Cognitive Abilities and their Influence on Speech-In-Noise Information Processing
- a Study on Different Kinds of Speech Support and Their Relation to the Human Cognition

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Abstract

In this paper, top-down and bottom-up processing were studied regarding their effect on speech-in-noise. Three cognitive functions were also studied (divided attention, executive functioning, and semantic comprehension), and the effect they have on the speech processing and on each other. The research questions asked were if a difference in speech-in noise perception can be observed regarding the different levels of top-down and bottom-up support, if speech-in-noise is related to any of the researched cognitive abilities, and if there exists any correlation between these abilities. The method is a within-subject experimental design, consisting of four different tests: PASAT, to measure attention, LIT, to measure semantic comprehension, TMT, to measure executive functioning and SIN, to measure speech-in noise. The results showed a significant difference between top-down and bottom-up processing, a significant difference between top-down processing in decreasing and increasing conditions could also be seen. A negative correlation between the benefit of top-down support and the semantic comprehension task was found. Regarding the cognitive abilities a few correlations were found; the semantic comprehension task had a positive correlation to both the central executive task and the attentional task, the attentional task had a negative correlation to the central executive task, and both of the central executive subtasks had a positive correlation to each other. Most of the findings were expected, built on earlier cognitive hearing theories and studies.
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Contents

Abstract iii
Acknowledgments iv
Contents v
List of Figures vii
List of Tables viii

1 Introduction 1
1.1 Background 1
1.1.1 Studies regarding hearing and speech perception 1
1.1.2 Studies on Cognitive functions 2
1.1.3 Studies combining Hearing science and Cognitive functions 2
1.2 Purpose and research questions 3
1.3 Delimitations 3

2 Theory 4
2.1 Hearing science 4
2.2 Attention 4
2.2.1 Divided attention 4
2.3 Semantic comprehension 5
2.4 Signal-Cognition Interface 6
2.4.1 Bottom-up processing 7
2.4.2 Top-down processing 7
2.5 Executive functioning 7
2.6 Experimental set-up 8

3 Method 10
3.1 Participants 10
3.2 Equipment 10
3.3 Pilot test 10
3.4 The Logical Inference-making Test (LIT) 10
3.5 Trail Making Test A and B 11
3.5.1 TMT A 11
3.5.2 TMT B 11
3.6 Paced Auditory Serial-Addition Test A and B 11
3.7 Speech-In-Noise Test (SIN-test) 11
3.7.1 Part 1 12
3.7.2 Part 2 and 3 12
3.8 Test procedure 12
3.9 Supplemental test session 13
3.10 Statistical analysis ......................................................... 13

4 Results ................................................................. 14
  4.1 Research Question 1 ................................................. 14
  4.2 Research Question 2 ................................................. 14
  4.3 Research Question 3 .................................................. 15

5 Discussion ............................................................... 17
  5.1 Results .............................................................. 17
  5.2 Critique .............................................................. 18
  5.3 In a wider context ................................................... 19

6 Conclusion ............................................................. 20

References .............................................................. 21

Appendix A Scatter-plots for SIN-tests ......................... 24
Appendix B Scatter-plots for SIN 1 and cognitive abilities .. 25
Appendix C Scatter-plots for SIN 2 and cognitive abilities .. 26
Appendix D Scatter-plots for SIN 3 and cognitive abilities .. 27
Appendix E Scatter-plots for SNR SIN1-2 and cognitive abilities 28
Appendix F Scatter-plots for SNR SIN1-3 and cognitive abilities 29
Appendix G Scatter-plots between cognitive abilities .......... 30
Appendix H Informed Consent Form ......................... 34
Appendix I Information Form ................................. 35
List of Figures

2.1 A model of top-down and bottom-up processing adapted from Stenfelt and Rönnberg. .................................................. 6

4.1 The scatter-plots of the performance in the two tests with extreme outliers. ........ 15
List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>The eight target words and their distract words.</td>
<td>12</td>
</tr>
<tr>
<td>3.2</td>
<td>The 32 unrelated words</td>
<td>12</td>
</tr>
<tr>
<td>3.3</td>
<td>The test order</td>
<td>13</td>
</tr>
<tr>
<td>4.1</td>
<td>The descriptive statistics for the SIN-tests.</td>
<td>14</td>
</tr>
<tr>
<td>4.2</td>
<td>Overview of the mean differences between the SIN-tests.</td>
<td>14</td>
</tr>
<tr>
<td>4.3</td>
<td>Overview of the $r$-values between the SIN1-2 and SIN1-3 difference and the cognitive abilities tests.</td>
<td>15</td>
</tr>
<tr>
<td>4.4</td>
<td>The descriptive statistics for each cognitive ability test.</td>
<td>15</td>
</tr>
<tr>
<td>4.5</td>
<td>Overview of the $r$-values of the cognitive ability tests.</td>
<td>16</td>
</tr>
</tbody>
</table>
Chapter 1
Introduction

Cognitive hearing science is an emerging field with research regarding the interaction between human hearing and cognition. The field has emerged from Cognitive Science, which is an interdisciplinary field across some traditional disciplines (as Artificial Intelligence, Linguistics, Anthropology, Psychology, Neuroscience, Philosophy, and Education). The field then developed into Cognitive Neuroscience, and then Cognitive Vision Science before the Auditory Cognitive Neuroscience Society was established in 2009. The discipline has developed through these sciences because they are all needed to be able to understand complex human behaviours, develop technologies and to find solutions for impairments in this area. Cognitive Hearing Science has three general topics which are mostly researched. These are, language processing in challenging listening conditions, the use of auditory communication technologies or the visual modality to boost performance, and changes in performance with development, ageing and rehabilitative training [Arlinger, Lunner, Lyxell, & Kathleen Pichora-Fuller, 2009].

1.1 Background

In this section some earlier studies concerning speech perception, auditory information processing and cognitive abilities are presented.

1.1.1 Studies regarding hearing and speech perception

The most common way of investigating speech understanding is by studying hearing loss [Akeroyd, 2008; Arlinger et al., 2009; Ronnberg et al., 2016; Stenfelt & Rönnberg, 2009]. To listen and understand speech is something effortless for an individual with normal hearing function when the environment is optimal (i.e., a quiet environment). But if another competing noise enter the environment it will result in an increasing listening effort. A person with hearing loss is in a similar situation even in the absence of competing noise. Thus the term Speech-In-Noise (SIN) refers to human speech being perceived at the same time as a competing noise. To investigate the relation between the speech signal and the noise signal, different modulation on Signal-to-Noise Ratio (SNR) is used. A SNR close to 0 means that the level of noise is equal to the level of speech, so a positive SNR means that the noise effect on the speech signal is low and a negative SNR means that the noise effect on the speech signal is high.

The diagnostic of a person with hearing impairment is based on their audiogram, which is the quietest pure-tone sound a person can hear measured on different frequencies. Even though people have equivalent audiograms their ability to perceive and understand speech might differ considerably. One reason for this might be the specifics of the hearing loss. Another might be the individual cognitive functions [Stenfelt & Rönnberg, 2009].

