Is there a correlation between the ability to recognise speech-in-noise and sensory memory?

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Abstract

Recently, research has begun to pay more attention to the cognitive functions associated with auditory perception. In this study, two tests are performed to investigate the correlation between the ability to recognise speech-in-noise and the performance of sensory memory, as well as to investigate whether the performance would improve during the sensory memory test. For measuring speech-in-noise, the Hagerman test was used. A random noise test to detect deviant noises was used to measure sensory memory. In total 16 participants took part in the study (mean age=24.8125, SD=3.14), half of the group began with the Hagerman test, and the other half with the random noise test. Two different statistical analyses were performed on the data. For examining the correlation between the performance on the Hagerman test and the random noise test, a Pearson correlation was used. The results were as follows: \( p = 0.4962, r = -0.1835734 \). Observing the results, the tests did indicate a slight negative correlation regarding the r-value, but not a significant correlation. Thus, the analysis did not derive any significant results. The second analysis was a dependent t-test to examine whether there was an improvement in performance during the random noise test, as it was divided into four separate blocks. The analysis showed the following results: \( t = 1.0266, \text{df} = 28.943, p = 0.3131 \). These results were not significant, though observing the block graph might indicate a tendency for improvement. For further studies, the random noise test should perhaps be modified into an easier version. This is based upon the data, as many of the participants merely got a score above, or even below, chance. Further studies should also use a higher number of participants as well to increase the chance of receiving significant results from the tests.

Keywords: Speech-in-noise, Sensory memory, Hagerman test, Pearson correlation, t-test.
Acknowledgement

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Stella Svedberg
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1. Introduction

1.1 Background

Perceptual abilities play an important role when navigating the world around us. The ability to hear is especially important for the social context and communication we have established as a species. As humans, our auditory senses have fine-tuned abilities such as differentiating between human speech and other sounds (Schnupp et al., 2011), as well as differing between small signals, communicative sounds, and non-communicative sounds made by humans (Enfield, 2013). As speech requires the integration of successive stimuli occurring over short intervals of time, this ability to rapidly process information is especially important for speech comprehension. This process occurs beyond one’s control (Alain et al., 1998). The advanced requirements for recognising words stem from the great complexity of speech, as it is built upon morphology, words, and sentences are built upon rules of grammar. As our ability to hear plays such a vital part in society, if one for example would be subject to severe hearing loss during their life, communication with society would become drastically more demanding (Schnupp et al., 2011). According to Plack (2018), gaining knowledge about how the ears and the brain process sound may not only be important to help those with problems connected to hearing loss. It is also important knowledge to design environments for the benefit of our ability to hear, along with creating technical systems like artificial speech recognition and alert signals.

Fixating in on the physiological and cognitive abilities behind hearing and language, the ability to hear is often referred to as our auditory perception. This is made up of the process of perceiving sounds by detecting vibrations. In humans, the physical foundation for this gentle process is made up of the ear (Plack, 2018). The ear itself consists of the outer ear, the middle ear, and the inner ear. When a sound has been processed by these parts of the ear, information about the sound is fired to the cochlear nucleus, where it projects the information forward to other parts of the neural network through the primary auditory pathway, where it ends up in the primary auditory cortex in the temporal lobe. This is where awareness of the sound is believed to occur. For speech, this is believed to occur in the secondary areas of the regions called the secondary auditory cortex, mainly the left hemisphere. This includes understanding speech, as well as recognition and comprehension of words. By way of explanation, the human brain has an individual process for understanding language in contrast to sound without linguistic content. For sound in general, the subjective qualities of loudness, pitch, and timbre are perceived in the primary auditory cortex processed in both hemispheres. Loudness is defined as the perceived intensity of the sound, pitch as higher and lower tones of the sound, and timbre as the quality that allows a listener to differentiate between sounds when the loudness and pitch are the same (Purves et al., 2013). This process in the primary auditory cortex is a part of sensory memory, a pit stop for sensory input. One can describe it as almost hearing the sound in one’s head for some seconds after it has been heard. The information is also compared to surrounding noise to understand the information (Thaut, 2016). It is the earliest stage of the formation of auditory memory and retains the information until it has been examined in detail by the working memory. The working memory, however, manipulates the information received, making it possible to rapidly understand and respond to it (Purves et al., 2013). Based on the information above, the cognitive ability to process a simple sound in sensory memory belongs to a different process than the recognition of words
in the secondary sensory cortex, though both are carried out in the temporal lobe. As widely known in the field of cognitive science and neurological studies, the different cognitive processes and parts of the human brain interfere with and affect each other in ways not fully investigated in science. For example, a study by Johns et al. (2023) chose to investigate whether there are individual differences in speech-in-noise recognition and working memory capacity. On a similar note, I will in this explorative study investigate if there is a correlation between speech-in-noise recognition and the performance of sensory memory. The motivation behind this is to, based on the earlier mentioned studies and facts about the human brain, gain more knowledge about auditory abilities and their connection. If a correlation would be discovered, a deeper insight could be gained about how the auditory abilities may interact with each other. Even if the results would settle in a non-correlation between speech-in-noise recognition and sensory memory, the study would provide the field with more knowledge regarding how cognitive abilities may not interact. This is the benefit of explorative studies within less explored fields. At the same time, it would be interesting to investigate if one could improve sensory memory ability through practice. Not much research has been made on the subject, but according to Thaut (2016), there are methods to practise one's sensory memory concerning musical abilities, whereas one of these is to play two close pitches immediately after one another and ask the participant if the two sounds were the same or different. I will in this study use a similar approach to both measuring sensory memory as well as investigating if one will improve this with practice, as later explained in both parts 1.1.2 and 2.3.2 of the study.

