

# How do noise reduction and task difficulty affect effort mobilization of hearing-aid users in a recall task?



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## Introduction

The Sentence-final Word Identification and Recall (SWIR) test is designed to measure the cognitive benefit of hearing-aid signal processing. Previous findings have shown that noise reduction can improve recall performance for speech heard in noise (e.g. Ng et al., 2013; Ng et al., 2015).

Literature indicates that pupil dilation indexes effort mobilization within listening tasks such as speech recognition in noise (e.g. Wendt et al., 2017). Previous studies have shown that noise reduction leads to a decreased pupil dilation during speech recognition, indicating decreased listening effort.

This study investigates the effort mobilization during a listening and recall task by measuring pupil response while performing a modified version of the Danish SWIR test. The specific aims are to examine the effects of the following factors on recall performance and effort mobilization (as indicated by the pupil response): 1) noise reduction, 2) task difficulty by varying the number of to-be-recalled items, and 3) prior knowledge of the number of to-be-recalled items in the task.

## Method

**Participants.** Sixteen habitual hearing aid users (mean age 62.3 years, SD 8.3) with bilateral sensorineural hearing loss (PTA mean 53.5 dB HL, SD 7.3) were recruited. All were native Danish speakers and had an average MoCA score of 26.6 and an average reading span score of 39.6%.

**SWIR test.** There were 42 SWIR sentence lists in the SWIR test. All sentences are chosen from the Danish HINT (Nielsen & Dau, 2011). There were two tasks in the SWIR tests: 1) the participants were asked to verbally repeat the last word of each sentence, and 2) When the end of a list was reached, they were asked to report back, in any order and as many as possible, the final words in the list.

**Procedure.** All participants were fitted bilaterally a pair of Oticon Opn S™ receiver-in-canal hearing aids. An individualized SNR (mean=6.7 dB SNR, SD=4.1) estimating 95% speech recognition in Danish 4-talker babble with individually prescribed amplification was applied to all test conditions for each participant to ensure intelligibility. The SWIR test was administered in the following conditions:

Two within-subject conditions

- Noise reduction setting (NR): *On* versus *Off*
- Number of sentences in a list (list length; LL): 3, 5 and 7