In a study conducted by Gatehouse et al. (2003), the audiometric and cognitive characteristics of a listener, together with the test conditions of speech recognition (presentation level, SNR and temporal characteristics of interfering noise), was investigated.
1.1. Background

The cognitive characteristics of the participants was measured as the performance in a test looking at the overall cognitive ability. The test showed two significant correlations with the cognitive ability of the participant, one correlation with hearing impairment, and one with the temporal characteristics of interfering noise and the time constants of non-linear amplification rationales. These findings show that the greater degrees of cognitive ability the listener has, the greater the speech intelligibility. Depending on the type and the level of background noise together with the listener’s cognitive ability, it will also effect the extent of the speech understanding of the listener.

Davis and Johnsrude (2007) further explains the auditory process and speech perception as complex interactions between multiple brain areas. Thus, for a successful speech perception, an interaction between higher-level linguistic knowledge and bottom-up perceptual processes is necessary. Evidence for this comes from cognitive and behavioural explorations of speech perception together with neuroscientific findings.

1.1.2 Studies on Cognitive functions

Different types of cognitive abilities have been investigated in relation to speech perception.

By using dual-tasks (i.e., two tasks which are performed simultaneously) the relation between attention and speech perception can be studied (Dittrich & Stahl, 2012). Especially by looking at the effect that cognitive load has on auditory selective attention. Cognitive load refers to the cognitive resources available for performing a task. If a task is too demanding, this means that a task uses so much of the human executive cognitive control processes that it is impossible to execute other tasks at the same time.

Another study which has been done regarding linguistic representation is by Hannon and Daneman (2001). They show how easily humans are lured by semantically related impostor words. They draw conclusions that this is related to the individual’s skill at accessing information from long-term memory and further processing it. Also, to be able to resist the impostor words even though the surrounding sentential context easily lures the individual is related to the ability to process and store information in working memory simultaneously.

Arlinger et al. (2009) discuss that, considering the evidence taken forward from working memory studies, that the working memory span measure depends on differences in listening effort. The measure can be modulated possibly by different kinds of cues available (context and/or visual speech cues), but also negatively by challenging environments with different sources of noise and distraction. Age-related auditory temporal processing deficits and mild hearing loss can also negatively affect the working memory.

1.1.3 Studies combining Hearing science and Cognitive functions

This study encompasses different challenging listening conditions for investigating speech perception. Earlier studies concerning cognitive hearing science has looked at both the top-down and bottom-up conditions and the effect they have on the threshold level at which words are perceived (Persson, 2012; Wilson, McArdle, & Smith, 2007). The findings have been that the threshold at which words could be identified is lower if you have top-down support compared to bottom-up support. What is unclear is which cognitive abilities could be related to the benefit of top-down support, and that is what is looked after in this study. How can this benefit be understood?

The layout of this study is based on an earlier study conducted by Widman Börjesson (2014). In that study bottom-up and top-down support on speech processing was researched and its correlation with cognitive abilities (working memory, inhibition ability and attention). The tests used were Speech-In-Noise (SIN) test, for investigating the role of bottom-up and top-down support, Reading span and SIC-span (Size Comparison span task), for measuring working memory, and PASAT (Pace Auditory Serial-Addition Test), for measuring attention capacity. The dB volume of the noise in the SIN-tests were calibrated to 65 dB SPL (Sound...
Pressure Level) at 1kHz. The results of this study showed that if there is top-down support, then the speech perception is facilitated. The study also found a correlation between speech intelligibility and attentional capacity.

1.2 Purpose and research questions

The purpose of this study is to understand the differences between top-down and bottom-up support, and which cognitive abilities affect each other and the speech-in-noise information processing. To understand this, two factors are studied. First, the relation and the differences between the thresholds at which speech is recognized, both through bottom-up and top-down support. Second, the cognitive abilities, divided attention, semantic comprehension and executive functioning, will be studied and compared to see if there is a relation between them and the results in the speech recognition test. These abilities have been chosen to delimit the study, since studying all different and complex cognitive abilities would not be possible. Also, because there are earlier studies which have looked at these abilities and have established tests to measure the performance, which will be used.

Based on this, the following research questions have been asked.

1. Are differences in speech-in-noise perception observed according to the different levels of top-down and bottom-up support?
2. Is speech-in-noise perception related to cognitive abilities, and if so, which ones?
3. Is there any correlation between the performance in the tests concerning the cognitive abilities?

There are three hypotheses in this study. It is expected that there is a difference in speech perception as a function of the support. Better results in SIN perception when top-down support is available is also expected. If the tested cognitive abilities are related to SIN perception, an observed correlation is expected between the benefit of top-down support and the performance on the cognitive tests. If the tests used for measuring cognitive abilities share the same cognitive functions, it is also expected to observe a correlation between them.

1.3 Delimitations

Regarding the methods used, it is a choice to have only three cognitive ability tests and to have one test to measure each ability, including the sub-tests. If more tests were included, the test sessions would be too long and too tiresome for the participants to execute, which would affect their performances.

Regarding the Speech-In-Noise test, it is chosen to have one test measuring bottom-up support in amounting volume, and two tests measuring top-down in amounting and in descending volume. This is because the Speech-In-Noise test already is established and will not be changed from its original form, and because the threshold in detecting speech in noise difference is more interesting in this study between top-down support rather than bottom-up support. The participants are limited to the amount of 15 because that is the necessary amount needed to make assumptions from statistical data.
Chapter 2
Theory

Before going into the methods used in this study it is important to get an understanding of the functioning of the auditory system, the theory behind the cognitive abilities being studied, and also to have a knowledge of the statistic analysis used.

2.1 Hearing science

Sound is basically the mechanical energy produced by the movements of air molecules. These molecules are taken up by the external ear and the auditory system then transforms them into neural signals which gives the energy its perceptual qualities. For humans, the auditory stimuli arise when the pressure changes in the surrounding auditory environment and thus make a sound wave. To be able to detect these pressure changes they need to be within the defined frequency-range, which the receptor cells in the inner ear are able to activate to. This is why the range of human hearing are defined by the sensitiveness of the receptor cells. The local pressure at the ear is defined by decibels (dB), which shows the sensitivity of human hearing. The sound pressure level of 0 dB usually indicates the lower threshold of human hearing, and the upper threshold is about 120 dB where the hair cells of the inner ear starts getting damage. The decibel scale is logarithmic, which means that a small change in dB-level means a large change in intensity (10dB means a ten time increasing of effect from reference level, 20dB means a hundred time increasing of effect from reference level and so on). The sound pressure level is measured by a sound pressure meter level, which consists of a microphone, an amplifier and a gauge. This kind of calibration is done when the sound stimulus perception of the human is of interest (Purves et al., 2013).

2.2 Attention

Attention is partly supported by habituation, familiar stimuli can be tuned out while new and unfamiliar stimuli gets the attention of the individual. But moreover, conscious attention also has four main functions, signal detection, selective attention, divided attention and search. Attention is a limited resource, which means that the individual can not give attention to everything in their environment, but the individual can distribute the limited amount of attention they have. Especially if the tasks which need attention have different modalities, for example to read and listening to music at the same time (Sternberg, 2009).