1.1 The study

1.1.1 Hagerman test

To investigate if the ability to recognise speech-in-noise is related to the ability of sensory memory, two different tests were carried out on each participant. The first test is known as the Hagerman test, a Swedish test originally developed by Björn Hagerman to measure one's ability to recognise words by measuring one's speech-in-noise ability (Hagerman, 1987). The test exposes the participant to pre-recorded sentences where the participant is asked to repeat the words spoken. The sentences are made without any semantic context to elude the use of contextual cues to predict the next word. Distracting noise in the form of the same voice speaking at the same time as the main sentence is played is then included to make the test more difficult. The intensity of the distracting noise is tailored to the participant's performance and is adjusted accordingly, in order to measure the participant's performance using signal-to-noise ratio (SNR). In the end, a higher score equals a higher recognition of words but is measured in negative numbers, so a higher score thus means a higher negative value. The Hagerman test has been used in several studies before, for example, to study the use of hearing aids, the auditory ability of 5-year-olds, and the working memory in children (Rönnberg et al., 2016; Hagesäter & Thern, 2003; Hagerman & Hermansson, 2015). An in-depth description of how the Hagerman test was carried out can be seen in part 2.3.1 of this study.

1.1.2 Random noise test

To measure sensory memory, a test for distinguishing deviant noises was used. This is based upon the earlier description of sounds being distinguished through loudness, pitch, and timber. The test can be compared to one of the methods by Thaut (2016) mentioned in part 1.1 of the study. Each participant was exposed to three short noises in a row, in support of sensory memory relying on surrounding sounds when defining incoming stimuli, also mentioned in part 1.1. For every three noises played, one of the noises was deviant in the format of pitch or duration. Using the fast reaction of sensory memory, the participant would be able to identify
the deviant noise. To be able to track if any progress is made from practice during the test, the test would be divided into four blocks to compare the performance of the different blocks upon each other. To avoid any participant being able to learn a pattern from the noise used, all noises were played in a randomised order. An in-depth description of how the random noise test was carried out can be found in part 2.3.2 of the study.

1.2 Aim of the study

The study aims to investigate if one's performance of recognising speech-in-noise is correlated to the performance of differentiating noises using sensory memory. This notion is backed up by the relevance of cognitive functions involved in auditory perception (Pichora-Fuller et al., 2016). The study will measure word recognition through speech-in-noise using the Hagerman test, and sensory memory using a random noise test. If a correlation is found, it could imply sensory memory capacity and word recognition are capabilities related to one another. Results are thus valuable for continued research interest in the cognitive functions associated with one's auditory ability regarding speech. A general hypothesis has been phrased based on earlier studies within the field and is divided into two more specific and measurable research questions.

