Exploring cognitive and linguistic predictors of speech recognition improvement in adults after cochlear implant activation

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The primary objective of the study is to investigate which cognitive abilities predict amount and time-course of individual improvement in speech understanding performance within the first three months after cochlear implant activation. The primary...

Ethical review	Approved WMO
Status	Recruitment stopped
Health condition type	Hearing disorders
Study type	Observational non invasive

Summary

ID

NL-OMON42097

Source
ToetsingOnline

Brief title
Cognitive predictors of speech perception benefit with a cochlear implant

Condition

- Hearing disorders

Synonym
Cochlear Implant, Inner-ear Prosthesis

Research involving
Human

Sponsors and support

Primary sponsor: Radboud Universiteit Nijmegen

Source(s) of monetary or material Support: VIDI beurs "What makes a good listener" (NWO projectnummer: 276-75-009) toegekend aan dr. Esther Janse

Intervention

Keyword: adaptation, cochlear implant, cognition, speech recognition

Outcome measures

Primary outcome

The main study parameters are participants' performance changes on four

measures of speech perception between baseline (one week after cochlear implant

activation) and endpoint (eleven weeks after cochlear implant activation)

performance:

• Number of correctly repeated speech sound of consonant-vowel-consonant words

• Number of correctly repeated keywords in sentences

• Accuracy of keyword identification in conversational speech

• Response time of word identification (in ms) in conversational speech

Secondary outcome

Secondary study parameters include performance on all cognitive and linguistic

tasks and participants' subjectively experienced benefit of the cochlear

implant:

Learning

• Statistical learning: Individual changes in click response times based on

changes in the predictability with which items co-occur in the task.

Memory

• Verbal short-term memory: Proportion of correctly repeated syllables of

nonwords

• Short-term memory: Proportion of correctly repeated sequences of digits.

• Working memory: Proportion of correctly repeated sequences of digits in reverse order.

Attention

• Attention switching control: Time ratio (in seconds) between the completion of two tasks: (a) connecting digits in ascending order (i.e., 1-2-3...); (b) alternatingly connecting numbers and letters in ascending order (i.e., 1-A-2-B-3-C...).

• Selective attention: Time ratio (in ms) between response times in two conditions: participants mean response time to correctly identify the stimulus (i.e., whether a '>' or a '<' is displayed in the middle of the screen) in a neutral condition (i.e., - - > - -), divided by response time in an incongruent condition (i.e., < < > < <).

Processing speed

• Digit-symbol-substitution task: Number of digits that are correctly recoded into assigned symbols within 90 seconds.

• Letter comparison task: Percentage of correctly identified pairs of consonant strings as being same or different.

Verbal ability

• Vocabulary test: Number of correctly identified synonyms in a five-choice multiple choice task.

• Language proficiency test: Number of words that are correctly inserted into text gaps.

• Articulatory precision: Difference in fricative frequencies (spectral moments, spectral peaks; in Hz) and difference in vowel formant frequencies (F1 and F2; in Hz) between patients' sound productions and articulatory norm data.

CI-benefit

• Overall experienced benefit: Pre- and post-surgery difference in mean score of all answers on the Nijmegen Cochlear Implant Questionnaire (on a Likert scale from 1-5)

• Benefit in communicative situations: Pre- and post-surgery difference in mean score of all answers (on a Likert scale from 1-5) in the domain "speech production" on the Nijmegen Cochlear Implant Questionnaire

• Social benefit: Pre- and post-surgery difference in mean score of all answers (on a Likert scale from 1-5) in the domains "activity limitations" and "social interactions" on the Nijmegen Cochlear Implant Questionnaire

• Sound perception benefit: Pre- and post-surgery difference in mean score of all answers (on a Likert scale from 1-5) in the domains "basic sound perception" and "advanced sound perception" on the Nijmegen Cochlear Implant Questionnaire

Data on the following demographic and baseline variables that may intervene with the study parameters are collected as control variables:

• Age

• Duration of hearing loss

• Etiology of hearing loss

• Bone and air conduction thresholds (0.5, 1, 2, 4 kHz) of both ears prior to implantation

• Best-aided speech reception threshold at 70 dB SPL of both ears prior to

implantation

• Changes in hearing-aid after cochlear implant activation

Study description

Background summary

Postlingually deafened adults who are provided with a cochlear implant (CI) face a great challenge: they have to learn to interpret a novel and rather artificial acoustic signal. Intriguingly, within a couple of weeks only, dramatic increases in patients* speech understanding performance have been reported. However, the benefit a patient experiences from a cochlear implant varies considerably between individuals. For example, individual improvement in spoken word recognition after six months of CI activation was found to range between 2% and 66% among CI recipients (Heydebrand et al., 2007). This raises the question which factors predict speech perception outcome after implantation. Knowledge about such factors is of clinical relevance as it may pave the way for individualized training and rehabilitation programs.