2.2.1 Divided attention

While using selective attention, the individual is exposed to two or more discrete tasks at the same time and has to give attention to just one of them, ignoring the other, but when using divided attention the individual has to give attention to more than one discrete task at the same time. This kind of task is usually very hard for humans to perform and a lot of the information given in the two tasks are not processed. When this phenomena first was studied
the researchers did not believe it was based on any special cognitive mechanism (Neisser &
Becklen, 1975), but later studies showed that divided attention could be trained and improved
(Spelke, Lliam Hirst, & Nelssen, 1976). Even though the tasks never became fully automatic,
they did involve relatively high levels of cognitive processing.

Another way to study divided attention has been by looking at the speed of the responses
on simple tasks executed consecutively (Pashler, 1994). In this study, the participant started
by doing one task, and then a second task starts soon after. The study shows that this dual
engagement makes the performance speed suffer, which gives a Psychological Refractory
Period (PRP) effect. When studying divided attention it can be seen that some preattentive
processes occurs, which process the physical properties of sensory stimuli, and can process
these properties simultaneously between different tasks. But cognitive tasks which require a
response, retrieving information from memory or engage in other cognitive operations, can
only occur simultaneously. If both tasks studied are cognitive tasks, one or both will probably
show the PRP effect.

Both selective and divided attention are interesting to study because they commonly occur
in the human everyday life since the human usually percept lots of different stimuli in their
environment and do more than one task at the same time (Sternberg, 2009). To measure
divided attention a Paced Auditory Serial-Addition Test (PASAT) can be used (Ruddick et
al., 1997; Widman Börjesson, 2014). In this test, the participants had to listen to a voice telling
numbers and add every two numbers with each other. This test consisted of two tasks which
the participants had to execute at the same time, to remember the number just told, and to
add it with the following number. The test was divided into two parts, an A and a B part,
but both have the same set-up, the only difference was the time for the pauses between the
numbers, which were 2 seconds respectively 3 seconds. The amount of correct answers which
the participants got in the tests showed their ability to divide their attention between the two
tasks.

2.3 Semantic comprehension

A process taking place during language comprehension is to construct a global description
of the meaning of the sentence by understanding the meaning of the individual words in the
sentence. Erickson and Mattson (1981) makes two assumptions about this. The first is that
the construction process involves the discovery of the relation between the individual words
and the meaning they together make. The second is that the meanings behind the different
words can be complex in their representation. The concepts or meanings represented by the
words can be decomposed into sets of different semantic features.

A correlation between working memory span and global reading comprehension has been
seen, especially in tests which looks at the participants ability to integrate encountered ideas
and to detect inconsistencies among them (Hannon & Daneman, 2001).

When researching people with agrammatism, a condition in which speech production
lacks grammatical structure, it has been found that the ventral and dorsal pathway, which
connects Broca’s area with Wernicke’s area, are involved. People with agrammatism usually
have damage to one of the pathways, or both, which have shown to make more syntax errors
than not having a damage on the pathways. Even though the semantic errors did not seem
to be affected by this in semantic comprehension tasks (Eysenck & Kaene, 2015).

A test to examine semantic comprehension is the Logical Interference Test (LIT) used by
Ronnberg et al. (2016). In this test participants had to answer 16 questions on a computer
(example: is a JAL larger than a PONY?), by using two statements given on the screen (in
this example: A JAL is larger than a TOC; A TOC is larger than a PONY). The participants
then answered the questions by “yes” or “no” using the keyboard. The amount of correct
answers and the time estimate for answering the questions gave a measure on the semantic
comprehension ability of the participants.
2.4 Signal-Cognition Interface

A model of how the signal-cognition interface looks like can be seen in Figure 2.1 below. This is an overall model of the two sub-models of bottom-up and top-down processing of sound signals, which is adapted from Stenfelt and Rönnberg (2009). In the first sub-model at the left, the bottom-up process is shown. The bottom-up strategy is used when processing an undistorted signal or general signal transmission. The process is a fast and implicit decoding of the sound signal of its phonetic content and lexical access. The other sub-model to the right shows the top-down process. This strategy is used when a signal is distorted, either by its source or in the transmission by the interference of noise and/or hearing impairment. The top-down process uses other cognitive resources (memory, attention, explicit decoding, etc.) to be able to decode and understand the phonological content of the signal (Stenfelt & Rönnberg, 2009). It is believed that these two processes interact with each others at different levels of the signal detection processing, but how and where is still unknown (Eysenck & Kaene, 2015).
participant usually does a shadowing task, which is to reproduce the words they have heard in the attended stimuli (Eysenck & Kaene, 2015). Treisman (1964) argued that expectations, in other words top-down processing, is important in these kinds of studies. When a participant is performing the shadowing task they might reproduce words from the unattended stimuli. This happens mostly when the word in the unattended stimuli is highly probable in the context of the attended stimuli, which is when the participant expect the word from the unattended output in the currently attended context. It has also been shown that the disruption in the speech perception processing differ between the two processes. In bottom-up processing it is the effect on speech perception through energetic masking, e.g., distracting sounds, which disrupt the process and thus can lead to errors. While in top-down processing it is the informational masking in speech perception which disrupt the process, which is a disruption in detecting and discrimination of a speech signal (Eysenck & Kaene, 2015).

2.4.1 Bottom-up processing

Bottom-up theory explains processing of low-level features which are driven by perceptual stimulus in the human environment (Sternberg, 2009). This process is serial, which means that the current process taking place is finished before the next process starts. This has been seen as an oversimplification of processing because there is also processes which occurs at the same time, as called parallel processing, especially when doing tasks which is practised. Bottom-up processing has been the traditional view which uses a feedforward hierarchical stream which systematically analyse the stimuli and then relay the information to relevant cognitive processing areas (Eysenck & Kaene, 2015).

2.4.2 Top-down processing

Top-down theory on the other hand is the process influenced by the individual’s expectations and knowledge, not just simply the stimulus itself. The individual’s expectation usually dominates over the actual stimuli, which means that the top-down processing usually dominates over bottom-up processing. Neurologically there is just as much projecting neurons flowing backwards as forwards, where the former is associated with top-down processing (Eysenck & Kaene, 2015).

Another important factor to consider is when the top-down process has their effect. This is debated but one view is that the process occur only after object recognition and it is related to semantic processing of already recognised objects. Another view is that the process, which might involve the prefrontal cortex, occurs prior to the object recognition and might be necessary for recognition to occur. The top-down process might also has an important part of object recognition if the information given by the bottom-down process is not enough (Eysenck & Kaene, 2015).

2.5 Executive functioning

The most important and versatile part of the working memory is the central executive, which resembles an attentional system. It is one of the most complex cognitive functions, but does not store information itself. The executive functions is assumed to be located in the prefrontal cortex for the most part, but does not seem to be solely dependent on it (Eysenck & Kaene, 2015). Beddeley has recognized an association between the central executive and executive processes, which is processes that organise and coordinate the functioning of the cognitive system to achieve current goals. He also has speculatively identified four executive processes. The first one is the focusing attention, the second is dividing attentions between two different kinds of stimuli, the third is the switching of attention between two tasks, and the fourth is the interfacing with long-term memory (Baddeley, 1996). But this is just one approach since
to get a consensus of the amount and nature of the executive processes has proven to be difficult [Eysenck & Kaern, 2015].