1.3 Hypothesis

(1) There is a correlation between the performance of recognising speech-in-noise and sensory memory, using the Hagerman test and random noise test.

1.4 Research questions

(1) Is there a significant correlation between the results of the Hagerman test and the random noise test? In other words, should a higher negative result in the Hagerman test correlate with a higher positive result in the random noise test?

(2) Do participants' scores improve during the different blocks of the random noise test?
2. Method

This part of the study serves to cover the methods chosen based on the hypothesis and research questions. It also aims at describing the process for obtaining the data collection and the participants who took part in the study.

2.1 Ethics

The ethics of the study for good research practice took its stance in accordance with the Swedish Research Council (Swedish Research Council, 2019). The purpose of these ethical guidelines is to protect participants of scientific studies as well as maintain honest results within research and its results. These ethics may be explained using four words of guidance:

1. Reliability
2. Honesty
3. Respect
4. Accountability

Beyond the basics of good research practice, the study also followed the General Data Protection Regulation (GDPR). This is a law of the European Union to protect the use and storage of personal data (European Commission, n.d).

2.2 Participants

The participants were recruited by contacting students in the sphere of Linköpings University, both verbally and through writing. In the end, 16 participants were recruited from Linköpings University (mean age = 24.8125, SD = 3.14). All of the participants were native Swedish speakers as the Hagerman test was performed using the Swedish language. The chosen participants did not have any known hearing impairments and reported normal hearing. Moreover, descriptive data on age and gender was collected by all participants and may be viewed in table 1 and table 2. No participants' data were excluded from the data analysis.
Table 1. The chart presents the ages of the participants.

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of participants in each age group</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>24</td>
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<td>1</td>
</tr>
<tr>
<td>36</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>16</td>
</tr>
</tbody>
</table>

Table 2. The chart represents the genders of the participants in the study.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Number of participants of each gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>6</td>
</tr>
<tr>
<td>Female</td>
<td>10</td>
</tr>
<tr>
<td>Other / Non-stated</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>16</td>
</tr>
</tbody>
</table>

2.3 Equipment

Before the tests, all participants signed an informed consent form. All materials for the Hagerman test were based on the updated sound material and instructions from Hagerman (1987). These took part as pre-recorded sound tapes for the test, together with instructions of use. For performing the test, a set of over-ear headphones were used together with a computer for both playing the tapes and collecting the data from each participant. For the random noise test, the same over-ear headphones and computer from the Hagerman test were used. All participants' data were collected in a room at Linköpings Universitet, where only the test leader and the participant were present. To interpret the data from the Hagerman test and random noise test, the program MatLab was used. This was accessed through the licence of Linköpings University. A program called GStreamer was used to run the files containing the recorded noise for the random noise test, downloaded from the website.
All the statistical analyses conducted were performed using the statistical software R.

2.4 Procedure

The study took place at the premises of Linköping University, campus Valla. All tests were performed individually by each participant in a pre-booked room during the morning, midday, or afternoon depending on the availability of the participant. All tests were carried out using Swedish as the main language, except for the written instructions during the random noise test. To avoid that instruction in English would be misinterpreted by Swedish speakers, the instructions were explained in Swedish before the random noise test began. The session began with the participants being informed about the study's aim of examining the correlation between one's ability to hear speech in noise and one's sensory memory. The participants gave informed consent for their participation both verbally and in written format (see Appendix A) and attesting they did not have any hearing impairments. Half the participants began with the Hagerman test, while the other half began with the random noise test for measuring sensory memory. This was to avoid any impact on the data from the order the tests were performed. For each test, the participants wore over-ear headphones connected with a wire to the computer running the test to avoid problems with battery or Bluetooth. After hearing the first sentence or noise, the participant got to turn up or down the volume once to fit their individual needs. A 10-minute break was offered between each test, as well as shorter breaks between the blocks of the random noise test. The total time spent during participation amounted to approximately 40 minutes. An in-depth description of how each test was carried out can be seen in parts 2.3.1 and 2.3.1 of this study.

