revealed that the strength of brain tracking of the unattended speech was stronger than that of the background babble, suggesting more obvious distinction between these two sounds.

Interpretations and conclusions

In this study, we observed that the brain tracking of the attended speaker was significantly enhanced by the activation of OSN. This finding provides evidence that OSN activation further strengthens the participant's natural ability to amplify the neural representation of the attended speech in noisy environments. This suggests that the improved audibility of and access to speech details provided by OSN contributes to the

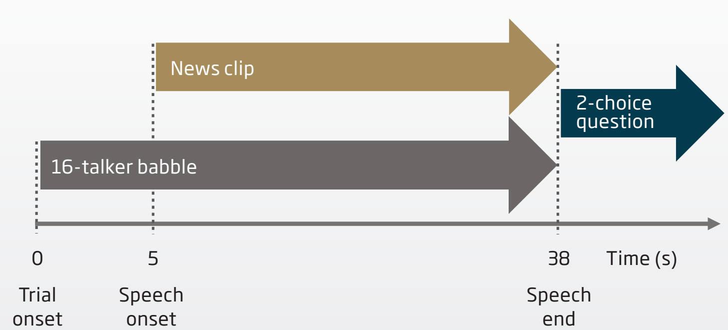

Figure 4. This figure shows what happens over the course of one trial in the experiment. The 16-talker babble starts first. Five seconds later, two different news clips are played separately (for 33 seconds) from the two target speakers in front to which the participant has to pay attention to either one. At 38 seconds, a 2-choice question concerning the news clip spoken by the attended speaker is presented to the participant to answer.

successful use of selective attention in challenging listening situations. Furthermore, improved distinction between the unattended speech and background babble indicates that the brain can track and follow different sound sources simultaneously. Taken together, the results of the study suggest that OSN helps the brain better monitor and organize different sources in the acoustic environments based on relevance. The strength of the brain tracking was strongest for the attended speech and weakest for the background babble. Better organization of different sound sources in the environment allows a smooth and rapid voluntary switching of attention between different talkers in the presence of noise when needed.

Our BrainHearing benefits play fundamental roles in speech processing. In our previous studies, we showed that compared to Oticon Opn, Opn S further improves speech intelligibility, reduces effort during active listening and enhances recall of relevant information stored in memory, which are important for reasoning, responding and reacting during speech communication (Juul Jensen, 2019).

Selecting information with attention during listening is an important attribute of successful speech communication. Listeners need to focus and sustain their attention towards the talker of interest while ignoring irrelevant sounds when there are simultaneous speech and noise sources in the environment. This is particularly challenging for people with hearing loss. This whitepaper presents evidence that, using the novel EEG research method, Opn S significantly enhances the listeners' ability to track the talker of interest and allows the listeners to better organize different sound sources based on relevance. This essential ability to selectively attend to what is important helps the hearing aid users monitor and navigate through complex acoustic environments throughout the day, allowing them to achieve successful speech communication and hence more actively participate and engage in social situations.

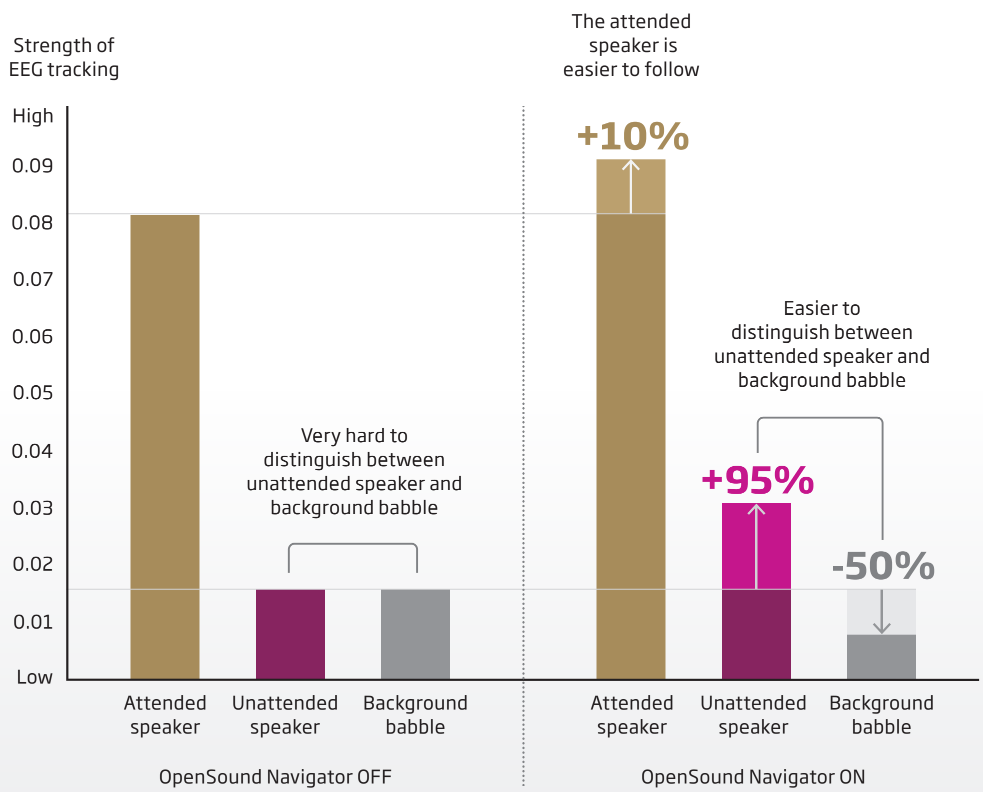

Figure 5. Results of the study. The participants were able to track the speech of interest with OSN OFF (left) and with OSN ON (right). As shown in the diagram, there is an improvement in the ability of the brain to track both the attended and unattended speech, as well as an increased suppression of babble noise with OSN ON.

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