Another view of the different executive functions comes from [Miyake et al., 2000]. To identify these they administrated several executive tasks for their participants, and then looked at the positive correlations between the tasks to identify which of them involved the same executive processes. The three executive functions they found which were separated but also related are: the inhibition function (the capacity to supersede responses which are dominant in a situation), the shifting function (the flexibility to switch between different tasks or mental states), and the updating function (the monitoring to quickly add or delete contents within the working memory).

Tombaugh (2004) used in their study a Trail Making Test (TMT) to measure executive functioning. The test consisted of two parts, A and B, and were executed by paper and pen. Both parts have the same layout, they consists of 25 circles which the participant should draw lines between. The circle in the A part consists of numbers in increasing order, starting with 1, and the task is to draw lines between them in the correct increasing order. The circles in the B part does also consists of numbers, but letters as well, both in increasing order, the task is the same as in the A part but the lines should go parallel between the numbers and the letters in the increasing order. The time estimate for completing these tasks indicates how effective the executive functioning of the individual is.

2.6 Experimental set-up

In experimental research a variable is manipulated to see if it effects another variable. In this kind of research the variables are taken out from its context, manipulated in a way which makes them easier to measure and then, by analysing the results, a connection between them might be found. A cause and effect relationship is measured. To be able to measure this relationship three things must be taken into consideration, first, the cause and effect must occur close together in time, second, the cause must occur before the effect, and third, the effect must never occur without the presence of the cause. Repeated-measure design is used to manipulate the independent variable using the same participants, in other words the same participants is being presented with each of the different conditions of the variable. For this experimental design, repeated-measure Analysis of Variance (ANOVA) is used. With this, the effect is measured within the participant variance, which consists of two things, the effect of the manipulation and the individual differences in performance. So, some of the variation in the individual’s scores will be due to the experimental manipulations [Field, 2009].

Pearson’s correlation coefficient (r) is used to measure the standardized covariance between two or more variables. To be able to measure the linear relationship between the variables this analysis method requires that the data are interval. Also, to be able to establish if the correlation coefficient is significant the sampling distribution need to be normally distributed. To see whether two or more variables are associated the covariance needs to be analysed. The variance of a variable is the the average amount the data vary from the mean. The problem which arise though is that this depends on the scales of the measurement used in the different variables (the scales can differ in size, units, etc.), which is why standard deviation is used as a unit of measurement which the variables can be converted into. The standard deviation is also measured in the average deviation from the mean value. By using the standardizing of the covariance we get a value between -1 and +1. If the value is closer to -1 it shows that the variables are negatively correlated, if it is closer to +1 they are positively correlated, and if it is closer to 0 it indicates no relationship at all. The effect of the relationship is also measured, if it is +/- 1 a small effect is shown and if it is +/- .5 a large effect is shown [Field, 2009].

In some cases, the data might consists of outliers, which are results from some participants which might be way off the mean value. Outliers can cause the estimated regression
coefficient (the r value) to be affected and thus give significant or non-significant values when there should not be one. If an outlier is suspected in the data then it is possible to calculate if there is one. An extreme outlier is an outlier which has results which is extremely off the main value. It can be defined as a point beyond the outer fence, which is calculated by taking out the lower threshold, quartile 1 - (3 * IQR (Interquartile range)), and the upper threshold, quartile 3 + (3 * IQR). If outliers are found using this analysis, they can be taken from the results (Field 2009).
Chapter 3
Method

This study used a within-subject experimental design, which means that all participants did the same tests. Three cognitive tests and one speech in noise test were used, all of them explained below. All the tests were executed consecutively at the same session. The location of the sessions were in a small, isolated room at Linköping University in the presence of a test manager. All the tests took about an hour to finish.

3.1 Participants

In the study 15 adults (7 females, 8 males) with no hearing disability participated. They were Swedish speaking students and had an age-span between 21 and 31 years ($M = 23, SD = 2.3$). The participants were recruited using a convenience sample by asking available students. Before each test the participants read an information form and filled an informed consent form (see Appendix H and I).

3.2 Equipment

The equipment used was a Dell laptop computer and the headset used was a Sennheiser HD 280 PRO 64 Ω. The sound intensity emitted from the headset was estimated at 91.4 dB HL (decibel hearing level) at 1kHz.

3.3 Pilot test

One pilot test was done before the actual tests. The outcome of it was some changes to the procedure of the session. The first one was to be meticulous with telling the participant that the tests are made to not be managed without errors, especially since many can feel bad afterwards because they felt that they did not succeed. The second notification was concerning the program which the SIN-test was being executed through, the program needed access to Internet to be able to function, else it crashed in the middle of the test. This was managed by changing the test location to another room with better possibilities to Internet access.

3.4 The Logical Inference-making Test (LIT)

The first test used was a Swedish version of the Logical Inference-making Test (LIT) to examine the semantic comprehension of the participants. In the test the participant was seated in front of the computer and got an initial text-based question on the computer screen (example: Är Knut tuffare än Sara?) below the question two statements were presented (in this example: Knut är mindre tuff än Doris; Doris är mindre tuff än Sara). And with the help of these two statements the participant would be able to answer "yes" or "no" on the question initially asked (by pressing either the buttons with the patches "ja" or "nej" on the keyboard).
The performance was measured by the response times and the amount of correct answers, and because there were 16 questions the maximum value able to achieve was 16.

### 3.5 Trail Making Test A and B

The second test used was the Trail Making Test A and B to examine the executive functioning of the participants. This was the only test executed with paper and pen. The test consisted of two parts explained below. Before the participant executed each test, the test manager showed how the test should be done on a simplified separate sample sheet. The participants were instructed to finish the task as quickly as possible without lifting the pencil from the paper sheet. This because the test was timed by the test manager and the result from these tests is the time it took for the participant to finish each part.

#### 3.5.1 TMT A

In the first test, TMT A, the paper sheet consisted of 25 circles with the number 1 to 25 written inside each of them. The task was to draw lines between the circles, starting with the circle with the number 1 written in it, and then continue to draw lines between the circles with increasing numbers (1-2-3-4-etc.). The task was finished when the participant had drawn all the lines to the final circle 25.

#### 3.5.2 TMT B

The second test, TMT B, was constructed the same way as TMT A, but with the inference of letters. The paper sheet consisted of 25 circles with the numbers 1-13 written in some and the letters A-L in the rest. The task was again to draw lines between the circles, starting with the circle with number 1 written in it, and then continue drawing lines between every other increasing number and every other increasing letter (1-A-2-B-3-C-etc.). The task was finished when the participant had drawn all the lines to the final circle 13.