Over the last decades, mainly impairment-related factors have been studied as possible factors accounting for this inter-individual variability. Although age at onset of hearing loss (e.g., Kaplan et al., 2003), duration of hearing loss (e.g., Chan et al., 2007; Hamzavi et al., 2003; Holden et al., 2013; Oh et al., 2003), and to lesser extents etiology (e.g., Blamey et al., 1996; Geier et al., 1999) and age at implantation (e.g., Holden et al., 2013) have been shown to explain adults' variability in speech perception skills after implantation, these factors were found to explain only 10 to 21% of the variance in CI-outcome (cf., Blamey et al., 1996; Blamey et al., 2013). This suggests that a large amount of variability between individual CI-recipients remains unexplained.

Individual cognitive abilities may account for additional variance in CI-recipients. Particularly in children with CIs, researchers have argued that individual differences in cognitive abilities that relate to perception, attention, learning or memory processes may explain the large variability in CI-outcome (Ingvalson & Wong, 2013; NIH Consens Statement, 1995; Pisoni et al., 1999). Indeed, research found that measures of behavioral inhibition (Horn et al., 2005), novel word learning ability (Davidson et al., 2014), short-term memory (Cleary et al., 2000; Edwards & Anderson, 2014; Pisoni et al., 1999; Willstedt-Svensson et al., 2004) and working memory (Cleary et al., 2000; Pisoni & Davis, 2003; Willstedt-Svensson et al., 2004) were associated with language outcome in children with CIs. However, children are typically implanted at such a young age that it is not possible to measure cognitive abilities prior to implantation. Moreover, children's cognitive and language development is highly intertwined and the relationship between cognitive and linguistic skills may be reciprocal. On the one hand, cognitive abilities may facilitate successful adaptation to a CI and hence language development. On the other hand, access to auditory and linguistic input after CI-activation may stimulate children's cognitive development by increasing children's attentional skills (Khan et al., 2005).

Testing adult postlingually deafened CI-recipients, who acquired linguistic and cognitive skills normally, allows us to approach the influence of specific cognitive abilities (as assessed prior to implantation) on CI adaptation success more directly. Although the number of postlingually deafened CI-recipients is rapidly increasing, only few studies have tried to link cognitive performance prior to surgery to speech perception outcome after CI activation. Early studies reported working memory (Lyxell et al., 1998) and fast visual sequence processing (Gantz et al., 1993; Knutson et al., 1991) to relate to speech perception performance at nine to eighteen months post-surgery. More recently, a study found patients* verbal learning ability to be predictive of their word recognition ability six months after CI activation (Heydebrand et al., 2007). These research findings are promising as they suggest cognitive abilities to play a role in CI-outcome. However, studies so far have only linked cognitive abilities to medium-term outcome. As CI-recipients receive intensive auditory training mainly during the first weeks after CI activation, knowledge about the influence of cognitive abilities on the initial adaptation process may be particularly valuable. For example, if memory abilities are associated with better hearing progress, treatment may be adapted for participants with poorer memory skills by extending the rehabilitation program or by providing memory exercises.

Evidence for the potential role of cognitive abilities in initial CI adaptation success comes from studies on perceptual learning in speech. In these studies, participants are exposed to unfamiliar speech input such as accented or noise-vocoded speech (which is a simulation of the auditory signal of a cochlear implant) and participants* improvement in speech understanding performance over exposure is investigated. Speech recognition improvement has been reported to relate to measures of statistical learning ability (Neger et al., 2014b), vocabulary knowledge (Janse & Adank, 2012; Neger et al., 2014b), and selective attention (Janse & Adank, 2012), with more improvement over exposure for those with better statistical learning, better vocabulary, and better selective attention. As CI recipients also have to adapt to a novel listening situation, adaptation to the signal of a CI may be considered a functional concept of perceptual learning. Further evidence backing up this assumption comes from the finding that, good CI performers show increased activity in brain areas (i.e., inferior frontal gyrus and angular gyrus) (Giraud & Lee, 2007) that have been linked to perceptual learning performance

(Eisner et al., 2010) as well as to executive functioning (Colom et al., 2013), compared to poor CI performers (Lyness et al, 2013).