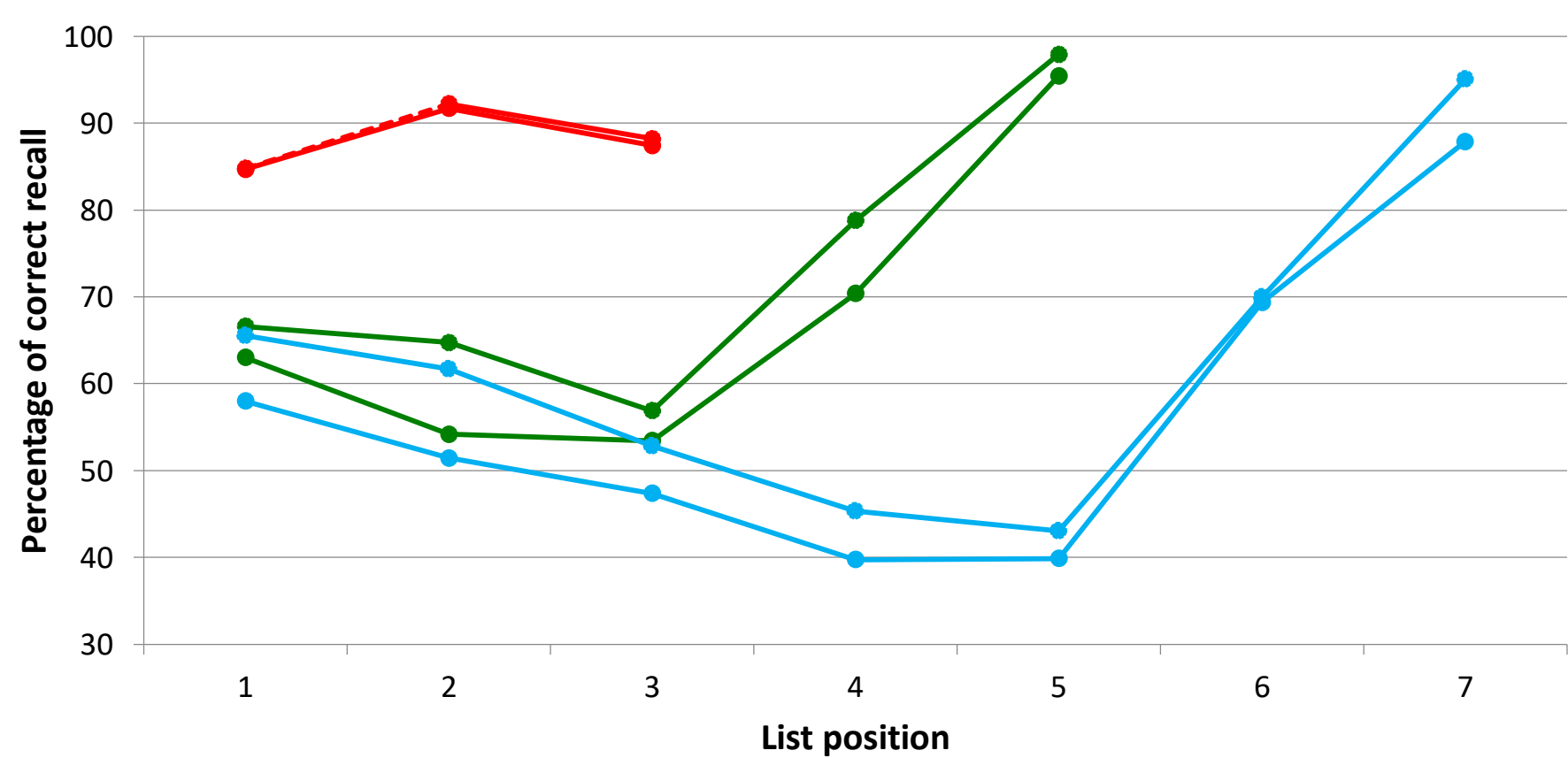
One between-subject condition

- Before each list, half of the subjects were informed about the length of the upcoming list (*Predictability*)

The SWIR sentence lists were presented in the presence of a 4-talker babble in a free field. All within-subject test conditions were randomized. To investigate the effort mobilization, pupil size was measured using an SMI Eyetracker.

## Results

Figure 1. Percentage of correctly recalled words in different test conditions as a function of list position.



The overall SWIR performance is shown in Figure 1. Table 1 shows the correlations between working memory capacity and overall recall performance. Recall performance for LL3 did not significantly correlate with the SWIR test, which could be related to the low task difficulty. Hence LL3 was not included in the subsequent analysis.

	LL3	LL5	LL7
Reading span	0.47	0.51*	0.58*

Table 1. Correlation between overall recall performance in different list lengths and reading span test (\*p < 0.05).

A 2x2(x2) ANOVA (NR x List Length x group) was performed. There was a main effect of NR,  $F(1, 13) = 6.5$ ,  $p = 0.02$ , suggesting better recall when NR was *On* (70.0%) than *Off* (64.6%). The main effect of LL,  $F(1, 13) = 46.4$ ,  $p < 0.01$ , indicated a significant difference in recall performance between LL5 (74.0%, or 3.7 words) and LL7 (60.5% or 4.2 words). In other words, even though participants recalled proportionally more words with a shorter list length, they were able to recall approximately 0.5 words more with a longer list length. The significant interaction between LL and *Predictability*,  $F(1, 13) = 5.3$ ,  $p < 0.04$ , is illustrated in Figure 2.