### 3.6 Paced Auditory Serial-Addition Test A and B

The third test was a Swedish version of the PASAT test, which consisted of two parts; PASAT A and PASAT B. This test measured the information processing and divided attention of the participants. The test was conducted through the use of the computer and the headphones. The participants heard a number between 1 and 9 through the headphones and their task was to add the numbers said after each other together and say the new number out loud (for example if the participant heard the following numbers: 1, 4, 5, 7, then the right answer for the participant to say would have been 5, 9, 12). The participant heard 61 numbers in each of the tests, the only difference between them was that in PASAT A the numbers were heard in an interval of 3 seconds and in PASAT B they were heard in an interval of 2 seconds. The tests were conducted directly after each other on the same sound file, with a little longer break between each test round.

### 3.7 Speech-In-Noise Test (SIN-test)

The last test used was Speech-In-Noise test, which consisted of three sub-tests. This test was executed with the use of the computer and the headset. The test manager used the computer to conduct the test while the participant did not get to see the computer screen, they only had the headphones on and answered verbally. Each test consisted of eight different target words, which the participant needed to perceive through the noise from the headset, and 64 distractor words (Table 3.1). The noise was at a constant level while the spoken words were
said in an amounting or decreasing volume. The volume levels at which the participant heard the correct target words were saved as the result.

### 3.7.1 Part 1

In the first part of the test, bottom-up was studied. The participant would try to perceive the words through the noise without knowing which words they would hear beforehand. The participant had to answer the word they heard, both the target words and the distractor words (see Table 3.1), and try to get it correct. In this test the words were said in an amounting volume, starting with barely audible. In this test, unrelated words were also mixed between the target and distractor words (see Table 3.2).

Table 3.1: The eight target words and their distractor words.

<table>
<thead>
<tr>
<th>vak</th>
<th>mor</th>
<th>kur</th>
<th>las</th>
<th>ren</th>
<th>vis</th>
<th>lar</th>
<th>rok</th>
</tr>
</thead>
<tbody>
<tr>
<td>rak</td>
<td>kor</td>
<td>kub</td>
<td>lag</td>
<td>red</td>
<td>vid</td>
<td>bar</td>
<td>rod</td>
</tr>
<tr>
<td>tak</td>
<td>for</td>
<td>kul</td>
<td>lan</td>
<td>rep</td>
<td>vig</td>
<td>dar</td>
<td>ron</td>
</tr>
<tr>
<td>bak</td>
<td>bor</td>
<td>kuf</td>
<td>lar</td>
<td>res</td>
<td>vik</td>
<td>nar</td>
<td>ros</td>
</tr>
<tr>
<td>sak</td>
<td>rok</td>
<td>kut</td>
<td>lat</td>
<td>rev</td>
<td>vin</td>
<td>sar</td>
<td>rot</td>
</tr>
<tr>
<td>val</td>
<td>mod</td>
<td>bur</td>
<td>bas</td>
<td>ben</td>
<td>dis</td>
<td>lak</td>
<td>dok</td>
</tr>
<tr>
<td>vad</td>
<td>mos</td>
<td>lur</td>
<td>gas</td>
<td>len</td>
<td>fis</td>
<td>man</td>
<td>lom</td>
</tr>
<tr>
<td>vas</td>
<td>mot</td>
<td>mur</td>
<td>mas</td>
<td>men</td>
<td>kis</td>
<td>las</td>
<td>bok</td>
</tr>
<tr>
<td>van</td>
<td>mon</td>
<td>sur</td>
<td>nas</td>
<td>ven</td>
<td>ris</td>
<td>lat</td>
<td>sok</td>
</tr>
</tbody>
</table>

Table 3.2: The 32 unrelated words

<table>
<thead>
<tr>
<th>rap</th>
<th>dag</th>
<th>fat</th>
<th>bal</th>
</tr>
</thead>
<tbody>
<tr>
<td>gol</td>
<td>ton</td>
<td>sot</td>
<td>dop</td>
</tr>
<tr>
<td>ful</td>
<td>bud</td>
<td>mus</td>
<td>tub</td>
</tr>
<tr>
<td>näl</td>
<td>rad</td>
<td>mån</td>
<td>päk</td>
</tr>
<tr>
<td>deg</td>
<td>fel</td>
<td>mes</td>
<td>seg</td>
</tr>
<tr>
<td>pil</td>
<td>fin</td>
<td>bit</td>
<td>rik</td>
</tr>
<tr>
<td>säd</td>
<td>ráv</td>
<td>nät</td>
<td>väg</td>
</tr>
<tr>
<td>döv</td>
<td>lös</td>
<td>pöl</td>
<td>fön</td>
</tr>
</tbody>
</table>

### 3.7.2 Part 2 and 3

In the second and third part of the test, top-down was studied. The participant was told the target word they would try to hear beforehand and then tried to perceive it through the noise and try to distinguish it from the other distractor words (see Table 3.1). The participant answered "yes" or "no" verbally if they heard the requested target word or not. In part 2, the spoken words were said in a descending volume, starting with very audible. While in test 3, the spoken words were said in an amounting volume, starting with barely audible.

### 3.8 Test procedure

The test session started with the participant reading through the consent form and the information form before giving their signed consent to take part of the study. The participant was also asked if they had any questions concerning the procedure. The tests were then executed in the order shown in Table 3.3 between each test the participant could rest however long they needed and also read through the part of the information form concerning the following test, they also had the possibility to ask questions. During this time period the test manager prepared the next test.
3.9 Supplemental test session

Because a problem with the data collection for the SIN 2 test was found after the sessions were done, a supplemental test session for the SIN 2 test had to be done. The set-up for the test was the same as in the first session, the only difference were the amount of participants, because one could not participate again. So in this result, 14 participants participated (7 females, 7 males), which had an age-span between 21 and 31 years ($M = 23, SD = 2.7$).

3.10 Statistical analysis

For the analysis of the results, SPSS 23 was used. For the first research question, repeated measures one-way ANOVA was used to compare the results between the SIN-tests. The mean value of the dB-value for all eight words for each participant were used.

For the second and third research question, Pearson correlation coefficient was used. For the second research question, the correlation was measured between the results for each cognitive ability test and the results for each participant’s mean value for each SIN-test. For the third question the correlation was measured between the results for each cognitive ability test and the difference in mean values between (SIN test 1 and 2) and (SIN test 1 and 3), reflecting the effect of top-down support. For the last research question, the mean values for each cognitive ability test were compared.

Table 3.3: The test order.

<table>
<thead>
<tr>
<th>Order</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LIT</td>
</tr>
<tr>
<td>2</td>
<td>TMT A</td>
</tr>
<tr>
<td>3</td>
<td>TMT B</td>
</tr>
<tr>
<td>4</td>
<td>PASAT A</td>
</tr>
<tr>
<td>5</td>
<td>PASAT B</td>
</tr>
<tr>
<td>6</td>
<td>SIN 1</td>
</tr>
<tr>
<td>7</td>
<td>SIN 2</td>
</tr>
<tr>
<td>8</td>
<td>SIN 3</td>
</tr>
<tr>
<td></td>
<td>Supplemental Test</td>
</tr>
</tbody>
</table>
Chapter 4
Results

In this section I will present the findings of the tests executed in relevance to the research questions asked.

