To my father

– to whom I promised to dedicate
this dissertation before he left this world
If we knew what it was we were doing, it would not be called research, would it?

Albert Einstein
Blindness and Second Language Acquisition

Studies of Cognitive Advantages in Blind L1 and L2 speakers

Helena Smeds

Centre for Research on Bilingualism
Department of the Swedish Language and Multilingualism
Stockholm University
I will start by telling you a few important stories to establish a context for my work and this dissertation. First, I am going to say a few words about a very special and unique boy and his experiences. He was born approximately 40 years ago, and he was born slightly different than his friends. He was born blind. Although his sensory interaction with the environment was very different from the experiences of his friends, he did not let his blindness stop him in any way and limit his life experience. He simply did what the rest of his friends did. He especially enjoyed riding motocross in the rough terrain of the forest, which he enjoyed together with his sighted friends. I asked him, “How is this possible? Didn’t you fall and hurt yourself?” He simply replied, “No. No more or less than my sighted friends.” I still haven’t been able to fully grasp this, but his story fills me with great awe and humility for human capacity. Imagine the incredible kinaesthetic precision, the ability to balance a moving motocross cycle while the terrain keeps changing beneath your wheels, the coordination between the remaining senses using the auditory sense for navigation and the kinaesthetic for balancing. Just try balancing on one leg with your eyes closed!

Such a story is empowering and unique, but there are many other stories just as surprising. For example, another man who also was born blind gained employment at an international company as an adult. He then chose to move to different countries around the world and, as he did so, learned seven different languages fluently in order to be able to communicate with native speakers and to feel integrated. Another story is told of a woman who was born blind and was kept at home because of her blindness, not being allowed to go to school with other children. She started to take singing lessons in secrecy. This girl happened to be born with a very special gift and eventually became a very famous singer – so famous, in fact, that she tours around the part of the world where she was born, and everybody from her country of origin knows of her. A few years ago I took a taxi ride here in Sweden, driven by a man born in this country, and when he understood me to be a friend of this woman, he gave me his business card and encouraged me to call him if I ever needed another taxi ride. When this woman came to Sweden as an adult, she started to study and go to school for the first time in her life, and in a few years time she had made the journey from illiteracy to a bachelor’s degree from a Swedish university. A few years back, she got a job at a government office in the country where she was born, and she continues to travel back and forth from her native country to Sweden.
There are many amazing stories that I have had the privilege of learning, and they have inspired me along the way, giving me a deep sense of gratitude towards my participants for letting me share these beautiful and sometimes very hard and tragic stories of their lives. They have made me even more convinced about the great capacity of the human mind and its ability to develop and adapt, both from necessity but also from great motivation and will. I have a great fascination for the inherent capacity of the human mind, and I have a feeling that we have just started to become aware of the great potential that we all possess, and I hope that my future career will keep giving me the opportunity to investigate the capacity of the human mind and consciousness even further. That is my passion.

The project "Perceptual compensation in blind second language learners" ["Perceptuell kompensation hos blinda andraspråksinlärare"], 2008–2010, was funded by the Swedish Research Council [Vetenskapsrådet] grant no. 2007–1679 to Niclas Abrahamsson and, in addition to the Swedish Research Council, I would like to thank my supervisors, Niclas Abrahamsson and Lars-Göran Nilsson, as well as my pre-opponent, Marianne Gullberg. Since there are so many more people that I would like to thank for their support along the way, and since there is a great risk that in doing so I would forget someone, I will do this in a different manner. There is a Swedish saying that goes “Ingen nämnd, ingen glömd,” and it means that if you don’t mention anyone you do not stand the risk of forgetting anyone. So, I want to thank everyone who contributed in some way to the developing process of this project and this dissertation, and that includes so many people! I deeply appreciate the great support I have received, even down to the smallest contribution. This contribution might not even be related to the work in and of itself, but to me personally, in order to support my ability to complete this project. Deep gratitude – you are ALL included!

Namaste (Sanskrit: “salutations, I bow to you”),

Stockholm, 20 January 2015

Helena Smeds

P.S. When I had almost finished writing this dissertation (and even the Preface and Acknowledgements had been written long before), I actually fell, just before the finish line, and did not know how to get back up. Two people and an email helped me get back up on my two feet again so that I could take the last necessary steps. The email was sent from you, Lars-Göran, on 2013-12-08, and I printed it out, hung it on the wall and read your reassuring words many, many times every day when life felt like a rollercoaster. The two people are you, Carina Shola, and you, Rolf, gratitude for your love and invaluable support!
Contents

Preface and Acknowledgements .............................................. vii
Contents .................................................................................. ix
Tables ..................................................................................... xv
Figures ..................................................................................... xvii
Appendices ............................................................................... ix

1 GENERAL INTRODUCTION ..................................................... 21
  1.1 Scope of the study ................................................................. 21
  1.2 Aims of the study ................................................................. 24
  1.3 Structure of the thesis .......................................................... 24

2 GENERAL THEORETICAL BACKGROUND ............................... 27
  2.1 First language acquisition in blind children ....................... 27
    2.1.1 Theoretical and methodological issues ......................... 28
    2.1.2 Preverbal communication .............................................. 29
    2.1.3 Acquisition of phonology ............................................. 31
      2.1.3.1 Speech perception ............................................. 31
      2.1.3.2 Speech production ............................................. 32
    2.1.4 Lexical and semantic development .............................. 34
      2.1.4.1 The first words of blind children ......................... 34
      2.1.4.2 Early lexicon .................................................... 35
      2.1.4.3 Word meaning and concept formation ................. 36
      2.1.4.4 The verbalism issue and the use of sighted terms .... 37
      2.1.4.5 Referential language and the concept of space ....... 38
    2.1.5 Morphology and syntax ................................................ 39
      2.1.5.1 Morphological development ................................ 39
      2.1.5.2 Syntactic development ....................................... 40
    2.1.6 Imitations, repetitions and routines ............................ 41
    2.1.7 Compensatory mechanisms in first language acquisition and possible relevance to second language acquisition ............ 43
  2.2 Second language acquisition in blind individuals .................. 44
  2.3 Neuropsychological aspects of blindness ............................ 47
    2.3.1 The Sensory Compensation Hypothesis ....................... 47
    2.3.2 The development of the human brain and neuroplasticity .... 48
    2.3.3 The effect of visual deprivation on neuroplasticity ........ 50
2.3.4 Age of onset of blindness ........................................................... 60

3 GENERAL METHODOLOGY ............................................................ 63

3.1 Participants and study design ........................................................... 63

3.1.1 Background data for the L1 speakers ......................................... 64

3.1.2 Background data for the L2 speakers ......................................... 65

3.1.3 Comparisons between L1 and L2 speakers on background data ........................................................... 67

3.2 Selection criteria ........................................................................... 68

3.3 Initial screening tests ........................................................................ 70

3.4 Participant recruitment procedure ..................................................... 71

3.5 General data collection procedure .................................................... 72

3.6 Statistical methods and data management ........................................ 72

4 STUDY I: MEMORY, BLINDNESS AND SECOND LANGUAGE ACQUISITION ................................................................. 75

4.1 Introduction ...................................................................................... 75

4.2 Theoretical background .................................................................... 77

4.2.1 Phonological short-term memory and the working memory model ........................................................... 77

4.2.1.1 Central Executive .............................................................. 79

4.2.1.2 The phonological loop ....................................................... 80

4.2.1.2.1 Characteristics and functions of the phonological loop component ........................................................ 80

4.2.1.2.2 The role of the phonological loop in second language acquisition ......................................................... 83

4.2.1.2.3 The phonological loop and blindness ........................................................ 86

4.2.1.3 The episodic buffer ........................................................... 88

4.2.1.4 The visuospatial sketchpad ................................................ 88

4.2.1.5 The link between working memory and long-term memory ........................................................... 89

4.2.1.6 Working memory – a constant trait or susceptible to training? Or even an expression of volatile and temporary plasticity? ........................................................... 89

4.2.1.7 Auditory memory versus phonological short-term memory ........................................................... 91

4.2.2 Recognition memory .................................................................... 91

4.2.2.1 Recognition memory and second language acquisition .... 92

4.2.2.2 Recognition memory and blindness ........................................... 94
4.2.3 Episodic memory ................................................................. 95
4.2.3.1 Episodic memory and second language acquisition ........ 96
4.2.3.2 Episodic memory and blindness ........................................ 99
4.3 Research questions ............................................................... 99
4.4 Method ................................................................................... 99
4.4.1 Participants ......................................................................... 99
4.4.2 Tests and predictions ......................................................... 99
4.4.2.1 Phonological short-term memory tests ............................ 99
4.4.2.1.1 Digit span ........................................................ 100
4.4.2.1.2 Nonword repetition tests ..................................... 102
4.4.2.2 Recognition memory test Llama D ............................... 106
4.4.2.3 Episodic memory test Alomba ..................................... 109
4.5 Results .................................................................................. 109
4.5.1 Phonological short-term memory tests ............................... 109
4.5.1.1 Digit Span ............................................................ 109
4.5.1.2 CNRep ............................................................... 110
4.5.1.3 Lat A .............................................................. 112
4.5.1.4 Summary of phonological short-term memory test results .............................................................................. 117
4.5.2 Llama D ............................................................................ 119
4.5.3 Alomba ............................................................................. 121
4.6 Discussion ............................................................................. 122
4.6.1 Phonological short-term memory ....................................... 122
4.6.2 Recognition memory .......................................................... 126
4.6.3 Episodic memory ............................................................... 128