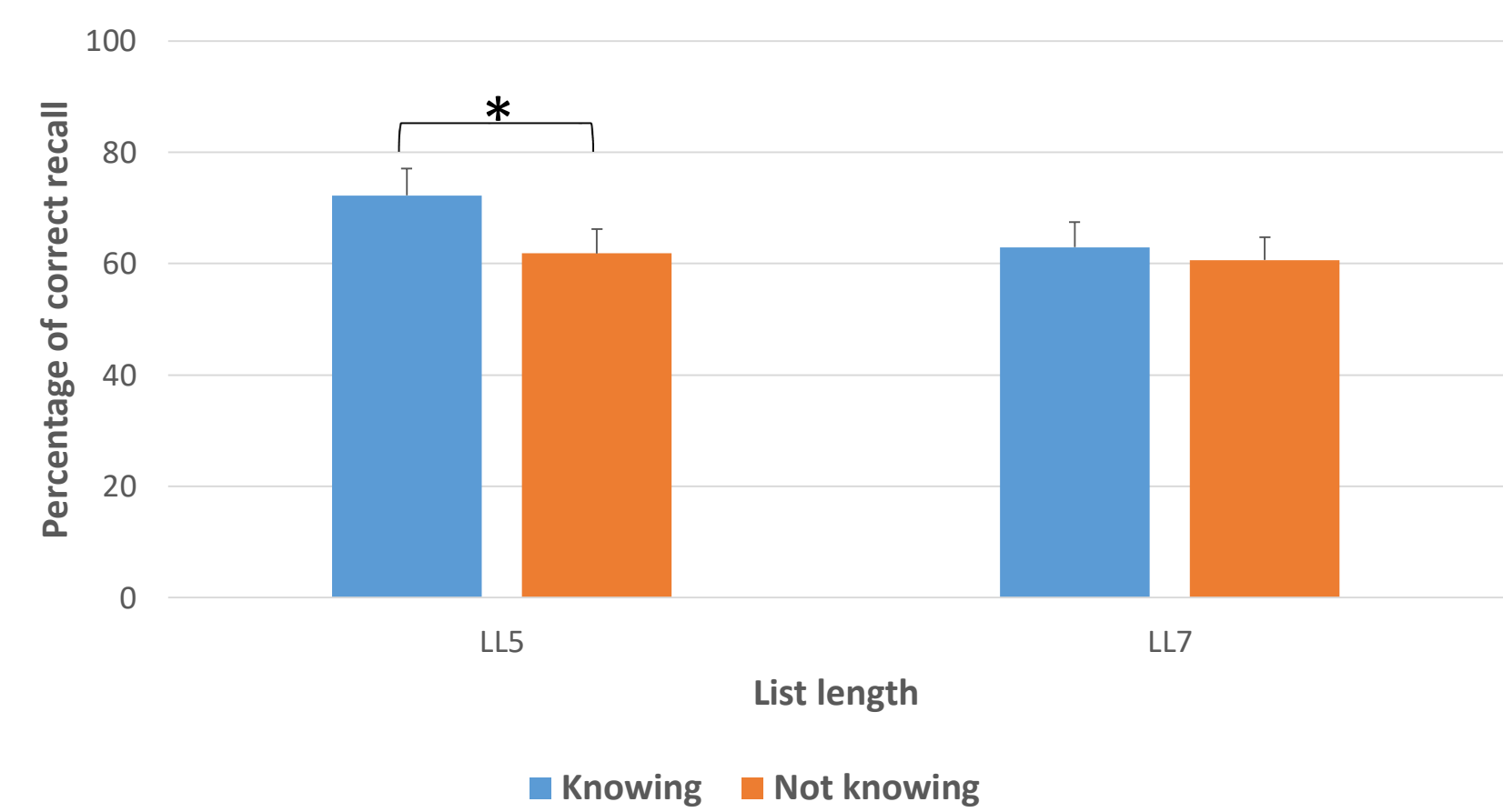


Figure 2. Significant interaction between list length (LL) and *Predictability*.

To investigate how pupil size increases across the presentation of the sentences throughout a list, the slope of pupil size was calculated by fitting a least-squares line to the 3, 5 or 7 data points of each sentence list. Each data point was the mean pupil size between 0 and 4 seconds relative to sentence onset. There was a significant slope increase for LL5 only when comparing NR *Off* and *On* (see Figure 3). This suggests increased effort mobilization when noise reduction is switched on during 5 sentences.

