Cochlear implant features and listening effort induction: measurement of the mental workload experienced during a word in noise recognition task

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Nowadays, thanks to technological developments, cochlear implant (CI) users showed continuous improvement in behavioral performances (e.g. percentage of words correctly recognized). However, behavioral data don’t provide full information concerning the level of listening effort experienced during the word’s recognition. Speech in noise recognition produced higher effort and/or stress in hearing impaired subjects in comparison to normal hearing listeners [1,2,3]. Questionnaires employed to assess such perceived effort (e.g. NASA TLX) are not sensitive to the detection of eventual improvements in comprehension during task execution, although reaction times measures such improvement linked to device’s spectral resolution increase [4]. Listening effort has been defined as the proportion of limited cognitive resources engaged in interpreting the incoming auditory signal, so the presence of noise or distortions in a speech signal increases cognitive demand and listening effort [5]. Worthily, listening effort level may change between CI processing conditions for which speech intelligibility remains constant [4].

Advances in the biomedical signal interpretation allow using cerebral signals to assess cognitive functions in humans, such as the cerebral workload. Neurophysiological measures have been already employed for assisting the clinical evaluation of hearing impaired subjects in CI candidates [6], CI users [7] and tinnitus [8,9,10]. Scientific evidences report that the cerebral workload, defined as index of workload (IWl) [11,12,13], increases at the increase in the frontal EEG power spectra in the theta band and the simultaneous decrease in the parietal EEG power spectra in the alpha band. IWl levels have been already estimated in CI users during a forced choice word recognition task in CI children, in order to investigate the reaction to different noise conditions [14]. Authors reported a modulation of the IWl in the phase preceding the listening of the word (IWl increase during the subjects’ most challenging noise condition) and in the phase before the word recognition execution (possible IWl burnout during the same condition). The present study aims at investigating, beyond “environmental factors” (the noise condition), the influence exerted on IWl by “device factors”, in particular the kind of processor and the noise filter features in use by the patient. With this purpose, in the present study 4 CI users (2M and 2F, mean age 52±22.73) have been tested while using three processors versions: Freedom (2005), CP810 (2009) and CP910 (2013), commercialized by the same company (Cochlear Ltd), so to maintain the same quality standard. Furthermore, since it has been shown that hearing-aid-like noise reduction strategies can improve performances on a secondary task, even when no improvement in speech intelligibility is seen [15], a hearing device feature, such as noise reduction, although maybe not relevant when assessed by an intelligibility test, may instead be beneficial leading to a reduction in listening effort. Due to the suggested influence of the background noise on the listening effort of CI recipients, two filters features conditions were tested: i) No noise filter reduction use, that is the use of ADRO alone, the normal default directionality response; ii) Noise filter reduction use, in other words the use of Beam, Zoom and SNR-NR features for the Freedom, CP810 and CP910 respectively. The task was a forced choice word recognition task with six conditions, resulting by the sum of the six possible combination of the use one at a time of one of the processors (Freedom, CP810 and CP910) in one of the filter features (No Noise filter and Noise Filter). Each experimental condition comprised 20 trials corresponding to 20 words, each trial lasting maximum 8 seconds and varying in length depending on the response time. The forced-choice task was constituted by a picture with 4 words placed each in different colored boxes. The subject had to read the words, identify the word just listened (target word) among the other ones, and selecting his choice pressing the corresponding colored button on a keyboard. Words were chosen so that the target word had an equal probability (25%) of being in one of the four possible colored boxes (and positions). Consistently in the experimental conditions noise and words stimuli were delivered form 1 front and 1 back loudspeakers, positioned 0° and +180° in relation to the subject. During the trials the background noise was emitted continuously. For the EEG acquisition and analysis a digital ambulatory monitoring system (Bemicro EBNeruo, Italy) was used for the EEG recording, with 19 channels EEG cap. After acquisition and pre-processing of the recordings the Power Spectrum Density (PSD) was calculated, observing the EEG PSD values in theta (4-8 Hz) and alpha (8-12 Hz) bands. The IWl was defined as the ratio between the EEG PSD in theta band over the frontal area (F7,F8,P3,F4,Fz) and the EEG PSD in alpha band over the parietal area (F7,F8,P3,F4,Pz) [12]. The IWl values were analyzed by the repeated measures Analysis of Variance (ANOVA) so to compare the different: processors (Freedom, CP810 and CP910) and the different noise filter conditions of the devices (No noise filter reduction and Noise filter reduction).

Results showed a statistical significant interaction between the factor processor and the factor filter (F= 51.21 p<0.001), but not for the effect of the processor (F=2.3 p=0.11) nor the filter (F=0.56 p=0.46) per se (Fig.).

In literature, evidences based on traditional clinical outcomes showed a significant improvement when using Nucleus 6 (CP910) in...
comparison to Nucleus 5 (CP810) in adults [16] and children, relatively to the speech in noise perception test [17]. Our results suggest the same trend from a neurometric approach, since the lower IWL values were obtained when the CP910 was used, even not reaching the statistical significance. Furthermore, Noise Reduction features in hearing devices may reduce listening effort making available cognitive resources for other tasks [15] and reducing the listeners’ cognitive load [18]. Our data also in this case accord to the literature, since the Noise Filter Reduction use induce the lower IWL values, despite not reaching the statistical significance. The study presents the obvious limitation of the employed sample, however data suggest the applicability and usefulness of IWL estimation for the evaluation of biomedical devices in patients.

Figure 1

References


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