Hearing and cognitive measures predict elderly listeners' difficulty ignoring competing speech

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Introduction

Listening to one person speaking while there are other speakers in the background can be a challenging task for elderly listeners. The primary reason for this increased difficulty with competing speech is age-related hearing loss. Yet, older adults tend to have greater difficulty than young adults in understanding speech in noisy backgrounds even when the two age groups are matched for pure-tone hearing acuity [1]. This could be due to two additional age-related issues. Age groups may also differ in temporal and frequency selectivity. Thirdly, there are indications that age-related cognitive decline may play a role as well. Elderly adults could have more problems with the strategic allocation of attention to focus on the target speaker and to effectively inhibit the irrelevant distractor speaker. Tun, O'Kane & Wingfield [2] found that elderly adults were disproportionally affected by competing speech that was meaningful to them, relative to young adults. Elderly listeners were more affected by competing speech if the competing speaker spoke their native language than if the competing speaker did not speak their native language, whereas young listeners' performance was not affected by native, compared to non-native, interference. If the meaningfulness of the distractor speech matters, it is also clear that speech from one competing speaker is more difficult to ignore than multi-talker babble. This is clear evidence that cognitive factors beyond age-related peripheral hearing impairment and central auditory processing play a role in elderly adults' problems with competing speakers in the background. Furthermore, Humes, Lee & Coughlin [3] showed that individual differences in memory capacity were associated with performance differences among elderly adults in listening situations of divided and selective attention.

The present study seeks additional support for this idea that age-related general cognitive factors, not specific to the auditory modality, may be involved in elderly adults' problems ignoring competing speech. One should note, however, that auditory and cognitive abilities may vary considerably within a group of elderly participants. Therefore, an individual approach was taken, rather than a comparison between age groups. If interference from competing speech was related to individual performance on cognitive measures in earlier studies, most have used measures of memory, or information processing speed. The current study, however, investigates whether there is a direct relationship between a measure of interference from irrelevant stimulus aspects, not specific to the auditory modality, and the amount of interference from competing speech. This builds on the idea that a decline in executive control is responsible for older adults' difficulty in ignoring irrelevant information [4,5]. As a measure of inhibition, a variant of the classic Stroop paradigm is used where participants have to name the colour of a rectangle, which either has the letterstring "XXXX" in it (i.e., the neutral condition) or an incongruent colour name (the word "GREEN" in a blue rectangle: the incongruent condition). Apart from elderly adults' hearing acuity and a number of other background measures, individual Stroop test performance was entered as a predictor for performance to investigate whether inhibitory abilities would predict performance in the listening study.

Whereas most studies on aging and distraction from competing speech have looked at offline speech comprehension (i.e., how much do listeners remember from the target speaker's speech or at which signal-to-noise ratio do they achieve 50% correct identification), the present study took an online approach and investigated not only the result of the speech recognition process, but also the time that listeners need to come up with a response. Response time is thought to be a more sensitive measure of speech identification effort. Thus, the aim of the present study is to investigate to what extent (age-related) hearing loss and a measure of inhibitory abilities contribute to listening effort in two listening situations: when they listen to a target talker without competition and when they listen to a target talker with competition from a distractor speaker.

Method

A phoneme detection experiment was set up in which participants were asked to press a response button when they detected a pre-assigned sound (such as /p, b, k/).

Materials

There were 76 test sentences all containing the pre-assigned target sound in word-initial position (if /p/ was the assigned target, the sentence contained the word *pill*). The word containing the target sound was not predictable from the preceding words in the sentence (e.g., "I heard that this small *pill* would improve your digestion"). Additionally, there were 40 filler sentences that did not contain the pre-assigned target sound, such that participants would not press the button randomly. The test and filler sentences were spoken by a young male speaker of standard Dutch. The competing speaker was a male speaker of standard Dutch as well. Each sentence of the target speaker was to be presented to each participant either in the single-speaker condition (no competition) or in the condition with competition where it was mixed with an equally long sentence of the competing speaker. In the competition condition, the two audio files were mixed for binaural presentation at a target-to-competing speaker ratio of +3.5 dB. Care was taken that the sentence of the competing speaker did not contain the target sound for that trial. The two conditions (with and without competition) were rotated over the 76 test sentences on two experimental lists, following a Latin square design to avoid multiple presentations of the same sentence. The filler materials (also divided over the conditions) were equal on the two lists, such that each participant was presented with half of the test and half of the filler trials in the no-competition condition and the other half of the materials in the competition condition.

