# Memory of a text heard in noise

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## INTRODUCTION

Cognitive effects of noise have been demonstrated in a large number of experimental studies (Beaman 1998; Jones 1990; Jones et al. 1990; Macken et al. 1999). There are also several studies that indicate that long-term exposure to noise may impair cognitive performance of school children (Haines et al. 2001; Shield & Dockrell 2003). Both the studies of acute effects and the effects of long-term exposure have almost exclusively used text based test material, although many tasks in schools and workplaces require processing and storing of orally presented information. The reason for the choice of written material is of course that the effects obtained should not be an effect of the noise making it impossible to hear what is said.

Rabbitt (1966) as well as Kjellberg et al. (2008) argued that a background noise may impair memory of spoken material also when it is possible to hear what is said. If the noise makes it more effortful to identify the words spoken, less of the limited working memory capacity should be available for the further processing and storing of the material. The results from these two studies confirmed this hypothesis. The memory of a word list was impaired by a background noise although subjects had repeated the words during their presentation to ensure that they were correctly identified.

When the content of the message is in correspondence with the context, and when the speech signal is clearly audible, speech understanding does not require any effort for normal hearing individuals. When listening conditions are degraded, speech understanding can still be good, if the semantic context and the linguistic structure offer redundancy, but then the speech signal gets less audible and one has to rely more on redundancy and top-down processes, speech understanding changes from being effortless to become straining. The more resources that are used for word recognition, the fewer are left for parallel processing and storage of information. Speech understanding in bad signal/noise conditions therefore requires more of the limited resources of the working memory, than speech understanding in good acoustical conditions does (Kjellberg 2004).

An analogue effect was demonstrated by Pichora-Fuller et al. (1995) who found that older subjects recalled fewer of the items in a working memory task than young subjects in noisy conditions, although there was no difference in the recall ability of the two age groups when they had read the items.

Given that this interpretation of the effect of background noise is correct, the effect should be related to working memory capacity. The less capacity the fewer resources should be left for the further processing of the speech after the identification of the words spoken.

Recall of word lists is a task rarely met outside the laboratory. From an ecological point of view it would be of more interest to study the effect of background noise on the recall of a longer spoken text. This was done by Rabbitt (1968) who showed that degraded listening conditions (+5 dB S/N) impaired memory of a spoken prose passage. However, it cannot be excluded that subjects actually did not heard the parts of the text.

In the present study recall and recognition of the content of shorter lectures were studied with and without a background noise. A hearing test was included to ensure that it was possible to hear what was said. To get a measure of the subjects' working memory capacity such tests were included.

## EXPERIMENT 1

### *Participants and design*

28 university students 19-35 years old were paid to participate in the experiment. All participants were native speakers of Swedish and reported normal hearing. The study had a within subject design, with two conditions. A noise condition where subjects listened to a text with a broadband background noise, and a control condition without the noise.

### *Speech and Noise*

In the noise condition, the broadband noise was presented simultaneously with the spoken text giving a signal-to-noise ratio of + 29 dBA. In the control condition The S/N ratio was +5 dB, which made listening demanding, but made it possible to hear all the text. The texts were presented by two loudspeakers, which were placed one on each side about 1.5 meters in front of the table where the subject was seated.

### *Memory and hearing tests*

*Hearing test.* The hearing tests consisted of two lists of ten sentences presented with and without recorded broadband noise. All sentences had the same structure (e.g. *Sean took eighteen old balls, Anna held three beautiful rings*), and were constructed to be non-redundant; i.e. the context gave few cues to what exact word would follow only to what word category the word belonged. The subjects immediately repeated each sentence aloud. The five first sentences in each list were considered as training, thus only the results from the five last sentences were used to measure the hearing ability. The sentences were taken from a standardized hearing test (Hagerman 1982).

*Reading Span test.* Working memory capacity was assessed with the reading span test, which was taken from the cognitive test battery TIPS (Hällgren et al. 2001). Series of sentences were presented in a word-by-word fashion. The subject's immediate task during a 1.75 s interval between sentences was to decide by pressing a key whether the sentence was absurd or normal. After a sequence of sentences (three, four, five or six sentences), the experimenter indicated that the subject should start to report orally as many as possible of either the first or the final words of the sentences. The subjects did not know beforehand if they should report the first or the last words. The number of correctly recalled words was used as the performance measure.

*Memory test of spoken narrative information.* The spoken texts (eight minutes long) were taken from two reading comprehension tests previously used in the Swedish University Test (SAT). The subjects listened to one text with recorded broadband background noise and another text without the background noise. One text dealt with inductivism and scientific methods, and the other text was about acting. After listening to a text, the subject was given eight multiple choice questions about comprehensive aspects of the text and eight open-ended questions about details of the text. The number of correctly answered questions was calculated for both categories of questions separately.