5 STUDY II: SPEECH PERCEPTION IN NOISE AND BLINDNESS ........ 129
5.1 Introduction .......................................................................... 129
5.2 Theoretical background ....................................................... 131
5.2.1 Speech perception ........................................................... 131
5.2.2 A model of speech processing .......................................... 133
5.2.3 Speech perception in L2 speakers, with and without noise .. 134
5.2.4 Speech perception in blind L1 speakers, with and without noise ................................................................................. 136
5.2.5 Speech perception in noise in blind L2 speakers .............. 140
5.3 Research question ............................................................... 141
5.4 Method .................................................................................. 141
5.4.1 Participants ......................................................................... 141
5.4.2 Speech perception in noise tests ............................................... 141
   5.4.2.1 Speech material ............................................................... 141
   5.4.2.2 Noise sources ................................................................. 142
   5.4.2.3 Speech perception of words in noise, a test with a phonological distance metric ........................................... 142
   5.4.2.4 Speech perception of sentences in noise, the Helen Task ................................................................................. 143
5.4.3 Predictions ................................................................................ 144
5.5 Results ............................................................................................ 145
   5.5.1 Speech perception of words in white noise ...................... 145
   5.5.2 Speech perception of words in babble noise ..................... 146
   5.5.3 Speech perception of sentences in white noise ................. 147
   5.5.4 Speech perception of sentences in babble noise ............... 148
5.6 Discussion ....................................................................................... 149
6 STUDY III: BLINDNESS AND ACCENTEDNESS IN A SECOND LANGUAGE ............................................................................................ 155
6.1 Introduction .................................................................................... 155
6.2 Theoretical background ................................................................. 157
   6.2.1 Factors affecting L2 pronunciation – findings from SLA .... 157
   6.2.2 Factors affecting L2 pronunciation – findings from psycholinguistics and neurolinguistics ............................... 159
6.2.3 Speech perception and speech production .............................. 162
   6.2.3.1 The development of speech production in the first language and the relationship to early speech perception ............... 162
   6.2.3.2 The relationship between second language speech perception and speech production in adults ...................... 166
   6.2.3.3 The relationship between speech perception and speech production in blind individuals ......................... 169
   6.2.3.4 Second language speech perception and speech production in blind individuals ................................. 170
   6.2.3.5 The relationship between speech perception and speech production and the phonological short-term memory ........................................ 171
6.3 Research question ........................................................................... 172
6.4 Method ............................................................................................ 172
   6.4.1 A Foreign Accent Rating experiment ................................. 172
   6.4.1.1 Speakers .......................................................................... 173
6.4.1.2 Speech material ............................................................... 173
6.4.1.3 Listeners ................................................................. 174
6.4.1.4 Scale ......................................................................... 175
6.4.1.5 Reliability ............................................................... 175
6.4.1.6 Procedure ............................................................... 176
6.4.2 Predictions ................................................................. 177
6.5 Results ........................................................................... 177
6.6 Discussion ..................................................................... 178

7 GENERAL DISCUSSION .......................................................... 181
7.1 Memory, blindness and second language acquisition .......... 181
7.2 Speech perception in noise and blindness ......................... 183
7.3 Blindness and accentedness in a second language .............. 184
7.4 Conclusion ....................................................................... 185
7.5 Theoretical and practical implications of the results .......... 185
7.6 Future research .............................................................. 186

SAMMANFATTNING PÅ SVENSKA ................................................. 189
REFERENCES ........................................................................... 195
APPENDICES ............................................................................ 217
### Tables

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Background data on early blind, late blind and sighted L1 speakers on the variables age, education and occupation</td>
<td>65</td>
</tr>
<tr>
<td>3.2</td>
<td>Background data on early blind, late blind and sighted L2 speakers on the variables age, education and occupation</td>
<td>66</td>
</tr>
<tr>
<td>3.3</td>
<td>Background data on early blind, late blind and sighted L2 speakers on the variables age of onset of L2 acquisition and length of residence</td>
<td>66</td>
</tr>
<tr>
<td>3.4</td>
<td>Background data on L1 and L2 speakers on the variables age, education and occupation</td>
<td>67</td>
</tr>
<tr>
<td>3.5</td>
<td>Background data on early blind and late blind participants on the variable age of onset of blindness</td>
<td>68</td>
</tr>
<tr>
<td>3.6</td>
<td>Background data on early blind and late blind participants on the variable length of blindness</td>
<td>68</td>
</tr>
<tr>
<td>4.1</td>
<td>Mean overall score for early blind, late blind and sighted L1 and L2 speakers on digit span</td>
<td>110</td>
</tr>
<tr>
<td>4.2</td>
<td>Mean overall score for early blind, late blind and sighted L1 and L2 speakers on CNRep test</td>
<td>111</td>
</tr>
<tr>
<td>4.3</td>
<td>Mean overall score for early blind, late blind and sighted L1 and L2 speakers on Lat A, correctly repeated syllables in the correct serial order</td>
<td>113</td>
</tr>
<tr>
<td>4.4</td>
<td>Mean overall score for early blind, late blind and sighted L1 and L2 speakers on Llama D</td>
<td>119</td>
</tr>
<tr>
<td>4.5</td>
<td>Amount of details recalled from the episode of hearing the auditory presentation of the story Alomba for early blind, late blind and sighted L1 and L2 speakers</td>
<td>121</td>
</tr>
<tr>
<td>5.1</td>
<td>Speech perception of words in white noise for early blind, late blind and sighted L1 and L2 speakers</td>
<td>145</td>
</tr>
<tr>
<td>5.2</td>
<td>Speech perception of words in babble noise for early blind, late blind and sighted L1 and L2 speakers</td>
<td>146</td>
</tr>
<tr>
<td>5.3</td>
<td>Speech perception of sentences in white noise for early blind, late blind and sighted L1 and L2 speakers</td>
<td>147</td>
</tr>
</tbody>
</table>
5.4 Speech perception of sentences in babble noise for early blind, late blind and sighted L1 and L2 speakers ................................. 148
6.1 The mean judgment scores for early blind, late blind and sighted L2 speakers on the Foreign Accent Rating experiment ............... 177
Figures

4.1 A schematic model of the Working Memory Model ........................ 78
4.2 Mean score in percent of correctly repeated items on Lat A, on
the collapsed 1–4, 5–8 and 10–13 syllable-levels .......................... 114
5.1 Model of the relationship between signal-dependent and signal-
independent information for speech comprehension ..................... 133
Appendices

| Appendix 1 | Digit span test ................................................. 217 |
| Appendix 2 | CNRep nonword repetition test ................................... 218 |
| Appendix 3 | Lat A nonword repetition test ..................................... 220 |
| Appendix 4 | Episodic memory test Alomba (in Swedish) ......................... 221 |
| Appendix 5 | Speech perception of sentences in noise (in Swedish) .......... 222 |
| Appendix 6 | Grammaticality judgment test (in Swedish) ......................... 224 |
| Appendix 7 | Figures for all test results of the study ........................... 226 |
1.1 Scope of the study

That blind people can compensate for their lack of vision by developing other senses and abilities has been suggested since antiquity. The anecdotes and impressions of this are countless. For instance, the blind have served as living databases in both ancient and recent times, memorizing by heart and passing down the teachings of canonical works such as the Torah and Koran, as they have often been considered to be the most trustworthy and skilled individuals for such assignments (Amedi et al., 2003; personal communication with a participant). Another example is that being a court musician was a traditional profession for blind individuals in ancient China, as they were found to be particularly talented musicians, something that most lay people of today might also agree on. It has also been the impression of language teachers that blind individuals are very talented at learning foreign languages, especially in acquiring the sounds of the language as well as accent-free speech. The general opinion is that the blind are especially attentive with respect to their perceptions of sounds and voices, having developed the necessary auditory abilities for being so because of their great dependency on the auditory modality to compensate for their visual loss. A reasonable question to ask is whether there is a shred of truth to these impressions and beliefs or if they are, in fact, only that – impressions and beliefs?

Since the end of the 19th century, empirical studies investigating the phenomenon of sensory compensation in blind individuals have been conducted, but the results between studies have varied, some affirming the ability of blind individuals to compensate for visual loss, and others not (Miller, 1992). Research investigating first language acquisition in blind children has also produced contradictory results, or, at least the interpretations of them have, even when the results have not differed greatly. Methodological problems, which are characteristic of the earlier research on blind individuals can, to a large extent, explain inconsistencies in the results produced. Selection criteria have, for example, not been sufficiently formulated, leading to participants with differing degrees of blindness and varying ages
Blindness and Second Language Acquisition

of onset in the same groups. Other problems include non-matching control participants or non-identical tasks for blind and sighted individuals, resulting in different prerequisites for blind and sighted participants (Röder, Rösler & Neville, 2001). A general difficulty concerning children and blindness is the problem of classifying degree of blindness, which can lead to non-matching participants. Another difficulty is that the classification system for degree of blindness varies by country. It was not uncommon in earlier research on first language acquisition among blind children that some participants suffered from additional handicaps (Rowland, 1983, 1984) while others did not.

No consistent results or firm conclusions on the matter could thus be drawn from empirical research until neuropsychology turned its interest to blind individuals in the mid 1990s with the aim of obtaining a deeper understanding of neural plasticity and the human organism’s ability to adapt to different sensory interactions with the environment. Within this field of research, there was knowledge of the importance of rigorous sample selection criteria that took degree and age of onset of blindness into account, excluded participants with additional handicaps and disabilities, and focused on congenitally blind individuals in order to minimize influence from any previous visual experience. Clear and consistent results have been generated ever since, which show that blind individuals, mainly congenitally blind but in some cases also individuals who have become blind later in life, can compensate for the loss of vision by developing a large number of skills compared to the sighted; for instance, in relation to language, the blind often develop a superior ability for recognizing words (episodic/recognition memory: Raz et al., 2005; Röder, Rösler & Neville, 2001), for immediately repeating auditory presented lists of words (phonological short-term memory: Röder & Neville, 2003; Rokem & Ahissar, 2009), and for possessing a higher phonological sensitivity to speech sounds (Hugdahl et al., 2004), an ability to process speech at faster speeds (Hugdahl et al., 2004; Röder, Rösler & Neville, 2001; Stevens & Weaver, 2005), and a greater ability for perceiving L1 speech in noise (Rokem & Ahissar, 2009).