Participants

A group of 39 elderly adults (15 male and 24 female) participated in this study: 20 of them were assigned to experimental list 1 and 19 to list 2. They were recruited via a call for participation in an article in a local newspaper and in an information letter for *Higher Education for the Elderly* students. This educational organisation is linked to several universities in the Netherlands and offers academic-level courses for people over 55 years of age. Participant characteristics are given in Table 1. The elderly had a mean age of 72 (range 65-83) and they were all highly educated. Hearing sensitivity was assessed by pure-tone audiometry (air conduction thresholds) with a Maico ST 20 audiometer. Individual hearing loss was defined as the mean pure-tone threshold over the frequencies 1, 2, and 4 kHz in their best ear (this ranged from 7-54 dB). As a test of their linguistic abilities, a vocabulary test was administered in which participants had to select, out of five options, a synonym for a given word (this test is part of the Groningen Intelligence Test, [6]). As mentioned in the Introduction, participants also did a variant of the Stroop colour naming test as a measure of effective inhibition of irrelevant stimuli. They were presented with big coloured rectangles on a computer screen and had to name the colour of the rectangle (blue, green, or red) as fast and as accurately as possible. The rectangle either had “XXXX” in it, or an incongruent colour name (60 presentations per participant per condition). Table 1 lists mean colour naming time in the neutral (XXXX) and the incongruent condition, and the interference effect (defined as (incongruent – neutral)/neutral). As a measure of information processing speed, participants did the paper-and-pencil Digit Symbol substitution test which measures the time needed to recode a number of digits to symbols (corrected for motor speed). The latter test is part of the Wechsler Adult Intelligence Scale test [7].

	Mean	*SD*
Age (years)	72	4.9
Vocabulary test (max. score 20)	18	1.2
Pure tone average in best ear (dB)	29	13
Stroop test performance (logRT)		
• Neutral	2.81	0.05
• Incongruent	2.90	0.06
• Interference effect	0.03	0.01
Processing speed measure (coding time per digit, in seconds)	0.94	0.54

Table 1: Descriptive characteristics of the participant group

Procedure

Participants were seated in front of a computer screen in a sound-insulated booth. The (mixed) auditory material was presented binaurally over closed headphones (Beyer Dynamic DT 250) at a mean level of 80 dB SPL. Participants were first familiarised with the target speaker’s voice so that they would know whom of the two competing talkers they would have to attend to. This familiarisation phase consisted of the presentation of 10 sentences spoken by the target speaker. Participants could play these sentences as often as they liked. They were then instructed that each trial would begin with the visual display of the target phoneme for that trial. It was displayed in a large font 1 s before the auditory presentation started and stayed on the screen during sentence presentation. After sentence offset, participants had 1 second during which they could still press the button. They would proceed to the next trial after another 1500 ms. The order of the items was randomised for each participant. Participants were told that there would also be filler trials in which the target sound would not occur in the sentence. There were 8 practice trials (4 in the single speaker condition and 4 in the condition with competition) after which participants could still ask questions if the procedure was not clear.

Results

Detection time of the target sound was measured from target sound offset. Collapsed over the two listening conditions, false hit rate was 6%: 3% in the single speaker condition and 9% in the condition with competition. Correct hit rate in the single talker condition was 94% and 78% in the condition with competition. Mean target detection time is given in Figure 1.

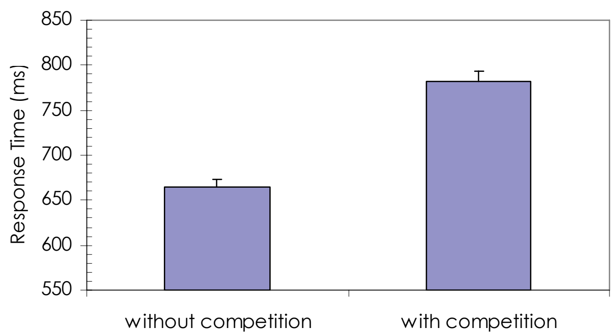

Figure 1: Mean response time in the two listening conditions (error bars represent 1 s.e.).

The two elderly adults with the highest false hit rates were excluded from subsequent analyses (both had more than 10% hits to filler trials; all others had 10% or less). In order to investigate which background measures are associated with performance in the two listening conditions, one analysis was carried out on the hit rates (whether or not one detected the target phoneme) and one on response times. Mixed-effects modelling was used to analyse the data because multiple crossed random factors (participants and items) affect performance in psycholinguistic designs as the one used here. The binomial hit rate data were analysed to test for the effects of Condition (with or without competition), Target Phoneme, Trial number, and the individual background measures: Age, Gender, Vocabulary test score, Pure-Tone-Average in best ear, the processing speed measure and Stroop test performance. Additionally, it was checked whether there were significant interactions between Condition and either of the background measures. Age and hearing loss were not correlated and neither were the outcomes of the two cognitive tests (Stroop test performance was not correlated with the processing speed measure). However, because Pure-Tone-Average and the Stroop measure of interference were correlated in the participant group (Pearson R=0.354, p<0.05), the two predictors were orthogonalised by replacing the Stroop effect predictor by the residuals of a linear regression model predicting Stroop effect as a function of hearing loss. Nonsignificant effects and interactions were removed from the model. For all significant effects and interactions, estimated coefficients (βs), with standard errors for β in brackets, and p-values are reported. Age, gender, vocabulary score, and the processing speed measure turned out to be non-significant predictors for hit rate. As expected, hit rates were lower in the condition with competition than in the single speaker condition (β=-2.15 (0.40), p<0.001). Target phonemes differed in hit rate: they were not all equally easy to detect (β=2.17 (0.91), p<0.05), and detection of some target phonemes was more affected by the competing speech than others (β=-1.03 (0.38), p<0.01). Hearing loss did not have a main effect on hit rate, but interacted with Condition: listeners with poorer hearing were more affected by the presence of a competing speaker (β=-0.03 (0.01), p<0.05). Trial number did not have a main effect on hit rate, but it did interact with the effect of competition: the competition effect got smaller over trials (β=0.01 (0.005), p<0.05). Lastly, the Stroop effect measure did not affect performance in the single-speaker condition, but it did affect performance in the competing-speaker condition (β=-23.64 (11.39), p<0.05): the more interference one experienced in the visual Stroop test, the more interference one experienced from the distractor speaker.