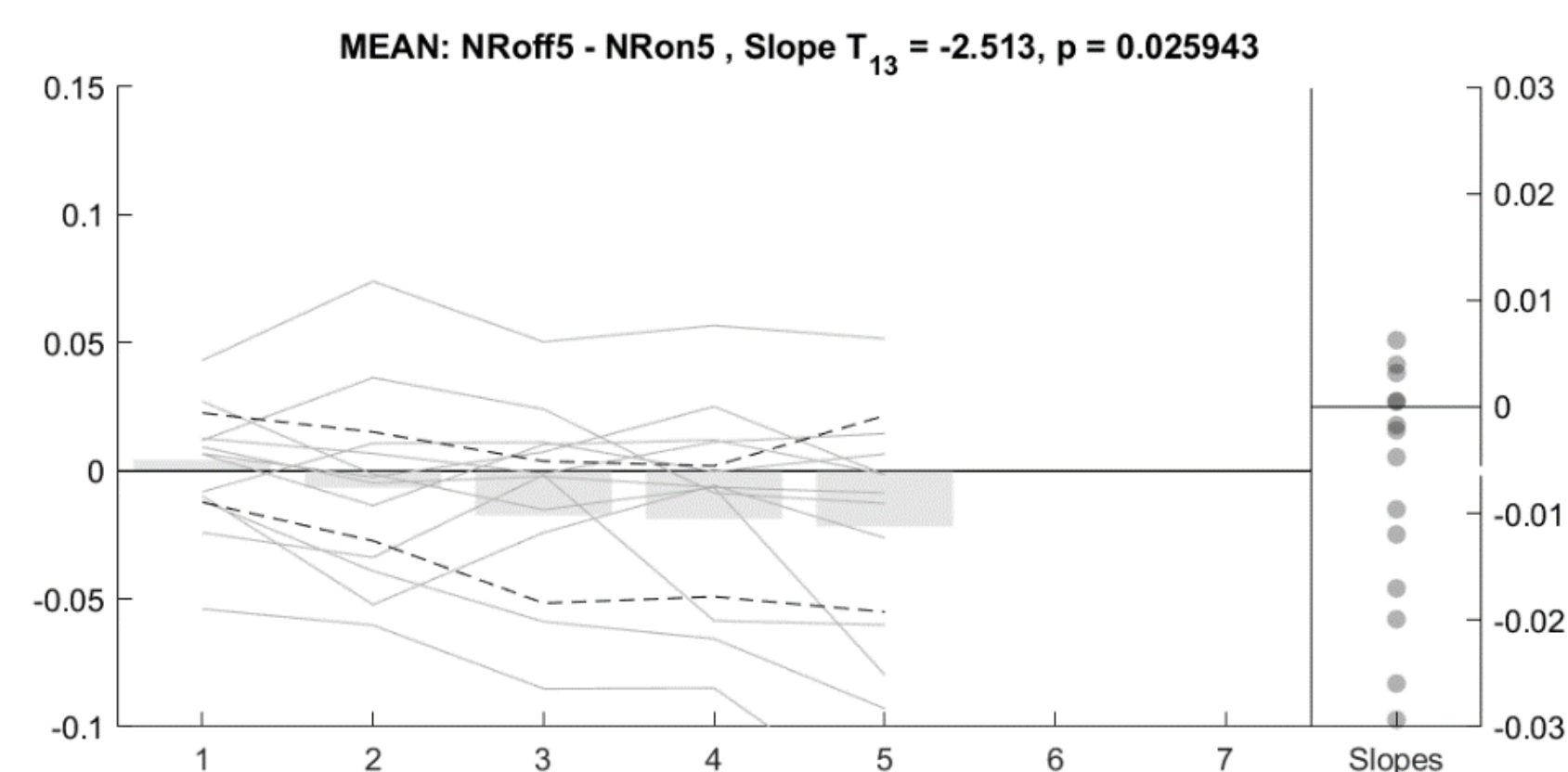


Figure 3. Left: Difference of mean pupil dilation throughout the presentation of five sentences (NR *Off* vs. *On*). Right: Average slope differences of single subjects.

## Discussions

- Noise reduction improves recall performance. This is in good agreement with previous studies (e.g. Ng et al., 2013; Ng et al., 2015)
- While individual recall performance is positively correlated with working memory capacity, the overall recall performance increases with task difficulty. Similar findings are shown in Micula et al. (2019) and Neher et al. (2018).
- Knowing the number of to-be-recalled items increases recall performance for moderate task difficulty.
- Pupil response indicates that more effort was mobilized across sentences in a list when noise reduction was activated (in LL5 only), which corroborates with better recall performance. The present study demonstrates that noise reduction allows listeners to engage more effort in an auditory memory task with moderate task difficulty, which results in better task performance.