These compensatory language and memory advantages are possible because of a different neurological development, in which the visual cortex has become “colonized” by the remaining sensory modalities, for instance, being activated during a variety of language tasks related to the L1 (Amedi et al., 2003; 2004; Raz, Amedi & Zohary, 2005; Büchel et al., 1998; Sadato et al., 1996; 1998; Röder et al., 2002; Hamilton et al., 2000), as well as during foreign language processing (Ofan & Zohary, 2007). Greater efficiency by the auditory cortex has also been found to contribute to a better performance in blind individuals (Hötting & Röder, 2009; Elbert et al., 2002; Stevens & Weaver, 2009). It thus seems clear, based on current findings from neuropsychology, that blind individuals, especially congenitally blind and individuals blind from an early age, benefit from a different neurological
development that gives them advantages with respect to a large variety of auditory perceptual and cognitive functions (Stevens & Weaver, 2005), of which many are important to language acquisition.

The only existing study from the field of neuropsychology that has investigated foreign language speakers (by the authors called second language speakers) is the study by Ofan and Zohary (2007), which investigated brain activity during foreign language use. There are no studies of blind individuals in relation to second language processing and use, according to the definition of a second language learner used in second language acquisition (SLA) research, that is, someone who lives in a second language environment, surrounded by and using the second language (L2) on a daily basis and enjoying the possibility of acquiring the L2 in a naturalistic and implicit fashion. There are a few studies of foreign and second language teaching involving blind individuals (e.g. Snyder & Kesselman, 1972; Aikin Araluce, 2002; Nikolic, 1987; Kashdan, Barnes & Walsh, 2002; Topor & Rosenblum, 2013), all of which investigated the efficiency of different teaching methods, with most being conducted at schools for blind individuals. None of these studies have, however, included sighted individuals, as the interest has not been in comparing blind and sighted individuals with respect to foreign or second language learning. That there exist so few studies of foreign and second language pedagogy in relation to blind individuals has been explained by the fact that it has been taken for granted that blind and sighted individuals process and learn languages in the same way (Aikin Araluce, 2002). But, this is not necessarily the case. In fact, it has been claimed that blind immigrants produce a less accented L2 speech than their sighted peers. This claim was expressed to the author by an experienced teacher of Swedish as a second language, who had worked with blind adult immigrants soon after their arrival in Sweden for her entire career. If this impression is true, it also suggests that it is not only speech production that is enhanced, but also speech perception, which presumably is related to the phenomenon of speech production (Llistterri, 1995). Further support for this claim are the findings of auditory perceptual, cognitive and language advantages in congenitally and early blind individuals from the field of neuroscience (e.g. Raz et al., 2005; Röder, Rösler & Neville, 2001; Hugdahl et al., 2004; Stevens & Weaver, 2005; Rokem & Ahissar, 2009).

To investigate this claim further, Smeds (as Kjellberg, 2003, 2004; both reported in Kjellberg Smeds, 2008) performed the only existing studies comparing blind with sighted second language learners. The two small-scale studies investigated both speech perception in noise and second language speech production (degree of accentedness). The results suggested that blind individuals have greater difficulties hearing words being presented in babble noise, but not greater difficulties hearing sentences presented in white noise. There were no group differences on the speech production task (that is, in
Blindness and Second Language Acquisition

degree of accentedness), but some of the blind participants were judged as producing non-accented speech, which none of the sighted participants were, and it was still an open question whether non-significant group differences could be attributed to the very limited size of the study. Another fact, which also remained unanswered, was the significance of the L2 factor, and whether this factor could be associated with advantages or not (Kjellberg, 2004). These studies are presented in greater detail later in this dissertation.

Based on these findings, the current research project was developed as an attempt to answer the questions that still persisted, and also to initiate and encourage research in a new research field – second language acquisition in blind individuals.

1.2 Aims of the study

The general aim of this study is to investigate blind individuals’ prerequisites for second language acquisition compared to those of sighted individuals, and the general hypothesis, based on the findings from neuroscience, is that, especially individuals that have become blind at an early age, will have better prerequisites because of advantages related to auditory perceptual and cognitive functions. The specific aim is to investigate whether these advantages can be found in relation to three aspects of cognition, which are of great importance to second language acquisition: memory functions, speech perception and speech production. These cognitive aspects or domains will be presented in three different substudies: study I – Memory, blindness and second language acquisition; study II – Speech perception in noise and blindness; and study III – Blindness and accentedness in a second language. The specific research questions related to each cognitive domain are presented in the substudies.

1.3 Structure of the thesis

The thesis consists of seven chapters. Chapter 1 presents a general introduction, including the scope of the study, the aims of the study and an outline of the structure of the thesis. The purpose of chapter 2 is to provide a theoretical framing to the study and to present the general theoretical background; it contains the following sections: First language acquisition in blind children, Second language acquisition in blind individuals and Neuropsychological aspects of blindness. In chapter 3, the general methodology of the study is presented. The three substudies are presented in chapters 4, 5 and 6: chapter 4 comprises “Study I – Memory, blindness and second language acquisition”; chapter 5 “Study II – Speech perception in noise and blindness” and chapter 6 “Study III – Blindness and accentedness in a second language.” Each of the substudies contains the theoretical background, re-
search question/s, methodology, results and discussion relevant for that specific area of investigation. Chapter 7 is a general discussion of the findings from all three substudies. Chapter 7 is followed by a Swedish summary of the study, references and appendices.
Chapter Two

General Theoretical Background

This section will present previous research from three different areas in order to provide the reader with a general theoretical framing of the dissertation as well as insights into the prerequisites of blind individuals, both in general (related to a unique neurological development) and in relation to language (both first and second language acquisition), before the specific topics of the three substudies are presented. The first section describes first language development in blind children and how this development looks the same or differs from the development of sighted children. The second section presents the meager amount of existing research on second and foreign language acquisition in blind individuals, which has had a pedagogical focus trying to evaluate different methods for teaching languages to blind individuals. The last section presents the effect of blindness on neurological development, also explaining how blind individuals can compensate for lack of vision by developing a variety of auditory perceptual and cognitive functions to a greater degree than sighted individuals.

2.1 First language acquisition in blind children

This section starts with the theoretical and methodological issues that have characterized this area of research, before moving on to linguistic development per se, in the following areas: preverbal communication, acquisition of phonology, lexical and semantic development, and morphological and syntactic development. This is followed by a discussion on a very characteristic feature of blind children’s first language acquisition, namely the use of imitations, repetitions and routines. After this, compensatory mechanisms are discussed, first as a new frame of reference used in research on L1 development in blind children, and secondly, from a neurological perspective. The section ends with a discussion on the subject’s relevance to second language acquisition by blind adults.
2.1.1 Theoretical and methodological issues

Research on blind children’s language acquisition has been conducted within a variety of different frameworks. Mulford (1988) concluded that although the descriptive findings by different researchers have been similar, their conclusions might vary because of these differing frameworks and perspectives. Earlier studies, mainly clinical case studies, used a psychoanalytic framework (e.g. Burlingham 1961, 1965; Wills 1979; Nagera & Colonna, 1965). These studies cannot be classified as empirical research. From the mid 1970s the first empirical studies were made within the same framework, for example, by Fraiberg (1977).

The majority of previous studies, however, have taken a cognitive view of language acquisition (e.g., Andersen, Dunlea & Kekelis 1984, 1993; Dunlea, 1989), in which there is a close link between specific areas of cognition and areas of linguistic development. This view is based on Piaget’s stages of cognitive development (Smith, 1993). The first stage, which is the essential one for this discussion, the sensorimotor stage, spans from birth until the age of two years. During this time, at about 18 months of age the child has learned object permanence, which means that the child now has a mental image or a word to represent the existence of an object when it is not in sight. This is obviously more difficult for a blind child, since it cannot experience an object with the visual sense. Piaget’s theory of cognitive development is based on studies of children with normal vision, and it also gives vision a primary role. It might, therefore, not be a suitable model for interpreting blind children’s cognitive and linguistic development (Urwin, 1983), as delays in linguistic development would be predicted by it, since blind children do not follow the same route of development due to their lack of vision (for example, in relation to object permanence).

A few researchers have developed new frameworks for interpretation of data, frameworks that do not deny the link between cognition and language but, on the other hand, do not directly connect a specific cognitive achievement to a specific achievement or level in language acquisition. Peters (1994), for example, stresses the interdependence of social, cognitive and linguistic factors in the development of blind children. Development in one of the areas fosters the development in the other two, that is, they “cross-catalyze” each other. Pérez-Pereira and Castro (1997) adopt a compensatory view that does not consider blind children’s language development delayed or aberrant, but rather, that it follows a different route and exploits different resources to a greater extent than that of sighted children. Landau and Gleitman (1985) employed an intralinguistic perspective on language development in which the meaning of a word is conveyed not only through extralinguistic information, that is, from the conversational setting, but also
from the position it holds in the linguistic context. This theory is known as the syntactic bootstrapping theory of word meaning (Gleitman, 1990).

In research comparing the language development of sighted and blind infants, there are some major methodological problems. One is that there are many degrees of visual handicap: ‘no light perception,’ ‘light perception,’ ‘perception of contours,’ and so on, and it might be difficult to determine the degree of blindness in an infant. Another problem is the difficulty in diagnosing the cause of blindness among infants. Age at onset of blindness might also vary, making comparisons between children with different onsets difficult or even impossible. Another very common problem is the occurrence of additional handicaps. According to some researchers, 50 to 90 percent of the blind children in North America are multihandicapped (Mulford, 1988). Another is that there are differences in how different countries define ‘blind.’ In order to determine the role of vision, ideally subjects should be congenitally blind, with minimal or no light perception, and have no other handicaps.