4.1 Research Question 1

The first research question asked was, *Are differences in speech-in-noise perception observed according to the different levels of top-down and bottom-up support?* First, an overview of the descriptive statistics for the SIN-tests are listed below (see Table 4.1). A lower signal-to-noise ratio (SNR) is observed for SIN 2 compared to SIN 3 and SIN 1, meaning that better performance are observed for SIN 2. For knowing if these differences are significant, a one-way ANOVA was done and the results are explained below.

Table 4.1: The descriptive statistics for the SIN-tests.

<table>
<thead>
<tr>
<th>Test</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIN 1</td>
<td>-4.94dB</td>
<td>1.34dB</td>
</tr>
<tr>
<td>SIN 2</td>
<td>-7.13dB</td>
<td>1.56dB</td>
</tr>
<tr>
<td>SIN 3</td>
<td>-4.26dB</td>
<td>1.07dB</td>
</tr>
</tbody>
</table>

ANOVA showed a main effect of support, $F(2, 26) = 32.228$, $p < .001$, $\eta^2 = .713$. Post-hoc analysis indicated that speech in noise were understood at a lower dB-level by using top-down processing in decreasing level rather than bottom-up processing ($p = .001$), and rather than top-down processing in increasing level ($p = .001$). An overview of the results is shown in Table 4.2 below.

Table 4.2: Overview of the mean differences between the SIN-tests.

<table>
<thead>
<tr>
<th>Test</th>
<th>SIN 2</th>
<th>SIN 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIN 1</td>
<td>2.187*</td>
<td>-.686</td>
</tr>
<tr>
<td>SIN 2</td>
<td></td>
<td>2.873*</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the .05 level.

4.2 Research Question 2

The second research question asked was, *Is speech-in-noise perception related to cognitive abilities, and if so, which ones?* When looking at the Pearson’s $r$ correlation between the differences between the SIN-tests and the performance in the cognitive tasks, one significant value was found. This significance was found as a high negative correlation between the difference between SIN 1 and SIN 2 (i.e., effect of top-down support in increasing level of difficulty) and the performance in the LIT test, $r (12) = -.66$, $p < .010$. This shows that the more one
benefit from top-down support, the less one perform in semantic comprehension tasks. For an overview of the results see Table 4.3.

Table 4.3: Overview of the $r$-values between the SIN1-2 and SIN1-3 difference and the cognitive abilities tests.

<table>
<thead>
<tr>
<th>Test</th>
<th>LIT score</th>
<th>TMT A</th>
<th>TMT B</th>
<th>PASAT A</th>
<th>PASAT B</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIN1-SIN2</td>
<td>-.663**</td>
<td>.029</td>
<td>-.118</td>
<td>-.515</td>
<td>.118</td>
</tr>
<tr>
<td>SIN1-SIN3</td>
<td>-.209</td>
<td>.061</td>
<td>.238</td>
<td>-.363</td>
<td>.132</td>
</tr>
</tbody>
</table>

** Correlation is significant at the .01 level (two-tailed).
* Correlation is significant at the .05 level (two-tailed).

By looking at the distribution of the results in some of the tests, two extreme outliers could be discovered. The first one is found in the LIT score (see Figure 4.1a) and if the outlier would be taken from the analysis, the results would have been a non-significant correlation value between the SIN1-2 difference and the LIT score, $r(11) = -.078, p < .080$. The second outlier is found in the TMT A score (see Figure 4.1b). By taking this participant off the analysis the result would change, but still be non-significant, $r(11) = .187, p < .540$.

![Scatter-plots](image)

(a) Scatter-plot for the SNR between SIN1-SIN2 and the LIT score. (b) Scatter-plot for the SNR between SIN1-SIN2 and TMT A.

Figure 4.1: The scatter-plots of the performance in the two tests with extreme outliers.

### 4.3 Research Question 3

The third research question was, *Is there any correlation between the performance in the tests concerning the cognitive abilities?* The descriptive statistics from the test results are listed below (see Table 4.4) and the statistic analysis showed five significant values (see Table 4.5).

Table 4.4: The descriptive statistics for each cognitive ability test.

<table>
<thead>
<tr>
<th>Test</th>
<th>Value Type</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIT score</td>
<td>correct answers</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>LIT time</td>
<td>reaction time (ms)</td>
<td>14437</td>
<td>6304</td>
</tr>
<tr>
<td>TMT A</td>
<td>reaction time (ms)</td>
<td>2550</td>
<td>818</td>
</tr>
<tr>
<td>TMT B</td>
<td>reaction time (ms)</td>
<td>8194</td>
<td>6036</td>
</tr>
<tr>
<td>PASAT A</td>
<td>correct answers</td>
<td>47</td>
<td>9</td>
</tr>
<tr>
<td>PASAT B</td>
<td>correct answers</td>
<td>36</td>
<td>9</td>
</tr>
</tbody>
</table>
Table 4.5: Overview of the $r$-values of the cognitive ability tests.

<table>
<thead>
<tr>
<th>Test</th>
<th>LIT score</th>
<th>TMT A</th>
<th>TMT B</th>
<th>PASAT A</th>
<th>PASAT B</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIT time</td>
<td>-.142</td>
<td>.207</td>
<td>.782**</td>
<td>-.175</td>
<td>-.539*</td>
</tr>
<tr>
<td>LIT score</td>
<td>-</td>
<td>.139</td>
<td>-.290</td>
<td>.595*</td>
<td>-.432</td>
</tr>
<tr>
<td>TMT A</td>
<td>-</td>
<td>-</td>
<td>.440</td>
<td>-.464</td>
<td>-.422</td>
</tr>
<tr>
<td>TMT B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-.504</td>
<td>-.688**</td>
</tr>
<tr>
<td>PASAT A</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.629*</td>
</tr>
</tbody>
</table>

** Correlation is significant at the .01 level (two-tailed).
* Correlation is significant at the .05 level (two-tailed).

The first positive correlation was between the time performance in the LIT test and the performance in the TMT B test, $r(13) = .78, p < .001$, which was a high correlation, and also with the PASAT B test, $r(13) = -.54, p < .038$, which was a low correlation. This results indicates that there is a positive correlation between the ability to understand semantic comprehension, executive function and divided attention.

A low positive correlation between the performance in the LIT test and the PASAT A test was seen, $r(13) = .60, p < .022$. This results indicates that the ability to understand semantic comprehension also has a positive correlation with divided attention.

Performance in the TMT B and PASAT B tests were highly negatively correlated, $r(13) = .69, p < .004$ which indicates that there is a negative association between information processing, divided attention and executive function, in other words that when the performance in the divided attention task increases, the performance in the executive function task decreases.

The last low positive correlation was between the performance in the PASAT A and PASAT B tests, $r(13) = .63, p < .012$. This results indicates that there is a positive correlation between if the divided attention task was executed with a 2 second or 3 second pause between each word.
Chapter 5
Discussion

In this part follows a discussion of the results given above and the execution of the study.