2.4.1 Hagerman test

Sentences, voice recordings, and instructions from the updated Hagerman test (Hagerman, 1987) were used to investigate the participant's ability to identify a spoken sentence in a stream of disorganised noise, using different levels of difficulty according to the participant’s performance. This stream of disorganised noise was in the format of spoken words in Swedish using the same voice as the original sentence the participant was supposed to identify. The volume of this stream of disorganised noise was the same as the original sentence or higher. For the easier levels of the trials, there could be zero or one to two disorganised voices. For the more challenging levels, when the participant had gathered numerous correct guesses, the amount of disorganised noise and their volume would increase. The levels of difficulty were modified according to the participant's performance to calculate a signal-to-noise ratio (SNR) from each trial. The SNR stands for how loud the disorganised noise is in comparison to the desirable sentence and is measured in decibels. The more skilled one is at detecting this desired sentence, the lower the value of this relationship is. In other words, better performance equals a more negative result. If the participants did well on one trial by addressing the correct words of the desirable sentence, the next trial would be modified to be more difficult with the help of more distracting speech. The same applies the other way around, as fewer correct sentences result in less distracting noises. This was applied using a staircase method, in which stimuli are presented and their sequence made more difficult or reversed according to the response of the participant. The thought behind this is to avoid stimuli far above or below the threshold (APA Dictionary of Psychology, 2023). Using this method, a mean performance for each participant's total SNR could be calculated. How the staircase method calculated the thresholds for the staircase is presented in Figure 1. For example, if a participant recalled all the correct words in the sentence, the SRN would decrease by the number three and thus
increase the disturbing noises. In total, 20 pre-recorded and shuffled sentences were used as the desired sentences. These sentences were created by putting 5 different words together to counteract the participant's ability to guess or recognize the sentences using semantic connections. Each sentence was put together randomly by the script during the test. An illustration exhibiting how this is done is displayed in Figure 2. The words used in each iteration consistently had the same part of speech for each sentence. The order was structured as the following: Noun, verb, number, adjective, and noun. The first noun always had the format of a name. The participants were instructed to repeat the sentences they heard out loud, and for each correct word the participant identified, one point was given. The test leader could see the correct sentence on their screen and select the right number of correct words the participant had repeated, as shown in Figure 3. The scripts for the Hagerman test were run directly in the program MATLAB, whereas all data collected from the test were automatically transferred into an Excel file with the data from each trial sorted. The scripts created one Excel file per participant. The collected data included the participant's ID, the signal-to-noise ratio for the played sentence, how many words the participant successfully repeated, the value of each iteration, as well as the total mean value of all trials together. For the present study, the data from the total mean value per participant were used in the following statistical analysis explained in parts 2.4 and 3 of the study. Additional data was stored for use in further studies. After collecting all the data, the mean values from each participant were transferred into a single Excel file to facilitate the data analysis, together with each participant's ID. The procedure for the Hagerman test took around 10 to 15 minutes for each participant.

```matlab
%% ADAPTIVE STAIRCASE
if current_response == 5
    current_snr_1 = current_snr_1 - 3;
elseif current_response == 4
    current_snr_1 = current_snr_1 - 2;
elseif current_response == 3
    current_snr_1 = current_snr_1 - 1;
elseif current_response == 2
    current_snr_1 = current_snr_1 + 0;
elseif current_response == 1
    current_snr_1 = current_snr_1 + 1;
elseif current_response == 0
    current_snr_1 = current_snr_1 + 2;
end
```

Figure 1. The picture shows a piece of the code for the Hagerman test. If a participant for example recalls all the five correct words in the sentence, the SNR will be decrease by 3 and thus increase the disturbing noises.
2.4.2 Sensory Memory Test

For the second test, the scripts were run in MatLab with help from the free-to-download program GStreamer. The participants were placed in front of the computer with a pair of over-ear headphones. When the participant felt ready, they were free to begin the test on their command by pressing computer key number 0 on the keyboard. This is shown in Figure 4. Upon initiating the test, three short noises could be heard after each other. These noises were all short signals of approximately 1.5 seconds of playtime together and can be described as a short crackle. This was followed by a pop-up on the screen, asking the participant which of the noises were deviant. The participant made their choice by pressing the corresponding button on the keyboard. Computer key number 1 represented the first noise, computer key...
number 2 the second, and computer key number 3 the last. See Figure 5 for an illustration. The participant received instant feedback on whether their choice was correct or not by presenting the participant with a box saying either “Correct!” (See Figure 6) or “Incorrect!!” (See Figure 7). The test then moved on automatically to playing the next three noises, and thus the cycle continued. These trials were divided into four larger blocks, whereas each block contained 50 of these cycles. In between these blocks, the participant could rest for a moment before continuing. The noises during the test were presented in a random order, so the participant would not be able to identify the deviant noise using any pattern.