The methodological inconsistencies described above, which characterize the field of first language acquisition in blind children, is something that science to a great degree has come to terms with, as there is currently a greater awareness of the importance in carefully selecting suitable participants, tasks, etc., for instance, within the field of neuropsychology. These studies are presented in the following section.

2.1.2 Preverbal communication

From the moment an infant is born it communicates. It produces signals that can be perceived and responded to by parents and others. Before the onset of the spoken language, communication between the sighted infant and the parents usually takes place, for example, through eye contact, smiling, body posture, manual signs and prelinguistic vocalizations. In order for these signals to be effective, they have to be perceived and responded to by the caregiver. The obvious purpose of these behaviors is to establish a communicative link between the infant and the caregiver.

The preverbal communication of blind infants is different from that of sighted infants. Eye contact, for instance, which is an important event in early bonding between sighted infants and their parents, cannot be established by blind infants. This is sometimes a difficult challenge for sighted parents (Warren, 1994; Fraiberg, 1977), as it means that they cannot rely on shared gaze when interpreting the communicative intention of the child, nor can they rely on the direction of gaze as indicating focus of attention (Mills, 1988, 1993a). Facial movements in blind infants and older children are generally described as muted (Mills, 1987). Another challenge for the parents is that important gestures like reaching and pointing, which are visually direc-
Blindness and Second Language Acquisition

ted, are missing in blind infants. In fact, referential gestures do not appear in blind children at all, and only if especially trained are they used by older blind people (Mulford, 1988). Instead the child might indicate direction of attention by the position of the hand, or expressing communicative intent by stilling or fussing (Mills, 1988, 1993a). Fraiberg (1977) found that blind children used their hands as part of a tactile language to express emotion, recognition, preference, to establish and maintain contact and to affirm the presence of the mother, which could not be expressed through facial signs or shared gaze.

The hands, not engaged, seek and find the mother’s hand or her body, the hands linger, lightly finger or grasp, withdraw, return. Sometimes we catch on film a kind of ballet in which the baby’s hands seek and find the mother’s hand, and the mother’s hand sustains or responds to the signal. (Fraiberg, 1977: 107)

Only two out of ten mothers in the study managed to respond to the very subtle non-visual sign language, the hand language, of their children without the help of experienced researchers and clinicians, who acted as translators between them and their babies. The babies started to use hand language from the age of two months, and it became increasingly differentiated in the ensuing months. According to Fraiberg (1977), linguistic development is highly dependent on the interacting adults’ sensitivity to these subtle signals. This is especially important for the blind child in establishing a vocal communicative pattern (Mills, 1993a; Rogers & Puchalski, 1984), a facet that is highly governed by the vision and visual cues of those involved in communication. It is not surprising that this presents a challenge for the blind child, since it might be harder to learn how to take turns when “speaking” without being able to visually perceive the interlocutor or knowing how to send those signals the way sighted do. Rowland (1984) found a lack of infants’ vocalizations in response to the mothers’ communicative signals but also found that the mothers’ vocal responses to the infants were weak (also found by Rogers & Puchalski, 1984) and inconsistent and that they instead tended to respond by touch or nonvocal sound. There are, however, reports of successful establishment of communicative patterns between blind children and caregivers, as well as maternal conversational responsiveness (for example Als, Tronick & Brazelton, 1980; Conti-Ramsden & Pérez-Pereira, 1999; Pérez-Pereira & Conti-Ramsden, 2001; Dote-Kwan, 1995; Peters, 1994; Urwin, 1978, 1983). Pérez-Pereira and Conti-Ramsden (1999) insist that it is too simplistic and misleading to characterize mothers of blind infants as a homogenous “non-responsive” group, since they have found a wide range of individual differences among the subjects of their studies. They also question the reliability of Rowland’s studies (1983, 1984) since the blind infants had
additional handicaps (also a problem of other studies, e.g. Rogers & Puchalski, 1984) that might have led to unresponsiveness in the child-parent dyads.

Like sighted babies, blind babies start to babble during their first year. Babbling is a stimulus for parental response, as well as the response by the baby to parental stimulation. The purpose of prelinguistic vocalization is to establish a communicative link with other people, as well as to prepare for future language production. Initially these sounds are not restricted to the sounds of the surrounding language, it is language-general, but due to maturation of, for example, the vocal apparatus and to the exposure of the native language, the sounds become language-specific (Warren, 1994; Walley, 2005; this is discussed further in study III). There seem to be no notable differences between sighted and blind babies concerning the onset of babbling (Mills, 1993b, Warren, 1984, 1994) nor its development (Fraiberg, 1977; Warren, 1994; Mills, 1993b). This might lend support to the Chomskyan nativist approach that states that there are only indirect links between language acquisition and cognitive development, and that language development is instead governed by innate biological processes. Fraiberg (1977), on the other hand, concludes that in cases of delay in language acquisition in blind babies, this is caused by experiential poverty, that is, by poor linguistic input. It seems that the language of blind infants primarily has an interactive and social, rather than referential, function. They do, however, add new communicative functions to their repertoire quite early, especially if the parents actively encourage their use, according to Urwin (referred to in Mulford, 1988).

2.1.3 Acquisition of phonology

2.1.3.1 Speech perception

Language experience is generally viewed as especially important to blind children since they are deprived of visual input and use language as an important means to obtain knowledge about the external reality that surrounds them, and to establish social contacts. It has therefore been suggested that blind children, as a consequence of this, pay special attention to language (Pérez-Pereira, 1994; Pérez-Pereira & Castro, 1997; Peters, 1987; 1994).

For sighted children lip-read information provides cues to the articulation of the sounds of the target language. During the preverbal period, children watch the mouth movements of adults and try to imitate them silently by moving their own lips (Pérez-Pereira & Conti-Ramsden, 1999). Eventually they start to associate the visual stimulus with their own production. This behavior has, however, not been observed in blind children, which is not surprising since they cannot perceive the face of their interlocutors. Mills (1987) found it probable that this lack of early visual perception and articulatory practice might lead to later differences in acquisition. It does not,
however, affect the time of onset of babbling (between six and seven months in all children: sighted, blind or deaf), which, according to Mills (1987) and Fraiberg (1977), points to the fact that this early perception and production is governed by biological maturation, as mentioned above. Mills (1987) thus concluded that lip-read information plays a small role in early acquisition. This is in line with research devoted to biological/maturational constraints on language acquisition. According to Ruben (1997), for instance, there is a critical period for phoneme discrimination until the end of the first year, when the time span of heightened phonetic sensitivity comes to an end. This is discussed further in study III.

No research has been devoted to phonological acquisition in blind children, despite that it could tell us something about how blind children, as well as perhaps blind adult L2 learners, process language. Blind children pay extra attention to purely auditory signals when listening to speech, since they cannot see gestures and mouth movements. It is therefore likely that the ability of blind children to perceive speech is more refined than it is for sighted children (since this is found in congenitally blind adults, e.g. by Hugdahl et al., 2004), although perceiving and producing sounds with visible articulation (e.g. labials) may present an extra challenge for them (Pérez-Pereira & Conti-Ramsden, 1999; Mills, 1993a). The only study devoted to speech perception in young blind children (between five and seven years, without additional handicaps) was conducted by Lucas (1984), who found that they were significantly better at identifying mispronounced words in a story context. Unfortunately, no detailed phonological analysis was performed in this study. We can only assume that blind infants discriminate phonemes as sighted infants do, since their sound discrimination in general seem to be no different from sighted children (Pérez-Pereira & Conti-Ramsden, 1999; Warren, 1994; Mills, 1993a). There is, however, a need for further research on this matter, since the production of speech sounds, which is related to auditory discrimination, develops differently in blind children (Mills, 1993a).

2.1.3.2 Speech production

A few studies have been devoted to sound production in blind children. Mills (e.g. 1983, 1987) studied the effect of visual information in acquisition of speech sounds in three blind infants learning German (age range 1:0–2:1). An analysis was performed on the word-initial consonants produced by them and three comparable sighted children in spontaneous production. The German consonant inventory was divided into two groups: those with clearly visible articulatory movements (labials and labiodentals; /b/, /m/, /f/), and those with minimally visible articulatory movements (alveolars, palatals, velars and glottals; /t/, /j/, /k/, /x/, /h/). She found that the blind children made a higher percentage of substitution errors in that they replaced con-
sonants with consonants with a perceptually different place of articulation, that is, belonging to another category of sounds. This meant, for instance, that these children replaced /m/ (labial) with /n/ (in German with alveolar place of articulation), which sounds similar but, as mentioned above, has a visually different articulation. The sighted children, on the other hand, rarely made substitutions across visual categories, but rather substituted a labial with another labial. The blind children’s production of consonants that do not have clearly visible articulation was, however, on the same level as the sighted children, and their overall phonetic development was normal. It seems that vision gives sighted children an advantage in producing sounds with visible articulation compared to other sounds, since they are significantly better at producing these than sounds with non-visible articulation (79% correct compared to 49%, according to Mills, 1988). For blind children, there is no significant difference in the production of sounds from different categories. This shows that blind children do not have a general delay in sound acquisition and production, but only a delay with sounds with visible articulation. It was also found that blind children used fewer words with visible articulation than the sighted children did. The reason for this is not quite clear. Mills’ results are supported by Dodd (1983), who found similar results investigating a blind child.

Lucas (1984), who compared speech imitation in blind and sighted children between five and seven years, found no significant differences between the two groups. In a study by Wakefield, Homewood and Taylor (2006), in which verbal fluency in 16 children between 11 and 18 years of age was tested, it was found, for instance, that blind children were better at producing lists of words starting with the same phonemic sound, for example, beginning with /t/. It was also found that these children made more switches between different phonemic clusters. The researchers concluded that the blind process language, and more specifically the initial phoneme, faster than sighted speakers and are therefore able to produce more phonemically related words.