5.1 Results

As expected by the first hypothesis, the results showed that top-down support is more efficient than bottom-up processing when listening to and understanding speech in noise. Earlier theories (Eysenck & Kaene, 2015; Sternberg, 2009) talked about the fact that in top-down processing the semantic processing occur before object recognition, and might therefore be necessary for the recognition to occur. This pre-recognition might help to distinguish the words from the noise, when in bottom-up processing one can only rely on the perceptual stimulus, which together with the noise more easily can lead to errors. Expectation might be an important factor, if a person expect a word to occur in the context then the person might more easily distinguish it through the noise.

The results also showed a difference between the decreasing and increasing speech volume on the top-down processing tasks. In the second task the speech was followed from a higher dB-level until the participant did not recognise the words anymore, but in the third task the participant had to start by recognising the words at lower dB-levels. This indicates that, when knowing which word to search for beforehand, one can follow a recognised word to lower dB-levels than one can identify the same word starting at a low dB-level.

When looking at the SIN-tests in relation to the cognitive abilities researched, a negative relation between the effect between top-down and bottom-up processing and the LIT test was seen. Which indicates that, the more you benefit from top-down support, the less the result will be in semantic comprehension tasks. The reason behind this might be that the bigger the benefit from top-down support is, then that means the threshold level for bottom-up processing is either really high, or the threshold level for top-down processing is really low. If it is the first, then we might think that an inferior semantic comprehension ability might affect the threshold level at which words are comprehended. But this result is most likely an effect of the outlier as shown in the results, which makes this result arguable. However, this result also makes it more interesting to look further into the relationship between semantic comprehension and the effect of top-down support.

Another of the hypotheses given was that if there is a relation between SIN perception and the cognitive abilities, a correlation should be observed. As discussed above, one negative correlation was observed which might be affected by the outlier. So, how come no more correlations were found? As will be discussed on the method critiques section below, the amount of the sample might have affect the results. Also, since the cognitive ability of the participants were calculated by their performance in one test for each ability, it might not give a realistic enough value for their overall performance regarding the ability.

One of the most interesting findings in the study is the significances found between the cognitive abilities. First and foremost it could be seen that a positive correlation between semantic comprehension (LIT-test) and all the other cognitive abilities test (PASAT, TMT)
5.2. Critique

There is some critical aspects which need discussion regarding this study. The first thing is that this study differs from the earlier speech-in-noise studies performed because of the dB-level the noise were set to. The calibration could not be done until after the tests were performed, so the computer was set at a "good enough" volume which then were calibrated at 91.4 dB HL, when the earlier studies were calibrated at a volume level of 65 dB. This should not change the general results and difference between the top-down and bottom-up processing tasks because it is still the difference in the speech which is shown in the results and not the noise. But it might have had some effect on the unexpected results on the SIN 1 and the SIN 3 test, which were very close together (SIN 1 \(M = -4.91\) dB, SIN 3 \(M = -4.38\) dB). Both tests were executed in an amounting volume, which means that the participant first barely heard any speech until they reach a dB-level at which they did. This common factor might show that the higher dB-level of the noise effected the dB-volume at which the speech first were correctly detected.

Regarding the method, the SIN 2 test had to be done a second time because of problems with the data collection. This meant that the same participants had to be collected a second time, with the loss of one participant. Because of this, only 14 participants could participate and thus the data from only these 14 participants could be taken into consideration in the data analysis regarding the SIN-tests. The results from the second SIN 2 tests should not have been affected by the fact that the same participants did it twice.

Because only 14 out of 15 participants could be used in the final analysis of the difference between the SIN-tests and the correlations between speech-in-noise and cognitive abilities, the data was still analysed including the two outliers. To improve this study, a bigger sample with a minimum of 30 participants should be used. By having a bigger sample there will be both more distribution in the group, and more statistical power (i.e., with a sample of 30 participants, the critical value for \(r = .361\), while, for a sample of 15, the critical value for \(r = .514\)). The amount of participants were also a factor in the choice of statistical correlation
method. Pearson is a more appropriate method than Spearman, which is the other commonly used alternative, for small numbers of participants and to avoid the exclusion of outliers.

Another fact which needs to be taken into consideration is the characteristics of the sample group. All participants were students between the age of 21 and 31, which makes the study more relevant for this age group. The fact that they were students might also affect the results. To be able to draw conclusion on the bigger population, further studies with a bigger and more diverse sample need to be done.

Another thing which needs to be considered regarding the method is that the test sessions were very long. The first time the tests were executed it took about an hour, and the second session with only the SIN 2 test took about 30 minutes. What is positive with having a session this long is that it gives a large amount of data at the same time, but what needs to be taken into consideration is that the cognitive abilities, which are being researched, might be affected by fatigue and that the participant might get bored by the repeating nature of the tasks. The tests measuring cognitive abilities were all fairly short and the tasks were different and kept the participants alert, but the SIN-tests were very repeatedly done, which also took a considerable amount of time to execute. During these tests the participants were also constantly exposed to noise, which means that they both got tired by the constant auditory perception and that they had to be constantly alert to try and detect the words in the noise. These facts might have lessen their performance during the tests. Also, the tests were executed in the same order each time. This was a choice because it was an easier structure to finish with the SIN-test, which was the longest of them. But it would also be good to execute these tests in a randomized order for each participant to be sure that the order does not affect the results.

By concluding these critiques it can be said that if a replication of this study would be done, the following method choices can be made. The sample should be randomized and more distributed, also the sample should be at least 30 participants big. The calibration of the SIN-test should be done beforehand and be at the level of 65 dB HL. Also, the test session should be shorter, either by having a less amount of tests or by dividing it into two sessions, the order of the tests should also be randomized.

5.3 In a wider context

Since less relations than assumed were found in this study between the cognitive functions studied (divided attention and information processing, executive function, semantic comprehension) and the ability to hear words in noise, it could be interesting to further study other cognitive abilities and their influence on understanding speech in noise. This study is limited to one test for each cognitive function, but it could be interesting to make a study which looks more into one cognitive ability with more tests to get a more exact and through value of the individual performance of the cognitive ability.

It could also be interesting to study bottom-up and top-down processing in different kinds of noise, talking noise, traffic noise, etc. Also to make further studies on the interaction between the two processes rather than the difference between them.

There is still many aspects of the interaction between cognitive abilities and speech understanding processes which is unknown, which is why these kinds of studies are important. The cognitive hearing science field is big and still needs exploring by making new studies and thus get new findings, but also by redoing old ones to be able to establish theories taken forward by the results found in them.
Chapter 6
Conclusion

The purpose of this study was to look at the relation and the differences between the thresholds of the level of noise which speech is recognized in, both by looking at top-down and bottom-up support. These results were also analysed in correlation to the performance on three different cognitive abilities tasks, which were divided attention, semantic comprehension and executive functioning. To fulfil this purpose, three research questions were asked regarding whether any differences in the speech-in-noise perception to the different levels of top-down support were found, if the speech-in-noise perception was related to any of the cognitive abilities, and if any correlations between the cognitive abilities were found.

The results showed that there was a difference in speech-in-noise perception regarding different levels of top-down support. One significant difference was between top-down processing and bottom-up processing, and the other difference was between top-down support in increasing contra decreasing dB-levels of speech. Regarding the speech-in-noise perception processing and its relation to cognitive abilities, the only significant correlation found was a negative one between semantic comprehension function and the benefit from top-down support.