Importantly, most studies on predictors of speech perception performance in CI-users used simple consonant-vowel-consonant (CVC) words. However, in everyday speech, CI recipients are generally confronted with conversational speech. In contrast to carefully designed audiological speech material, conversational speech consists of sentences that vary in speech rate and include hesitations and sloppily articulated speech etc. That is, audiological testing material is clearly different from conversational speech and, hence, from the speech material cochlear implant recipients are exposed to during the adaptation process. Processing of longer stretches of speech may, thus, be more ecologically valid to measure patients' progress in speech understanding performance. Therefore, individuals' cognitive abilities and individuals' subjective CI-benefit will be compared to speech recognition performance in three conditions of increasing ecological validity: a standard CVC-recognition task, a sentence repetition task (clear speech) and a word identification task in conversational speech.

In sum, this study aims to investigate the role of learning ability, linguistic knowledge, and general cognitive abilities of processing speed, memory and attention during the initial adaptation phase after CI-activation. We hypothesize that these individual cognitive abilities can be used to predict patients' amount and time course of improvement over the first three months of CI-use. Moreover, we assume that individuals' speech recognition performance will be associated with their subjectively reported benefit, particularly in ecologically valid sentences recognition tasks.

Study objective

The primary objective of the study is to investigate which cognitive abilities predict amount and time-course of individual improvement in speech understanding performance within the first three months after cochlear implant activation. The primary hypothesis is that part of the variance in patients' improvement in speech understanding performance during the first weeks after cochlear implant activation is explained by patients' learning ability, linguistic knowledge, processing speed, memory and attention. Moreover, we aim to assess the use of ecologically valid speech materials for audiological testing in CI-users. The hypothesis is that with increasing ecological validity speech perception measures are more predictive of the subjective benefit patients experience with a cochlear implant.

The secondary objective of the study is to investigate participants' changes in articulatory precision (i.e., one measure of verbal ability in the current study) in relation to their individual changes in speech perception. Prior to implantation, CI recipients typically produce imprecise sound contrasts in their speech due to insufficient auditory feedback (Lane et al., 2007). After

CI activation, auditory feedback is restored but the auditory input is rather artificial and shifted in frequencies. That is, patients have to retune their speech productions mechanisms based on this altered auditory feedback (Lane et al., 2007). Links have been demonstrated between discrimination of speech sounds and articulatory precision in normal-hearing adults (Perkell et al., 2004a; Perkell et al., 2004b). Therefore, we hypothesize that individual improvement in general speech perception abilities is related to individual improvement in articulatory precision after CI activation.

Study design

The investigation is designed as an explorative, observational, longitudinal study and will take place within one single center. Patient inclusion of this clinical investigation will be performed among patients that already have been audiologically and otologically evaluated and have been assessed as suitable candidates for treatment with a cochlear implant. The group includes approximately 30 patients. All participants will undergo the regular clinical practice. However, in addition, participants will be tested at five points in time. Patients will come for testing of individual cognitive and verbal abilities one to three weeks prior to surgery and will come for check-ups one week, three weeks, seven weeks and eleven weeks following cochlear implant activation. These visits will include a clinical evaluation of patients* speech understanding performance with the cochlear implant. Moreover, a short test of processing speed will be administered at the beginning of each visit to measure patients' alertness and general cognitive processing ability per test session. Additionally, patients' articulatory precision will be tested during the first and last follow up moment.
All data is to be registered in digital Case Report Forms.

Project duration
The experiment will run from 01-01-2015 to 30-11-2015. During that time span, postlingually deafened patients, who are provided with a CI at the Hearing & Implant department of the Radboud UMC in Nijmegen, who meet the criteria for inclusion in our study, and who confirm their participation in written consent, can participate in the project.

Session duration
All testing will take place at the Radboud UMC. Evaluation of participants' cognitive skills will require 2 hours and will be combined with one of the preoperative visits. Similarly, testing of patients' speech recognition performance after cochlear implant activation will be combined with four follow-up sessions at the Radboud UMC to cause minimal inconvenience for the participants. The first and last follow-up test moments will take 40-55 minutes, as multiple measures of speech understanding performance as well as a measure of articulatory performance will be administered. The second and third follow-up test moments will only take 15 minutes, implying a time investment of 4 hours per participant (spread over 4 months).