It was mentioned above that facial movements in blind children have been described as muted (Mills, 1987), that is, that they use less lip movement in articulation. In a study by Brieland (1950) on 84 congenitally blind children between 12 and 18 years, it was found that this, however, resulted in minimal deviations in acoustic properties (also found by Göllecz, 1972). Pérez-Pereira and Conti-Ramsden (1999) concluded that neither pattern nor rate of development differ greatly between sighted and blind children/infants, but since blind children cannot lip-read, they might show higher incidences of delays in learning phonological sounds with visible articulation. This is, however, not a lasting phenomenon, since they learn to make use of the acoustic information and eventually reach standard adult pronunciation.
2.1.4 Lexical and semantic development

2.1.4.1 The first words of blind children

Some studies of blind children’s first words (individual cases rather than group data) report that their acquisition is like that of the sighted population (Andersen, Dunlea & Kekelis, 1984; Mills, 1983; Bigelow, 1987), while others have found evidence of a lag, although usually within the normal range (Fraiberg, 1977; Landau, 1983; Landau & Gleitman, 1985). Landau and Gleitman (1985) concluded that “an initial delay for blind children is predicted by this biologically imposed constraint on the opportunity to experience the world of objects and events” (p. 27). They attributed this delay to the lack of worldly experience among these children, since they cannot see or, initially, even reach out and touch satisfactorily. They also suspected that there might be another factor influencing the delay found in the two blind children in their sample (Kelli and Carlo), which is prematurity. Warren (1994) found that other researchers attribute this delay of first-word onset to factors like an inappropriate or different linguistic context provided by the parents or to other circumstances in the child’s situation, that is, not to lack of vision itself. Bigelow (1987) and Mills (1993b) suspected that the reported lag might have been caused by additional handicaps, a problem for which more recent studies have provided better screening. Mulford (1988) ascribed the lag found in earlier studies to two different factors. One is a shift in causes of blindness. A common cause of blindness at one time was retrolental fibroplasia (RLF), which was the result of too much oxygen being administered to premature babies, something that also has been shown to cause Minimal Brain Damage (MBD) (Mills, 1993b). Mulford (1988) therefore suspected that earlier studies may well have included participants with MBD, since this is usually not discovered until later in the child’s development. For instance, 71% of the 295 participants in Norris et al. (1957) and the subjects Kelli and Carlo studied by Landau (1983) and Landau and Gleitman (1985) were victims of RLF. The other factor is differences in data collection methods. Mulford (1988) concluded, after summarizing the results from 14 more recent studies, that blind infants do not differ from sighted infants in rate of linguistic development. Their ages of acquisition of particular quantitative milestones – the age of first word, as well as the first 10, 50 and 100 words attained – do not differ, but in a qualitative sense, however, there are some differences that will be discussed below.
2.1.4.2 Early lexicon

Several investigators of blind children’s early words have used Nelson’s (1973) framework for analyzing the 50-word vocabulary of sighted children (e.g. Andersen, Dunlea & Kekelis, 1984; Bigelow, 1987; Landau, 1983). The words are classified as belonging to specific nominals (names of people, toys or pets), general nominals (refers to all members of a class, e.g. “cat”), action words (showing a manner of direction of action, e.g. “up” and “go”), modifiers (qualities of objects, e.g. “big”), personal-social words (used in social interaction, e.g. “thank you”) and function words (which fulfill a solely grammatical function, e.g. “what” and “is”) (Warren, 1994). Mulford (1988) presented an integration of the data found in the 14 studies on blind children and made a comparison with those of Nelson. She found differences between the two groups for three types of words: specific nominals, general nominals and action words. Both groups used approximately the same overall amount of nominals, but blind children produced more specific nominals and fewer general nominals than sighted (for a further discussion on this topic see the following section on concept formation). According to Nelson (1973), individual children may be characterized as having a more or less referential or expressive language style. The referential style is characterized by a high proportion of general nominals that have a cognitive rather than a social-interactive function. The expressive style is characterized by fewer general nominals and more specific ones that have a more social-interactive function.

Mulford (1988), Andersen, Dunlea and Kekelis (1984), Bigelow (1987), and Landau (1983) all found that blind children have a greater tendency to use the expressive style, and Bigelow (1987) suggested that this might be the result of the limited experience blind children have with external reality. This makes them less generalized in their word usage, and the usage remains more tied to the original referent of the word. For example, Bigelow reported that one of her subjects related the word “bunny” only to one specific toy rabbit (Mulford, 1988). Andersen, Dunlea and Kekelis (1984), on the other hand, did not attribute the infrequency of general nominals to limited experience, but to limited ability for forming general concepts, that is, they considered it a cognitive inability. They argued that this suggests that they do not generalize and construct hypotheses about the nature and meaning of words (meaning of words is discussed below) to the same degree as sighted children (Andersen, Dunlea & Kekelis, 1984, 1993). Warren (1994) drew the conclusion that either way, the ultimate cause must lie in the restriction of experience: “The phenomenon has nothing necessarily to do with visual impairment, except that visual impairment tends to restrict experience in such a way that terms classified as specific nominals often occur in the child’s 50-word vocabulary” (Warren, 1994:138–139).
Another difference found by Mulford (1988) in her integration of studies was that blind children also produced more action words. These words were used in fairly limited contexts, primarily as comments on their own actions (e.g. in Andersen, Dunlea & Kekelis, 1984; Dunlea & Andersen, 1992), or to demand or request. Sighted children primarily use action words to comment on their own actions, too, but soon go on to comment on the actions of other people. These comments are usually prompted by actually seeing the actions of others, something that is not possible for blind children. Mulford (1988) suggested that blind children might need more time to understand external agency, that is, the actions of others, and to relate that to what is happening around them. Both action and object words tend to be used non-referentially in tightly constrained contexts, often as part of a routine or relating to the child’s own actions. Less contextually bound ways of using words (e.g. to remember actions, to label new persons or objects) appear rather late. The blind use more words associated with parent-child routines and with sounds. Bigelow (1987) found that words for outdoor objects, for example, “moon” and “flag,” were lacking in the blind children’s vocabulary, as opposed to household items, for which they had more terms (and plenty of experience). They use fewer terms for animals and fewer deictic terms (e.g. “this,” “here”). Although the spread of words belonging to different semantic categories are comparable with sighted children, it is obvious that there are differences caused by their differing experience.

Dunlea (1989) and Landau and Gleitman (1985) found that blind and sighted children start to combine two and three words at about the same time. Andersen, Dunlea and Kekelis (1993) found that blind children’s complex constructions more often refer to past events, while sighted children’s constructions typically describe current events. The focus on past events helps to establish a shared knowledge with the caregiver, and this is done in order to promote and strengthen social contact (Perez-Pereira & Conti-Ramsden, 1999; Peters, 1987), which is the same goal as sighted children have talking about “here and now.”

2.1.4.3 Word meaning and concept formation

One issue on which researchers disagree concerns the occurrence and significance of the inability or difficulty in forming general concepts, that is, in the ability to extend the domain and application of a word to new and different referents that share criterial features. This is a process of extension and it might result in salient overextensions in blind children, for example, when *doggie* might be extended to all four-legged creatures, or in underextensions, for instance when the word *cat* is used for the one cat that they know, and not for other cats. This problem of extension in blind children has thus been interpreted as evidence of a delay in the ability to sort and categorize, and to form general concepts. Many researchers have found evidence of this in
blind children (Andersen, Dunlea & Kekelis, 1984; Bigelow, 1987; Landau & Gleitman, 1985), although other researchers question this (Pérez-Pereira & Castro, 1997). Andersen, Dunlea and Kekelis (1984) found that their blind subjects rarely overextended their first words (8–13% of early words compared to 41% in the sighted children), suggesting difficulties in forming general concepts. Perez-Pereira and Castro (1997), on the other hand, found that their blind subject produced approximately the same amount of overextensions as their sighted subject.

Although some researchers question the interpretation that blind children have difficulties in forming concepts, there is a general agreement that there are differences between sighted and blind children in this respect. The disagreement is instead related to the significance of these differences to language acquisition. Andersen, Dunlea and Kekelis (1984), for instance, found that problems of extension reflect a cognitive inability to form concepts and categorization schemata, which are thought to underlie lexical extension. This can have a “detrimental effect” on language acquisition, caused by lack of vision. Landau and Gleitman (1985), on the other hand, did not make such a close link between cognition and language, but rather found these extensions unimportant for the purposes of language acquisition. Instead, they claimed that a relevant component of the meaning of a word comes from the position it occupies in the sentence and from the other words that accompany it (intralinguistic). According to this view of language development, blind and sighted children have more or less the same prerequisites when learning a language. They also think overgeneralizations of word meaning, as in the example *doggie* above, is a much rarer phenomenon than many have thought and that they are restricted to the first 75 words acquired. Pérez-Pereira and Conti-Ramsden (1999) also opposed the view that lack of vision leads to a cognitive inability, and they find it reasonable to suppose that the lack of vision in blind children limits their opportunity to generalize, but that this in no way means that they are less capable of decontextualizing words.

Warren (1994) summarized the existing research on word meaning and concluded that the issue is complex and requires further study. The word meanings of blind children seem to be very similar to those of sighted children. The differences found seem linked to the lack of visual experience, but there is little evidence from these studies that the underlying concepts that the words represent are impaired. However, too few (individual) cases have been studied so far for any general conclusions to be made.