*Ratings of effort, attention and audibility* After each condition the subject was asked to rate effort and audibility with Borg's CRT-scale (Borg 1998) where 0 means *No effort at all* and 10 means *Extremely strong effort.* Audibility and attention were rated with a five-step scales (20 % of the words or more were impossible to hear-it was possible to hear almost every word; very difficult-very easy to keep attention on the task).

## PROCEDURE

The experiment was conducted in a sound attenuated climate chamber, with the subjects seated at a desk in the middle of the room. The experiment took approximately 60 minutes. The order between conditions and between texts was counterbalanced.

## RESULTS

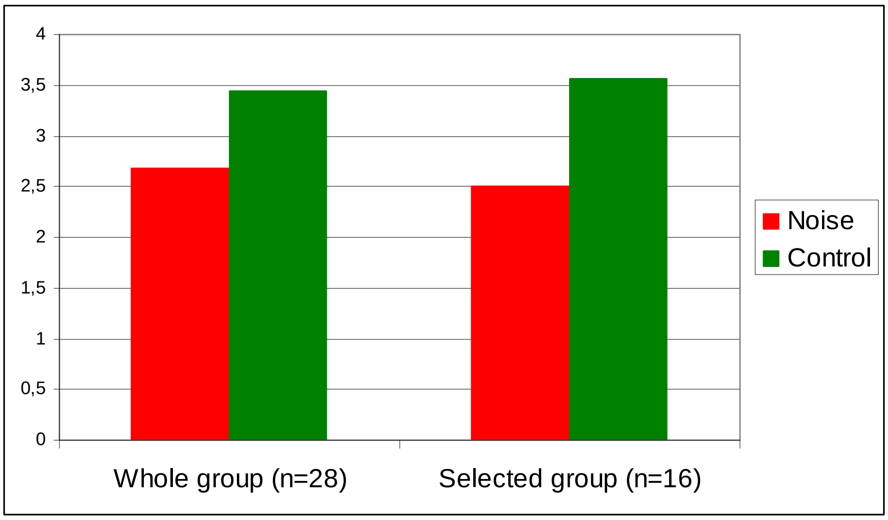
The mean number of hearing errors was small but differed significantly between the two conditions (0.5 and 0.07 for the noise and control condition, respectively). Two types of analyses were therefore performed: Analyses that included all subjects (n=28) and analyses only including subjects without any error in the hearing test with the background noise (n=16).

The order between conditions was balanced also among the16 selected subjects and the two texts appeared eight times in both conditions.

*Subjective measurements of effort, attention and audibility* The listening was rated as considerably more effortful and requiring more concentration in the noise condition in both the whole and the reduced group.

*Memory test of the texts* The multiple choice questions regarding general understanding of the texts did not show any significant effect of the noise neither in the whole or the selected group. Scores of the open-ended recall questions of detailed information were significantly lower in the noise than in the control condition, $F(1,26)=7.26$, $p=.012$), and the effect did not differ between the two texts. Subjects without hearing faults showed the same pattern of results as the whole group (Figure 1).

**Figure 1:** Mean number of correct answers to open questions about details of the two texts in the noise and control conditions in the whole group and the selected without any errors in the hearing test in the noise condition.



There were no significant correlations between the effects of noise on the memory tests and the reading span performance. Neither did the noise effect correlate with differences in rated effort in the two conditions.

## DISCUSSION

The experiment showed that recall of an orally presented text is impaired by a background noise. The overall comprehension of the texts was not affected by noise, but recall of detailed information was significantly worse when the text was heard in the noise condition. The fact that this effect was seen also in the group that had no error in the hearing test with a background noise makes it improbable that missed words could explain the noise effect.

The experiment gave no support to the hypothesis that larger working memory capacity (as measured by reading span) reduced the noise effect. One possible interpretation of this result is that the reading span test does not assess a capacity that is critical for the understanding, storing and recall of a spoken text. However, it is also possible that the number of correct words in the reading span test isn't sensitive enough to catch such an effect. It would probably be better to use a test that also allows the measurement of processing times. The issue of how the noise effect is related to working memory capacity is an important one. Tests of working memory capacity, like reading span and updating tests have repeatedly been shown to be closely related to scholastic performance. Thus, if the hypothesis is correct, it means that bad acoustic conditions would be especially detrimental for students that also for other reasons have problem of understanding and remembering what the teacher says.

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