As the random noise test was designed using four blocks, each block gave a separate score for the participants' performance. The score of mere chance at guess would be a score of 33% correct answers, thus a score higher than that would imply results aren’t explained by chance but by skill. These scores were displayed in the MATLAB console and were manually put into an Excel file, displayed for each participant and their separated blocks. This way of representing the data made it possible to detect in the statistical analysis if the participants improved during the trials. These values were later extracted into the same document as the collected mean values from the Hagerman test, so the data of each participant could be overviewed for both tests at the same time. The procedure for the random noise test took approximately 15 minutes for each participant.

Figure 4. This is the picture shown on the screen between each block, as well as at the beginning of the test. The participant may take a short break, and press 0 on the keyboard when they wish to continue.
Figure 5. This is the picture shown on the screen between each block, as well as at the beginning of the test. The participant may take a short break and press 0 on the keyboard when they wish to continue.

Figure 6. When the participant chooses the correct deviant noise during the random noise test, a green box containing the text “Correct!” appears on the screen for approximately a second.

Figure 7. When the participant chooses the incorrect deviant noise during the random noise test, a red box containing the text “Incorrect!!” appears on the screen for about approximately a second.
2.5 Statistical Analysis

To interpret the data from the study at hand, two methods of statistical analysis were chosen. For analysis of an eventual correlation between performance in the Hagerman test and the random noise test, a Pearson correlation was chosen. For this analysis, the mean signal-to-noise Ratio (SNR) of all 20 trials of the Hagerman test was independently compared to the total proportion of correct answers in the random noise test. This was done for each participant, resulting in 16 separate data points. To visualise the data and results, an error bar graph was used. For the second analysis to compare the four blocks of the random noise test to examine any improvement during the different blocks, a dependent t-test was used. This was later presented as a box plot.
3. Results

The following section will present how the collected data has been analysed. The results from these analyses are presented through text and graphs. Two separate statistical tests were performed on the collected data. One test compared the block performances during the random noise test, while the other statistical test examined the correlation between performance on the Hagerman test and the random noise test.

3.1 Correlation between the Hagerman test and the random noise test

The analysis of the correlation between the Hagerman test and the random noise test resulted in the following: $p = 0.4962$, $r = -0.1835734$. This was produced through a Pearson correlation. Regarding the p-value, the outcome was above $p < 0.05$ and thus non-significant. Regarding the value of $r$, it is negative and hence shows a weak low negative correlation. This means a lower SNR in the Hagerman test representing a higher performance in the test, correlates to a higher performance in the random noise test. Though, as the results were not significant, these results are not strong enough to draw any conclusions. These results are illustrated through an error bar graph, presenting the data from both tests in relation to each other (Figure 8). The horizontal red line displays the value of 33%, representing the mere chance of selecting the correct deviant noise by making a guess. Each vertical line represents a participant and the 95% error bar in the confidence interval for the random noise test, with the black dot indicating the mean value per participant. Their placement on the x-axis demonstrates how high of a score they received on the Hagerman test, where a higher negative score equals higher performance.

![Figure 8. The figure illustrates the correlation between the Hagerman test and the random noise test.](image-url)
3.2 Block performance
The results from the dependent test when comparing block performance during the random noise test resulted in the following: $t = 1.0266$, $df = 28.943$, $p = 0.3131$. For the value of $t$, it is lower than +2 and thereby not a strong indicator of the coefficient as a predictor. The degrees of freedom resulted in 23.943 independent variables of the analysis. The $p$-value revealed a value above $p < 0.05$ and thus is non-significant.

To explain the graph of Figure 9, each block represents a block in the test, and the highest and lowest points of the blocks show the over and under quantiles. The black line in each block symbolises the median, and the dots show outliers. Observing the graph, a slight tendency of improvement might be observed, though not confirmed by the statistical values.