Response times (to target phonemes) were first logtransformed and then tested for main effects and interactions of the same factors and predictors as in the hit rate analysis. Again, age, vocabulary score, and the processing speed measure were non-significant predictors for detection RT. Condition significantly affected RTs: detection times were longer in the condition with competition from the distractor speaker (β=0.075 (0.01), p<0.001), as was clear from Figure 1. Target phoneme had an effect on detection speed (β=0.24 (0.06), p<0.001) and also interacted with Condition (β=0.04 (0.01), p<0.05), as found in the hit rate analysis. Hearing loss affected overall RT: the more hearing loss, the slower the response (β=0.004 (0.001), p<0.001). Trial number also affected RT: the later the trial, the slower the response (β=2.8e-04 (8.35e-05), p<0.001). The Stroop effect measure did not predict RTs, nor did it interact with Condition. However, mean colour naming time in the incongruent Stroop condition was correlated with overall RT in the listening experiment: the longer one took to name the incongruent colour name in the Stroop test, the slower the responses in the listening study (β=0.58 (0.27), p<0.05).

Discussion and Conclusion

This study was set up to investigate the relative contribution of age-related hearing loss and general cognitive decline to elderly adults' increased effort in listening situations with competition from a distractor speaker. Importantly, average hearing loss and the measure of inhibitory control (the Stroop measure of interference), both being age-related forms of decline, were indeed correlated in the test population. After these two predictors had been orthogonalised (i.e., their explanatory power had been teased apart), the following results were obtained concerning listening effort. Target detection time in the single-speaker condition, as well as in the condition with competition, could be predicted by an individual's hearing loss. Thus, even when detection performance is still at ceiling level, response time can be a subtle indicator of speech identification effort. Furthermore, individual hearing loss was correlated with the effect of adding a competing speaker on detection rate performance. The most important outcome, however, is that inhibitory ability measures can provide additional insight into the amount of interference one experiences from competing speech: the non-auditory measure of Stroop colour naming interference also significantly predicted how much hindrance one experienced from the distractor speaker. This is a direct indication that cognitive decline plays a role in aggravating the interfering-speaker effect for elderly listeners, over and above their hearing problems. These cognitive problems are not revealed in standard audiological screening, but are important for developing more realistic expectations of performance in difficult communication settings.

References

[1] Dubno, J.R., Dirks, D.D., & Morgan, D.E. (1984). Effects of age and mild hearing loss on speech recognition in noise. *Journal of the Acoustical Society of America, 76,* 87-96.

[2] Tun, P.A., O'Kane, G., & Wingfield, A. (2002). Distraction by competing speech by young and older adult listeners. *Psychology and Aging, 17,* 453-467.

[3] Humes, L. E., Lee, J. H., & Coughlin, M. P. (2006). Auditory measures of selective and divided attention in young and older adults using single-talker competition. *Journal of the Acoustical Society of America, 120,* 2926-2937.

[4] Connelly, S. L., Hasher, L., & Zacks, R. T. (1991). Age and reading: The impact of distraction. *Psychology and Aging, 6,* 533–541.

[5] Hasher, L., Zacks, R. T., & May, C. P. (1998). *Inhibitory control, circadian arousal, and age.* In D. Gopher & A. Koriat (Eds.), Attention and performance XVII: Cognitive regulation of performance. Interaction

of theory and application (pp. 653–675). Cambridge, MA: MIT Press.

[6] Luteijn, F., & van der Ploeg, F. A. E. (1983). Handleiding Groninger Intelligentietest (Manual Groningen Intelligence Test). Lisse, The Netherlands: Swets and Zeitlinger.

[7] Wechsler Adult Intelligence Test (2004). 3rd ed., Dutch version. Amsterdam: Harcourt Test Publishers.