When looking at the correlation between the cognitive abilities, more were found. Performance in the semantic comprehension task had a positive correlation with the performance both in the central executive task and the divided attention task, while the central executive task and the divided attention task had a negative relation between each other. Also, a positive correlation were found between the two divided attention sub-tasks.

These results both strengthen earlier findings, regarding the difference in speech-in-noise perception on the different levels of top-down support, and give further proof of the correlation between different cognitive abilities. Also, these findings lift the question if there is further correlation than found in this study between semantic comprehension function and the benefit from top-down support.
References


References


Appendix A
Scatter-plots for SIN-tests

(a) Scatter plot of the relation between SIN1 and SIN2.

(b) Scatter plot of the relation between SIN1 and SIN3.

(c) Scatter plot of the relation between SIN2 and SIN3.
Appendix B

Scatter-plots for SIN 1 and cognitive abilities

(a) Scatter plot of the relation between SIN1 and LIT score.

(b) Scatter plot of the relation between SIN1 and LIT time estimate.

(c) Scatter plot of the relation between SIN1 and TMT A.

(d) Scatter plot of the relation between SIN1 and TMT B.

(e) Scatter plot of the relation between SIN1 and PASAT A.

(f) Scatter plot of the relation between SIN1 and PASAT B.
Appendix C
Scatter-plots for SIN 2 and cognitive abilities

(a) Scatter plot of the relation between SIN2 and LIT score.

(b) Scatter plot of the relation between SIN2 and LIT time estimate.

(c) Scatter plot of the relation between SIN2 and TMT A.

(d) Scatter plot of the relation between SIN2 and TMT B.

(e) Scatter plot of the relation between SIN2 and PASAT A.

(f) Scatter plot of the relation between SIN2 and PASAT B.
Appendix D
Scatter-plots for SIN 3 and cognitive abilities

(a) Scatter plot of the relation between SIN3 and LIT score.
(b) Scatter plot of the relation between SIN3 and LIT time estimate.
(c) Scatter plot of the relation between SIN3 and TMT A.
(d) Scatter plot of the relation between SIN3 and TMT B.
(e) Scatter plot of the relation between SIN3 and PASAT A.
(f) Scatter plot of the relation between SIN3 and PASAT B.
Appendix E

Scatter-plots for SNR SIN1-2 and cognitive abilities

(a) Scatter plot of the relation between SNR SIN1-2 and LIT score.

(b) Scatter plot of the relation between SNR SIN1-2 and LIT time estimate.

(c) Scatter plot of the relation between SNR SIN1-2 and TMT A.

(d) Scatter plot of the relation between SNR SIN1-2 and TMT B.

(e) Scatter plot of the relation between SNR SIN1-2 and PASAT A.

(f) Scatter plot of the relation between SNR SIN1-2 and PASAT B.
Appendix F

Scatter-plots for SNR SIN1-3 and cognitive abilities

(a) Scatter plot of the relation between SNR SIN1-3 and LIT score.

(b) Scatter plot of the relation between SNR SIN1-3 and LIT time estimate.

(c) Scatter plot of the relation between SNR SIN1-3 and TMT A.

(d) Scatter plot of the relation between SNR SIN1-3 and TMT B.

(e) Scatter plot of the relation between SNR SIN1-3 and PASAT A.

(f) Scatter plot of the relation between SNR SIN1-3 and PASAT B.
Appendix G
Scatter-plots between cognitive abilities

(a) Scatter plot of the relation between the LIT score and time estimate.

(b) Scatter plot of the relation between PASAT A and PASAT B.

(c) Scatter plot of the relation between TMT A and TMT B.
(a) Scatter plot of the relation between the LIT score and TMT A.

(b) Scatter plot of the relation between the LIT score and TMT B.

(c) Scatter plot of the relation between the LIT score and PASAT A.

(d) Scatter plot of the relation between the LIT score and PASAT B.
(a) Scatter plot of the relation between the LIT time estimate and TMT A.

(b) Scatter plot of the relation between the LIT time estimate and TMT B.

(c) Scatter plot of the relation between the LIT time estimate and PASAT A.

(d) Scatter plot of the relation between the LIT time estimate and PASAT B.
(a) Scatter plot of the relation between TMT A and PASAT A.

(b) Scatter plot of the relation between TMT A and PASAT B.

(c) Scatter plot of the relation between PASAT A and TMT B.

(d) Scatter plot of the relation between PASAT B and TMT B.
Appendix H
Informed Consent Form

Medgivandeblankett för deltagande i kognitionsvetenskaplig studie

Denna studie är uppdelad i fyra delar som du kommer att få utföra efter varandra. Du kommer att få skriftliga instruktioner innan varje test som förklarar tests utförande och de flesta av testen inleds även med en kort testomgång. Om du har något som du undrar över eller inte förstår så får du fråga testledaren när som helst.

Den data som vi kommer att få ut ifrån denna studie kommer att behandlas anonymt.

Deltagandet i denna studie är helt frivilligt och du får avbryta studien när du vill.

Tack för ditt deltagande!

Nedan följer ditt skriftliga medgivande.

Genom att fylla i informationen nedan och skriva under så går du med på att du har:

- Läst instruktionerna ovan och Informationsbladet, och har förstått vad studien innefattar.
- Förstått att om du når som helst väljer att avbryta studien så kan du informera testledaren och avlägsna dig direkt.
- Givet ditt medgivande till att testledaren får processa din personliga information för studiens syfte.
- Förstått att du kan informeras om studiens slutgiltiga resultat vid efterfrågande av testledaren.
- Givet ditt medgivande att den ovan namngivna studien har förklarats för dig till din tillfredsställelse och att du går med på att delta i denna studie.

Försöksdeltagare: ______________________________

Namn: ________________________________________

Ålder: __________________

Datum: ________________

Kön: 
- [ ] Man
- [ ] Kvinnan
- [ ] Annat

Jag har inte någon hörande/svardsättning:
- [ ] Instämmer
- [ ] Instämmer inte

Underskrift: __________________________________________
Appendix I
Information Form

Informationsblad för kognitionsvetenskaplig studie

I följande del kommer de fyra testen att förklaras. Mellan varje test får du ta en frivillig paus om du skulle villja och behöva det.

Test 1

Test 2
Detta test utförs med pennor och papper och är indelat i två delar. Testledaren kommer att visa innan de båda delarna hur de kommer att utföras.
I del 1 ska du dra streck från cirkel 1 och sedan fortsätta dra streck till de cirklar med siffror i stigande ordning (1-2-3-4-osv.) utan att lyfta penna från pappret tills du kommer till cirkel nummer 25. Då lägger du ner pennen.

Test 3

Test 4
Det sista testet utförs också med hörlurar och är indelat i tre delar. I detta test kommer du att få förstå urskilda ord i bruset.
I del två och tre kommer testledaren att säga till dig före vilket ord du ska lyssna efter, så ska du högt säga "ja" om du hör ordet i bruset.