![Graph showing block performance](image)

Figure 9. The figure shows the results from the scores in the random noise test, divided into four different blocks.
4. Discussion

In this study, sensory memory performance was examined in relation to the ability to recognise speech-in-noise. In this section, the data interpretations and other factors influencing the results will be discussed. In the end, propositions for further research will be presented.

4.1 Data analysis

(3) The first research question of the study had the aim of examining whether there was a correlation between results from the Hagerman test and the random noise test. It was phrased as the following: *Is there a significant correlation between the results of the Hagerman test and the random noise test? In other words, should a higher negative result in the Hagerman test correlate with a higher positive result in the random noise test?* (p. 3). This is since the signal-to-noise ratio in the Hagerman test is measured as negative, and the more negative, the higher performance. To investigate if there was any correlation, a Pearson correlation was performed on the data. To be precise, the mean SNR from each participant of the Hagerman test was compared to the same participants’ percentage of correct answers from the random noise test. The choice of using a Pearson test for correlation may be argued with the linear data collected, proving appropriate for the requirements of a Pearson correlation. The analysis of this investigation of correlation showed there was no statistically significant correlation between the performance of the two tests, though a slight correlation might be implied by the negative r-value. This is not significant enough to draw any conclusions. The lack of findings may be explained by comparing the study to other areas. For example, the working memory of the participants were not measured in any way in relation to the tests of sensory memory and the ability of hearing words in noise. As mentioned earlier in the study, the working memory is believed to play a part of the later processing of the information attained (Purves et al., 2013). It is not far reached to question if this process might play a role for the performance of the sensory memory as well. For example, a study by Pasternak and Greenlee (2005) suggests sensory memory and working memory use the same neural basis, making the two processes tightly connected. This also correlates with the notion that the human memory is made up by coupled sub systems, including the sensory memory, and working memory (Bonetti et al., 2018). According to Deary et al. (2012), the sensitivity of the sensory memory and its ability of recognising sound-related changes should be connected to cognitive abilities higher up in the hierarchy. This is since the ability of connecting these changes to earlier experiences and foreseeing future events are made by these higher cognitive abilities, as the working memory. To put this information in perspective of the study at hand, the results unable to show any correlation between the sensory memory and the ability of hearing words in noise might be explained by the narrow field investigated. If remade, with more furrow testing by the working memory of the participants as well, the results might be different, if these connected abilities may interfere with how one performs during sensory memory testing. Still, a correlation would not have been unusual to expect based on previous knowledge of the two processes being carried out in the temporal lobe with involvement of the working memory (Purves et al., 2013) A higher number of participants might show more reliable results, as a small correlation was implied by the negative r-value.

(4) Regarding the second research question, it was phrased as the following: *Do participants’ scores improve during the different blocks of the random noise test?* (p. 4). The aim of this was to compare the performance during the four different blocks of the random noise test to investigate if participants would perform with increased correct answers towards the subsequent blocks compared to the earlier ones. This would then indicate a learning curve of
using one's sensory memory. To investigate this, a dependent T-test was used with the motivation of results of the different blocks being dependent on each other. The results of this showed no significant difference but observing the graph (figure 9) a slight tendency for improvement might be implied. If this is the case, it would cohere with the study by Thaut (2016), who describes a method for improving one's sensory memory in a musical aspect, using a method very alike the one seen in the study at hand. Thus, the results being non-significant might be because of the low number of participants in the study. Perhaps with more people involved, more reliable results might be found. If it were possible to practice one's sensory memory abilities, it would prove useful for people struggling with perceiving the fine-tuned information important in everyday life.

Mainly the results tell us the study did not conclude with any statistically significant results regarding either the first or second research question. However, the weak negative correlation of the first statistical test might indicate a significant result might possibly be attained improving the number of participants, and thus gaining more reliable results. Observing the graph of Figure 8, a slight tendency for improvement might be detected along the different blocks of the random noise test but it is not significant. The foundation for the statistical analysis was not large-scale enough to support these results nonetheless and neither test gave a significant result.