2.1.4.4 The verbalism issue and the use of sighted terms

An early controversy that arose in the field of blind children’s language acquisition concerned the use of words by blind children for concepts that they could not have had first-hand sensory experience of, for example, “look” and “see.” Cutsforth (1932) called this phenomenon “verbalism” and
concluded that the visual terms used by blind children must be meaningless and empty to them and that continued use must lead to “incoherent and loose thinking” (Warren, 1994; Pérez-Pereira & Conti-Ramsden, 1999; Landau, 1983; Landau & Gleitman, 1985). In the psychoanalytic literature Burlingham (1965) wrote about a similar phenomenon that she called “parroting,” that is, speaking/repeating without understanding, which essentially mean that blind people use words that are meaningless to them because of missing external experience. Landau (1983) concluded that the evidence presented for these claims has been limited because of flaws in methodology and lack of theoretical articulation. Nor has there been a serious discussion about what it is exactly that these children are lacking in their experience and how this lack affects the learning process. The expression “I see,” for instance, often has the meaning “I understand/OK,” which has nothing to do with the sensory perception of seeing.

Landau and Gleitman (1985) conducted a study with a girl called Kelli when she was between 33 and 42 months of age and found that she used the word “look” in relation to haptic exploration, and they draw the conclusion that “look” means to “explore with the dominant modality used for apprehending an object” (p. 69); that is vision for sighted children and tactility for blind children. It is obvious from the examples presented by the researchers of Kelli’s production of “look” and “see,” that she was able to learn the right meaning of the words without direct visual experience. From the results, the researchers concluded that “a congenitally blind child can acquire considerable sophistication with the sighted vocabulary” (Landau & Gleitman 1985: 3). McGinnis (1981) also found that blind children use “see” verbs correctly.

2.1.4.5 Referential language and the concept of space

There are two types of referential or deictic language that seem to present a difficulty for blind children, and they are both connected to understanding contextual information, that is, the concept of space. Their meaning constantly changes depending on place (and not on time, in this case). One area is the use of pronouns. To be able to understand and use personal pronouns correctly, the blind child has to understand the change of perspective between the people involved in conversation. For example: When the parent says “you,” the child is being referred to, and when the child says “you,” the parent is being referred to. “I” or “she” may be applied to different people depending on who the speaker is, and it takes a certain degree of “cognitive relativity” to resolve this (Fraiberg & Adelson, 1976). In resolving this cognitive relativity in referential language, the vision provides the sighted child with an extralinguistic source of referential information that is not available to the blind child. Researchers have found that it is very common for blind children to refer to themselves in third person, as “he” or “she” (McGuire &
Meyers, 1971) rather than “I.” It has also been found that blind children are delayed in their use of first person pronouns, and Mulford suggests that the reason for this also lies in the problem of determining shifting roles, which is related to the concept of space (Mills, 1993a). Pérez-Pereira (1999), on the other hand, found that the problem with pronouns is not a general problem in blind children, although some blind children have difficulties with them.

Another form of referential vocabulary is spatial terms like “this,” “that,” “here” and “there.” Mulford found that blind children are delayed in acquiring these compared to sighted children and that they were still making errors at six years of age. They also used these terms more seldom and without clarifying gestures (Mills, 1993b). They learned the proximal terms (“this,” “here”) before the distal ones (“that,” “there”), which the sighted children did simultaneously. Mulford thinks that this also is related to a delay in acquiring the concept of space. This means that blind children acquire a concept of space that is primarily centered around them and that literally expands and widens as they incorporate new experiences of it.

2.1.5 Morphology and syntax

There seem to be no major differences between blind and sighted children (with no additional handicaps) in morphological and syntactic development regardless of age.

2.1.5.1 Morphological development

Few studies of the morphological development in blind children have been conducted. Dunlea and Andersen (1992) compared the morphological development in a blind boy, a partially sighted girl and a sighted boy. They found that the sighted child used the plural morphemes, the locative prepositions “on” and “in” and the third person present indicative before the blind child. The blind child used these forms early in formulaic speech and imitations, that is, in “non-productive” unanalyzed speech (Pérez-Pereira & Castro, 1999). The blind child first used “on” as a verb particle (“put on,” “get on”) and started to use it as a locative preposition later. The sighted child, on the other hand, did it in the reverse order by using them first as locative prepositions and later as verb particles. The blind child also started to use possessive pronouns later without introducing the deictic shift.

On the other hand, the blind child used regular past, present progressive and contractible auxiliary “be” earlier than the sighted child. The blind child also over-extended the regular past tense, using forms like “goed” and “thowed” between the ages of 1:11 and 3:0. Present progressive and contractible auxiliary “be” were used when the child spoke of his ongoing or intended actions, when expressing wishes or in unanalyzed forms. Another difference in relation to morpheme development is that blind children deal
with concepts of time before space rather than space before time, which is the reverse of the more usual development among sighted children (Andersen, Dunlea & Kekelis, 1993). The first morphemes to emerge were regular past tense markers. Andersen, Dunlea and Kekelis (1993) think that making the past topic of conversation may represent an adaptive strategy of the blind in order to avoid misunderstanding of the present context. Besides these differences between the blind and sighted child, other morphemes emerged at about the same time in the two. The researchers concluded that morphological development in visually impaired children is neither delayed nor impaired in comparison to sighted children, but that it is different (Dunlea & Andersen, 1992).

2.1.5.2 Syntactic development

Landau and Gleitman (1985) compared the internal complexity of two blind children’s sentence surface structure, analyzing the number and complexity of noun phrases and verb phrases. They used the coding categories developed by Newport (1977) and compared the results from Newport’s sighted subjects with that of blind children at the same MLU levels. At comparable linguistic levels, the blind children produced an internal syntactic structure equal to sighted children. There was, however, one exception: they were both delayed in the development of verb-auxiliary structure. Landau and Gleitman (1985) concluded that this delay is caused by the linguistic environment offered to blind children, since their primary caregivers ask few questions and give many commands. Mills (1993b) found that there is a clear causal relation between this syntactic delay and a lower frequency of verbal auxiliary in English maternal input. Pérez-Pereria and Conti-Ramsden (1999) also pointed out that this delay is specific to blind children learning English and that it is not the same case for blind children learning other languages. Furthermore, Landau and Gleitman (1985) found that at the age of three the sighted and the visually impaired population are linguistically indistinguishable from each other (including internal organization of syntax, but also thematic relations and vocabulary). The emergence and percentage of use of coordinate and subordinate clauses follow a normal pattern of development in blind children (Pérez-Pereira & Conti-Ramsden, 1999).

\[1\] Mean Length of Utterance (MLU) is a measure of linguistic productivity in children. It is traditionally calculated by collecting 100 utterances spoken by a child and dividing the number of morphemes by the number of utterances. A higher MLU is taken to indicate a higher level of language proficiency (Ellis, 1985).
2.1.6 Imitations, repetitions and routines

It has been widely reported that blind children use imitative speech, verbal routines and formulaic speech to a larger extent than sighted children (e.g. Pérez-Pereira, 1994; Pérez-Pereira & Castro, 1992, 1997; Peters, 1994). Studies of sighted children have shown that some children do not imitate verbal models at all, while others imitate up to 25% of the time (Peters, 1987). Stereotypic speech is defined as chunks of maternal/paternal speech that are reproduced by children. These chunks are initially unanalyzed units of language, used in a specific context to which the meaning is tied (Pérez-Pereira & Conti-Ramsden, 1999). Gradually the units are analyzed, broken into their constituents and the meaning extended to new situations (Dunlea, 1989).

Some researchers have found the use of formulaic speech to be a non-productive strategy that does not lead to language development (e.g. Burlingham, 1961; 1965; Wills, 1979; Andersen, Dunlea & Kekelis, 1984), while others have considered formulaic speech to be an important tool in promoting linguistic, cognitive and social development (e.g. Pérez-Pereira, 1994; Pérez-Pereira & Castro, 1997; Peters, 1987; 1994). Andersen, Dunlea and Kekelis (1984) held the opinion that blind children are very good at producing chunks, but consider them to be:

[...] no more than delayed imitation, without any fine level of analysis. The difference we have noted between blind and sighted children certainly are not totally qualitative: all children probably use some unanalyzed 'chunks' (delayed imitation?) in constructing language [...]. The absence of visual input, however, appears not only to lead blind children to rely particularly heavily on this strategy in acquiring language but also to delay the analysis of meaning necessary for the extension of early words. (p. 661)

Peters (1987), on the other hand, found the use of formulaic speech and chunks to be highly productive. She studied the role of imitation in a blind child called Seth when he was between the ages of 19 and 40 months. According to the researcher, the lack of visually oriented means of communication (eye contact and shared gaze) makes blind children more dependent on the vocal channel in social interaction, and they rely heavily on partially analyzed and imitated segments of speech. Seth’s ability to imitate can be traced back to a time before he was able to use proper words. His memory for speech sounds developed well and early, and his sensitivity for intonation made him a proficient turn-taker in conversation long before he could produce more than coos and squeals. As he grew older, he started to imitate sentences from his father’s speech that included, for instance, interactive questions.
Seth’s blindness seems to have affected his father’s use of interactional strategies. He used a high rate of questions (which is different from many other caregivers of blind children, according to Landau & Gleitman, 1985) and placed an emphasis on rehearsal of already shared experiences instead of focusing on objects or shared experiences “here and now.” These strategies encouraged Seth to use different kinds of imitations (for example, spontaneous, requested, literal or expanded) in order to memorize newly learnt language. He then used these imitated chunks of his father’s speech in conversation. Seth’s strategy was to “use first and analyze later.” This, in turn, affected the way he acquired the syntactic system.

In another study of Seth (between 20 and 30 months), Peters (1994) found that Seth’s father’s highly contextualized speech also contributed to Seth’s initially high use of formulaic phrases. In this study, Peters (1994) focused on the interdependence of social, cognitive and linguistic development, and found three elements of Seth’s language use to be relevant in relation to these aspects. The first was Seth’s reliance on routines to enhance social contact, to comprehend linguistic input and to acquire information about the world and how it works. The second was his heavy use of imitation as a strategy to promote social interaction and language use. The third was his transformation of language used in routine situations into private speech that then guided his own thinking and activities. Unlike those researchers who dissociate language and cognition, Peters (1994) found that development in one area, that is the social, cognitive or biological area, fosters the development of the other two areas (“cross-catalyzing”), which in turn affects the growth of language. Moreover, language itself turns back to affect those areas by building neural pathways, strengthening social bonds and enabling the complexification of cognitive organization.