Tasks per session
To measure individual abilities, we administer a set of cognitive and linguistic tests prior to surgery. These tests include:

Cognitive and verbal abilities
To measure individual abilities, we administer a set of cognitive and verbal tests prior to surgery. These tests include:
Learning ability
• Statistical learning: visual artificial grammar learning task (ability to derive implicit regularities based on frequency of co-occurrences) (Neger et al., 2014b). As participants have to be unaware of the aim of the task to be able to measure implicit learning, participants are informed that the task measures motor speed.
Memory
• Short term memory: Digit Span Forward Test (Daneman & Carpenter, 1980)
• Verbal short term memory: Non-word repetition task (Gathercole et al., 1994)
• Working memory: Digit Span Backward Test (Daneman & Carpenter, 1980)
Attention
• Attention switching/mental flexibility: Trail-Making Test (Salthouse et al., 2000)
• Selective attention: Flanker test (Richard Ridderinkhof et al., 1999)
Processing speed
• Motor and mental speed: Digit-Symbol-Substitution task (Wechsler, 2004)
• Scanning speed: Letter comparison task (Salthouse & Babcock, 1991)
Verbal ability
• Vocabulary: Vocabulary knowledge test (Andringa et al., 2012)
• Language proficiency: Cloze test (ability to correctly guess which words might be missing from incomplete texts) (Neger et al., 2014a)
• Articulatory precision: Word reading task (ability to disambiguate sound categories). Words are embedded in short carrier sentences. Please note that the speech of the participant will be recorded in this task.
Subjective cochlear implant benefit
To evaluate participants' subjective benefit in hearing, we collect data on patients' hearing experience prior to surgery and eleven weeks after implantation. As patients are standardly asked to fill in this questionnaire prior to implantation, we only administer the questionnaire eleven weeks after implant activation:
• Nijmegen Cochlear Implant Questionnaire

Speech understanding
Participants perform three different task to measure speech recognition performance after activation of the cochlear implant. Participants perform all tasks in their best-aided, bimodal hearing condition Participants perform all tasks in their best-aided, bimodal hearing condition (i.e., with the hearing aid(s) and CI they use in their daily life at that moment) to resemble patients' everyday listening experience:
• Speech audiometry: Percentage of correctly repeated speech sounds of

auditorily presented consonant-vowel-consonant words at 70 dB SPL. This task is standardly used to measure patients' hearing ability with their CIs and to adjust CI-settings. It is part of the general follow-up examinations and will, therefore, impose no additional load on participants.
• Sentence recognition test: Percentage correctly identified keywords in sentences. Sentences are presented at a fixed intensity of 70 dB SPL and participants have to repeat what they understand. Sentences come from audiology testing materials (Versfeld et al., 2000). During each test moment participants are presented with three lists of 13 sentences (different lists at each test moment), each sentence containing three to four keywords.
• Word identification in conversational speech: Accuracy and speed with which participants are able to correctly identify one out of four possible words in conversational speech (Koch & Janse, 2014). Speech materials are presented at a fixed intensity of 70 dB SPL.

Study burden and risks

Following the risk classification guidelines of the NFU, the risk of participating in this study is negligible. The implant, surgery and rehabilitation process are identical to the regular clinical practice and will, therefore, not contribute to any additional risk. No type of complications is anticipated other than those that might occur when rehabilitating patients with a cochlear implant outside the study. Thus, there are no medical risks associated with participation.
Overall, participation in the study requires visits for the patient with the same frequency, but with longer duration of some of these visits. This imposes extra load on patients, however, patients will receive financial compensation for their time investment (i.e., travel reimbursement per visit and an once-only payment of 40 ¤ after completion of all follow-ups). Additionally, by participating in the study, patients have the possibility to gain detailed insight into their speech understanding improvement in communicative settings, which is one of the key aspects of rehabilitation. We conclude that the risks of this exploratory study are acceptable when weighted against the gain in terms of research results in a field that has received little attention but may be important for long-term patient outcomes.

Contacts

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Trial sites

Listed location countries

Netherlands

Eligibility criteria

Age
Adults (18-64 years)
Elderly (65 years and older)

Inclusion criteria

• 18 years or older
• Post-lingual deafness (deafness that developed after acquisition of speech and language; onset of deafness after the age of six)
• Patient indicated for a cochlear implant
• Normal or corrected to normal vision
• Written informed consent

Exclusion criteria

• Mental disabilities
• Visual disabilities
• Hearing loss as a result of meningitis or as part of a syndrome
• Partial insertion of the cochlear implant
• Patient received special education
• Doubts, for any reason, about whether the patient may not be able to show up on all follow ups

Study design

Design

Study type: Observational non invasive

Masking:	Open (masking not used)
Control:	Uncontrolled
Primary purpose:	Diagnostic

Recruitment

NL

Recruitment status:	Recruitment stopped
Start date (anticipated):	20-02-2015
Enrollment:	30
Type:	Actual

Ethics review

Approved WMO

Date:	29-01-2015
Application type:	First submission
Review commission:	CMO regio Arnhem-Nijmegen (Nijmegen)

Study registrations

Followed up by the following (possibly more current) registration

No registrations found.

Other (possibly less up-to-date) registrations in this register

No registrations found.

In other registers

Register	ID
CCMO	NL51331.091.14