4.2 Method discussion

Some factors regarding the method should be evaluated. First of all, there are several methods to measure one's ability of speech-in-noise recognition. Apart from the Hagerman test, one could for example use the Samuelsson and Rönnberg outcome test designed in 1993 for similar studies. This is like the Hagerman test designed to compute a mean of recognized words in sentences but with the aspect of for example contextual cues (Samuelsson & Rönnberg, 1993). One could also use the standardised platform SPIN (Francart et al., 2016), allowing the user for more customisation through the use of any speech material together with calibration from the platform. Though, the motivation behind using the Hagerman test is its good reputation as it has been used in numerous studies before, as mentioned in part 1.1 of the study. Regarding the execution of the Hagerman test in the study at hand, some modifications were done that might be important to mention. For example, no pre-test was used for the participants before they performed the actual test for data collection. Instead, the participants received detailed verbal instructions about how the test would be executed. According to Hagerman and Kinnefors (1995), using the pre-test would minimise the risk of participants gaining a learning curve during the actual data collection. If the study would be remade, including a pre-test would be preferred. One could also question the volume of the test and if that might have interfered with the results. As the volume was controlled by the test leader, the participant was asked after the first sentence if they would like the volume turned up, down, or kept at the level it was. The thought behind this was to make sure no participants were uncomfortable with the volume, as some people are more sound-sensitive than others. The problem with this is some participants might have chosen a lower volume, and so might have had a more challenging time hearing the correct sentence in the test.

Regarding the random noise test, some modifications could be made as well. The most important factor might be that the test was too hard for the participants regarding the task at hand. The reasoning behind designing the test as more demanding was to avoid a ceiling effect, where most participants would gain a high or highest score and thus distort the results (Salkind, 2010). Considering the results, several of the participants received a score below pure chance or slightly above, resulting in rather the opposite of a ceiling effect. To gain a more reliable result, it would be necessary to simplify the test to gain more correctly
distributed results. For the random noise test of the present study, modifications in pitch and duration of the noises were the only modified aspects of the deviant noise. As noise is perceptually processed through loudness, pitch, and timbre (Purves et al. 2013), modifying loudness or timbre could also be used for creating differences. An interesting aspect would be to see if this would affect the results, and perhaps make a compartment of how well one performs to the different variations. Regarding the volume of the noises played in the test, the participants were encouraged to change it according to their own preferred loudness. Since the participants sat in front of the computer themselves and pushed the buttons during the test, they got to do this on their own. Just like with the Hagerman test, this could have interfered with the results since some people might have chosen a higher volume and thus found it easier to hear the differences in the noises. The reasoning behind this choice was, just like with the Hagerman test, to make sure the participants were comfortable with the volume from an ethical perspective. Other than this, the participants’ continuity received feedback when they performed the random noise test. For each answer they gave, they would be met with a pop-up telling them either “Correct!” or “Wrong!!” (see Figure 5 and Figure 6). Some participants commented on this phenomenon as being bothersome or causing irritation. Choosing to include this can still be defended by making sure the participants stay engaged during the test, as they get direct feedback for each answer. This approach of retaining attention through direct feedback has been investigated and used before, often in the sphere of online teaching (Cavalcanti et al, 2021). Regardless, some participants commented on losing one's attention during the test. This might also be of greater risk for the random noise test rather than the Hagerman test, as the participants had to tell the test leader their answers during the Hagerman test, rather than giving answers on their own. The pressure of giving your answer to another person might increase the feeling of high expectations. To combat loss of attention during the random noise test, the participants were also offered short breaks between the four blocks, as they could rest for a moment before starting the next test on their intent (see Figure 3). Furthermore, one could also examine sensory memory by using methods more prevalent within the studies of neurology, such as Event-related potentials or functional magnetic resonance imaging. This would yield results showing activation patterns within the brain area (Purves et al. 2013) and might eliminate the risk of not measuring exactly what the tests in this study were designed to measure.