Pérez-Pereira (1994) studied imitations, repetitions and routines used by a blind girl and her sighted twin sister from 2,5 to 3,5 years of age. He found that both children used imitations and (self-)repetitions to keep a conversation going and to perform speech acts. They fulfilled different pragmatic and conversational functions, as in, for instance, making requests, repeating offerings, attracting the attention of a listener and agreeing with what had been said. The researcher also found that, like Peters (1994), verbal routines were used to promote social interaction, which included, among other things, the initiation of shared activity or social play. The blind child used a significantly greater percentage of routines than her sighted sister (the blind child used routines 7.91% of the time and the sighted child 1.86%), and Pérez-Pereira (1994) considered this to be an adaptive strategy that blind children use to avoid social isolation. Furthermore, he found that routines play an important role in language analysis. Both children imitated routines that they later analyzed, modified and expanded. The blind child, however, used a significantly higher proportion of modified imitations and repetitions than
the sighted child (22.42% vs. 12.16%), which again indicates that modeled speech is part of a language inventory more prominent in blind children. Pérez-Pereira (1994) also analyzed whether utterances containing imitations, repetitions and routines had a higher MLU than so called productive utterances, and found that this was the case for both children. The blind child’s MLU measures were, however, higher than the sighted child’s. Pérez-Pereira (1994) referred to other studies that have proposed that imitations and repetitions reduce the memory load in blind children when they speak, making them able to produce longer utterances since they can focus on new elements or modifications. He concludes that modeled speech has a self-scaffolding function. This is in line with the arguments of Peters (1987, 1994), who found that blind children use this holistic Gestalt style of language acquisition – “use first, analyze later” – reproducing whole sentences and phrases uttered by an adult with roughly the same intonation. Pérez-Pereira (1994) concluded that formulaic speech fulfils important functions for the blind child: it promotes conversational interaction, it helps the child to express many pragmatic functions and it is a strategy used to analyze language. Their reliance on routines, stereotypic speech, imitations and so on also results in the ability of blind children to use verbal memory more fully compared to sighted children (Pérez-Pereira & Conti-Ramsden, 1999).

2.1.7 Compensatory mechanisms in first language acquisition and possible relevance to second language acquisition

Since blind children have the ability to acquire a non-deficient language without the aid of vision, Pérez-Pereira and Conti-Ramsden (1999) concluded that there must be some compensatory mechanisms involved in the process. Some researchers have proposed that blind children have the ability to pay special attention to language, that is, the auditory signal, since the linguistic input is more salient and in some ways more important to them, than to sighted children (e.g. Pérez-Pereira, 1994; Pérez-Pereira & Castro, 1997; Peters, 1987). In support of this idea are some features of blind children’s language, according to Pérez-Pereira and Conti-Ramsden (1999), which include greater use of routines and ready-made phrases and the use of imitations and repetitions. The heavy use of modeled speech also shows that they may use their verbal memory more fully than sighted children do, as mentioned above. We can conclude that the compensatory mechanisms are, according to these researchers, the heightened ability to pay attention to spoken language, and the use of certain processing strategies, like chunking, in order to increase verbal memory performance. The greater ability to chunk verbal material is also discussed as a compensatory mechanism by researchers from the neuropsychological field (Rokem & Ahissar, 2009; this study will be presented in later chapters of the dissertation). The discussion
Blindness and Second Language Acquisition

on compensatory mechanisms in blind individuals in relation to language and speech processing will be continued in the section entitled “Neuropsychological aspects of blindness.”

2.2 Second language acquisition in blind individuals

While first language acquisition in blind individuals has been studied extensively, very little attention has been devoted to second language acquisition:

There is a dearth of material in the field of second language acquisition for learners with visual impairments, probably due to the generalized assumption that these students follow the same patterns of learning as their sighted counterparts; provided there is reasonable competence in the mother tongue, a second language will be learned successfully […]. (Aikin Araluce, 2002:77)

The meager amount of research on foreign and second language acquisition in blind students, to which Aikin Araluce (2002) referred, all come from a teaching perspective, focusing on different methodologies for teaching foreign and second languages to blind individuals (Kashdan, Barnes & Walsh, 2002; Topor & Rosenblum, 2013; Aiazzi, 2008; Guinan, 1997; Snyder & Kesselman, 1972; Couper, 1996; Milian & Pearson, 2005; Nikolic, 1987; Hub, Diepstraten & Ertl, 2005). None of these studies, however, had the aim of comparing blind and sighted individuals’ prerequisites for L2 acquisition, which is the focus of the current study. Nor have these studies compared sighted and blind individuals’ L2 development, since no sighted participants have been included in these studies.

The only studies with a focus on investigating possible similarities and differences between blind and sighted individuals learning a second language (including both sighted and blind participants) are the small-scale studies of Smeds (Kjellberg, 2003, 2004, both of which were reported in Kjellberg Smeds, 2008). It can therefore be concluded that the dearth of material is even greater in this area of research.

In some of the studies referred to above, the researchers have made general comments on the language acquisition abilities of blind children or adults. Couper (1996) cited some of these studies, as she aimed to investigate whether blind and visually impaired children could be considered “gifted linguists.” Her general impression was that “there seemed to be a universal consensus that these pupils were adept, at least, at languages” (p. 6). The specific advantages of blind students, which have been taken up time and again by different authors are, according to Couper (1996), “the ability to mimic and recognize aural patterns” (p. 6), and the ability to develop a well-trained memory. The researcher also cites a report from the Royal School for the Blind in Liverpool (1966; called The teacher of the blind), where the
teachers marveled over the success of blind students in language learning laboratories, and where this ability was attributed to the “good ear” of the blind students. The experience of Couper (1996), from participating in the language classroom where the foreign languages French and German were taught, was that these students were impressive in their ability to produce authentic intonation.

It is also interesting to note that one of the teaching methods recommended in these studies, developed in the 1960s, focuses on the acquisition of phonetics and accents (e.g. Snyder & Kesselman, 1972), as well as on the use of an oral-aural method for second language acquisition. All initial training was received aurally and orally, and the students primarily had to master the sound-system of the L2 before being taught to read and write. The acquisition of phonetics and accents have, according to Nikolic (1987), held a special position in foreign language teaching for blind individuals, as it is evident that blind students can acquire the specific phonetics and accents of a foreign language only by ear without any explanation of the pronunciation of the specific sounds of the respective language. This ability seems to be related to the natural ability of a baby to utter sounds in any language. (p. 64)

Nikolic (1987) also stressed the need for more research being conducted in relation to these aspects of language acquisition in blind individuals, and the phonological short-term memory, as well as the ability to recognize aural patterns, is investigated in the current study (study I).

Smeds (Kjellberg, 2003, 2004, reported in Kjellberg Smeds, 2008) specifically compared speech perception in noise (sentences in white noise and words in babble noise) and L2 speech production, that is, accentedness in L2 speech. The participants were seven blind and seven sighted L2 learners, who were studying Swedish at secondary school level, and seven blind and seven sighted matching L1 speakers. In sum, the results showed that blind L2 learners had greater trouble perceiving speech in babble noise, but not in white noise, than sighted L2 learners and that some of the blind participants were judged to produce non-accented L2 speech by a panel of native speakers of Swedish, which none of the sighted L2 learners were. The difference in accentedness between the blind and sighted L2 groups did, however, not reach significance. The results suggested that blind and sighted L2 learners might have different prerequisites in L2 acquisition. The results of Smeds (Kjellberg, 2003, 2004) will be presented in greater detail in studies II and III.

It is clear that the prerequisites for language perception and possibly also production is different in blind individuals compared to sighted, and there is no empirical evidence showing to what extent second language development in blind individuals follows the same route as in sighted individuals, as Aikin Araluce (2002) concluded. It might thus be expected that differences in the
neurological development of blind individuals result in compensatory cognitive and memory skills being developed that give blind individuals an advantage in second language acquisition, for instance, in relation to verbal short- and long-term memory functions, for example, phonological short-term memory (Hull & Mason, 1995; Röder & Neville, 2003; Rokem & Ahissar, 2009) and auditory word recognition memory (Röder, Rösler & Neville, 2001; Raz et al., 2005; see Study I). This is thus dependent on the plasticity profile of the specific language aspect of interest and on the age of onset of blindness.

It has, for instance, been found that semantic or lexical aspects of language are neurological systems that are open-ended (i.e. not constricted by a sensitive period in development), with a relatively flexible organization that can be reorganized by experience throughout the lifespan, while phonological and grammatical aspects are neurologically predisposed to develop during a more narrowly defined sensitive period during development. During this more limited sensitive period, the system is highly modifiable by experience but is much less so after the closure of this period (Newport, Bavelier & Neville, 2001). This implies that a compensatory neurological development of the different linguistic systems (phonological, grammatical, semantic and lexical) in congenitally blind and early blind individuals are more modifiable according to experience than in late or adult blind, since some of the neurological language systems of the late blind have already undergone neurogenesis and are less plastic and modifiable by experience. The sensitive periods of some of the linguistic systems in adult blind have thus passed, for example, the sensitive periods of the phonological and the grammatical systems. But, as the researchers point out, experience can modify the timing of sensitive periods (Newport, Bavelier & Neville, 2001), which, for example, has been found in the visual cortex of early blind individuals (Veerart et al., 1990). And, Newport, Bavelier and Neville (2001) exemplified this in relation to adult L2 learners who achieve very high or near native competence and suggest that other cognitive skills and former experiences of learning languages also might explain the success in L2 acquisition in those individuals, despite that they ought to have passed the sensitive periods of phonology and grammar. It becomes obvious that the great variability that exists between individuals concerning these aspects might be even greater in blind L2 learners, especially among late/adult blind individuals, depending on the complex interaction between the biological development of different neurological subsystems (for instance, the sensory systems as well as the linguistic systems) and experience or use, which include influence from interaction with the (L2) environment. This will be discussed further in the next section.
2.3 Neuropsychological aspects of blindness

This section covers neuropsychological aspects of blindness, and it starts by presenting earlier research that was devoted to investigating the possible existence of sensory compensation in blind individuals. The following section is devoted to a description of the development of the human brain and neuroplasticity, and it is followed by a presentation of research findings of the effects of visual deprivation on the neurological development and on neuroplasticity. The last section presents the significance of the age of onset of blindness for the neuropsychological development of blind individuals.