Moving on from the tests, factors considering the participants might interfere with the results as well. The participants of the study were all students at a university and might have taken part in similar studies before. Perhaps, participants who are not in the immediate sphere of research and studies might yield a lower result than the participants in the present study. Other than this, one may comment on how the participants did not have their general working memory examined before taking part in the study. The participants’ hearing was not tested before taking part in the tests either, instead, they attested they did not have any known hearing impairments or other problems regarding audio. Furthermore, one must consider the ethical aspects of conducting studies using participants. Especially with studies measuring cognitive abilities as the ones seen here, the results may be extra vulnerable for the people involved. Therefore, the right to scientific sportsmanship is of high importance, and the participants have been protected under both GDPR (European Commission, n.d) and ethical guidelines for scientific studies presented by the Swedish Research Council (2019). One aspect to take into consideration was how some of the participants expressed feeling frustration during the tests. To inhibit this reaction, participants were offered shorter breaks during the testing.
Since this explorative study was performed in a field not fully investigated, the consequences of the study would be the bestowment of new perspectives and knowledge about the different cognitive functions and how they may be connected. Above all, it grants the scientific field a new perspective. Hopefully, the consequences of this would be additional similar studies that perform more elaborated analyses within the same field. The outcome of this would be more knowledge about the cognitive functions that in the end could perhaps help us understand more about problems connected to the speech-in-noise ability and sensory memory. As pointed out by Plack (2018), knowledge of this kind is of great importance to studies within the field of problems with hearing loss, as well as artificial speech recognition and alert systems.

4.3 Future research

For future studies, some modifications might be recommended to go through based on the method discussion. The most important one would be to make the random noise test more manageable by making the deviant sounds more deviant in terms of pitch and length, and thus easier to identify. This would perhaps solve the problem of a high number of participants barely making it above the line of guessing the correct answer. This would also make the results more trustworthy. Regarding the research question of whether the participants may improve during the random noise test, one could add one or several additional blocks to receive more data to rely on. This would be interesting since the results were non-significant; however, might indicate improvement with practice. Continuing exploring this field would also be relevant to investigate if methods like the one described by Thaut (2016) for musical abilities could accord with other studies about sensory memory in general. Apart from the factors mentioned, further studies should expand their number of participants to gain a higher reliability of true results.

4.4 Conclusion

This study investigated if there was any correlation between the performance of recognising speech-in-noise and sensory memory. The study also investigated if there was any improvement in performance of sensory memory from practice. The thought behind this was to fill in a gap in science since not much research has been done in the area. The results showed no significant results in either the Pearson correlation to investigate any correlation between the Hagerman test and the random noise test, or the dependent t-test for observing differences in performance during sensory memory practice. A last thought to take with you from this study is to continue to extend the curious approach to the different cognitive abilities that make up the complicated and impressive system we call the human brain.
Reference List


Appendix A

Studie om förmågan att uppfatta ord
i relation till det sensoriska minnet

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Om studien
Denna studie utförs vid Linköpings Universitet som en del av en kandidatuppsats inom det kognitionsvetenskapliga programmet. Studien leds av den kognitionsvetenskapliga studenten Stella Svedberg i samråd med Carlos Tirado (carlos.tirado@liu.se), postdoktor vid Linköpings universitet. Ansvarig för kursen är Arne Jönsson (arne.jonsson@liu.se). Syftet med studien är att undersöka om det finns något samband mellan det auditiva sensoriska minnet och förmågan att uppfatta ord. Syftet är ej att mäta din individuella prestation som individ, istället är det att se samband mellan de två förmågorna på en generell nivå.

Studien tar som mest en timme att delta i och består av två separata tester. Det första testet mäter förmågan att uppfatta ord, medan det andra testet mäter förmågan hos det sensoriska minnet. Mellan varje test kommer du att erbjudas en paus.

2. Vid det andra testet kommer tre korta ljud att spelas upp i olika etapper. Din uppgift är att identifiera vilket av ljuden som är avvikande och peka ut detta med hjälp av tangenterna på datorn.

Etiska riktlinjer
All insamlad data sker anonymt under riktlinjerna för GDPR. All medverkan i studien sker frivillig och kan när som helst avbrytas vid begäran. Den anonyma datan från studien kan eventuellt komma att delas med ytterligare forskarkollegor inom området.

Medgivande
Härmed intygar jag att den data som samlas in från mitt deltagande får användas som underlag i förevarande studie, samt att jag har läst igenom och godkänt villkoren. Jag går även med på att fylla i den efterfrågade informationen på följande sida.

_________________________
Datum och ort
_________________________
Namnunderskrift
_________________________
Namnförtydligande