2.3.1 The Sensory Compensation Hypothesis

Some of the early experimental studies on the **Sensory Compensation Hypothesis** reported an enhanced performance, while other studies reported a deficient performance by blind compared to sighted individuals (Miller, 1992), which made it impossible to draw any firm conclusions on the matter.

Stankov and Spilsbury (1978), for instance, compared 30 blind, 30 sighted and 30 children with low vision (10–15 years) on 26 different auditory tests with respect to temporal tracking, discrimination among sound patterns, speech perception in noise, and maintaining and judging rhythm. On most of the tests, the groups of blind and sighted children got similar results, but for the blind it was easier to discriminate among sound patterns but more difficult to maintain and judge rhythm. The results from the two tests of speech perception in noise, one with white noise and one with cocktail noise, showed that blind and sighted performed equally. The children with low vision performed lower results on all the tests than the other groups, which the authors attribute to possible cognitive and/or personal problems. This explanation might, however, not be sufficient since the neurological mechanisms also would have to be considered for a more complete explanation. This was, however, not methodologically possible at the time the study was conducted, as was previously mentioned.

Contradictory results were reported in an often cited article by Niemeyer and Starlinger (1981), in which different aspects of speech perception in 18 blind adults and 18 matched sighted adults were investigated using different types of test conditions. The researchers used a dichotic listening experiment, four speech audiometric tests (speech on different semantic levels, both with and without noise [type of noise was not specified]), and they elicited auditory evoked cortical responses to record the speed of processing. No significant differences between blind and sighted on the dichotic listening experiment were found, but differences were found on all speech audiometric tests and also on speed of processing. For speech perception, the blind were superior on all semantic levels, especially on sentence discrimination with and without noise. The researchers also found that reaction times
were significantly shorter among the blind participants, confirmed by many other studies (see below). The better auditory skills of the blind were ascribed by the researchers to the plasticity of the brain.

The two experimental studies mentioned above are examples of studies with inconsistent results pointing in different directions. The inconsistent results produced in earlier research on the sensory compensation hypothesis were ascribed to methodological inconsistencies (Röder, Rösler & Neville, 2001; Röder & Neville, 2003). Sometimes, the criteria employed for selecting participants were not optimal, resulting in participants with varying degrees and/or durations of blindness, or varying age of onset of blindness in the same study or test group. Another problem was that there were sometimes differences between control groups as well as that the tasks performed by sighted and blind participants were not identical (Röder & Neville, 2003).

In the early research on blind individuals, there was no awareness of the importance of these issues, despite that they have great neurological implications, affecting blind individuals’ prerequisites in daily life. Thus, it was not until the relatively new area of research – neuroscience – turned its interest to neuroplasticity and the potential for change of the human brain that any firm conclusions could be drawn. With the aim of understanding the experience-dependent cortical reorganization found in blind individuals, neuropsychology produced clear and consistent results showing that blind individuals can compensate for the loss of vision by developing superior auditory, tactile and cognitive skills. These issues will be discussed in the following sections.

2.3.2 The development of the human brain and neuroplasticity

The structural development and maturational process of the human brain displays great variability within different neural systems and subsystems. Some systems (a) mature early in life, for example, aspects of the visual system, and they are strongly determined and change very little from altered experience (e.g. in cases of complete blindness) and a different interaction with the environment. Other systems (b) can change considerably, but only during a specific “sensitive” time period during development, when it is dependent and modified by experience. There is also a third type of neural system (c) that is highly plastic and modifiable throughout life (Neville & Bavelier, 2002; Neville, 2006). Neuroplasticity can be defined as:

The capacity of the nervous system to modify its organization. Such changes can occur as a consequence of many events, including the normal development and maturation of the organism, the acquisition of new skills (‘learning’) in immature and mature organisms, after damage to the nervous system and as a result of sensory deprivation. (Bavelier & Neville, 2002:443)
More research is needed to fully understand why different subsystems of the nervous system have varying profiles of neuroplasticity and also to what degree these profiles are shaped by genetic heritage and experience, respectively. According to Neville and Bavelier (2002), one major hypothesis about what regulates the duration and timing of these sensitive periods\(^2\) states that it is related to the over-production of synapses that occur during cortical development. An adult brain has about 100 billion nerve cells/neurons, which is about the same amount as in a newborn baby’s brain. The difference is that a baby’s brain weighs only about one-quarter of the adult brain and still contains the same amount of nerve cells, which makes the relative amount of connections (synapses) much larger in the baby’s brain. At birth, each single neuron in the brain has about 2,500 synapses, and, at age two to three, the number of synapses\(^3\) per neuron is as many as 15,000. After the over-production of synapse formation,\(^4\) the brain starts to lose neural connections in a process called *pruning* (synapse elimination of unused or weak connections), and an adult brain will eventually have about 60% of the connections that it had in early childhood (Neville & Bavelier, 2002; Huttenlocher & Dabholkar, 1997; Gopnik, Meltzoff & Kuhl, 1999). The neural connections in a baby’s brain are spread all over the cortex, in a seemingly chaotic and unsystematic fashion, and the synapses that eventually endure the pruning process are the ones being frequently used. In other words, the cells frequently firing (their neurotransmitters) at the same time become connected and established, as “cells that fire together wire together” (Neville & Bavelier, 2002; Gopnik, Meltzoff & Kuhl, 1999), while the neural connections that are not used do not get established.

As was mentioned above, this process is shaped both by genetics and experience, it is “activity dependent.” According to Neville and Bavelier (2001), researchers agree that experience affects local circuit organization rather than major pathways, since the neural organization of major pathways have already been established before the onset of most sensitive periods. As was mentioned above, different neural systems have different time-courses for synapse formation and synapse elimination. For example, in the primary visual cortex the burst in synapse formation occurs about three to four months of age, and synapse elimination occurs at about four years of age, while, for example, synapse formation in prefrontal cortex (e.g. regulating complex cognitive behaviours, decision making and moderating correct social behavior) takes longer, occurring at about 3.5 years of age and

---

\(^2\) Sensitive/critical period: The developmental time period during which experience can significantly alter the organism’s behavioral performance, and related aspects of brain structure and/or function (Bavelier & Neville, 2002:443).

\(^3\) Synapse: The small gap between neurons in which neurotransmitters are released, permitting signaling between neurons (Ward, 2010:19).

\(^4\) Synapse formation = synaptogenesis
synapse elimination lasts until the age of 20. That the neurological development is shaped not only by genetics but is also dependent on activity and use will be seen in the discussion of within-modality reorganization of the visual cortex in early and late blind individuals.

It is assumed that the sensory modalities are hierarchically organized systems that begin with specialized receptors of unimodal signals (e.g. auditory signals) to the primary cortical area (e.g. primary auditory cortex). After this, different aspects of the processed information become integrated in the secondary cortical areas (unimodally). At the highest level, multimodal association areas integrate this information with information deriving from other sensory modalities, providing a multimodal perceptual experience of the world. This means that we have an integrated sensory experience of the world by processing, for instance, visual, auditory, olfactory information simultaneously. One sensory modality influences the experience of other sensory modalities (Pascual-Leone & Hamilton, 2001). The processes of myelinisation and pruning, mentioned above, take place earlier in primary sensory cortices than in areas situated higher in the cortical hierarchy, e.g. multimodal association areas. According to Röder, Rösler and Neville (2000), it has been speculated that these two processes do not, take place in the visually dominated brain areas in blind individuals, or do so incompletely, which is supported by the findings of Veraart et al. (1990).

2.3.3 The effect of visual deprivation on neuroplasticity

Blindness, especially early onset blindness, leads to a dramatic alteration of the way the world and the surrounding environment is perceived, and this change affects the organisation of the brain. In studies made on animals, it has been found that sensory deprivation to one sensory modality of the brain results in plastic changes to other, still intact, sensory modalities of the brain, a process often referred to as cross-modal plasticity. In the last ten years, the effects of sensory deprivation (auditory and visual) on human brain development has been studied extensively within the field of neuropsychology, and it has been shown that blind people, who primarily rely on audition and tactility in their interaction with the environment, are able to compensate for their lack of vision by developing, for instance, superior auditory and tactile skills. This is currently referred to as perceptual compensation rather than sensory compensation ( Muchnik et al., 1991; Rice, 1969; Röder, Rösler & Neville, 2000).

In relation to tactility, for example, early blind individuals have not been found to have lower absolute tactile thresholds, but rather they display a more well-defined ability to discriminate tactile stimuli with the fingertips (lower two-point thresholds; Röder & Neville, 2003). In relation to auditory processing, it has been found, for example, that blind individuals have supe-
rior auditory verbal memory performance (Amedi et al., 2003; Röder, Rösler & Neville, 2001), higher phonological sensitivity for speech sounds (Hugdahl et al., 2004), superior pitch discrimination (Gougoux et al., 2004), higher prevalence of absolute pitch\(^5\) among blind musicians (Hamilton, Pascual-Leone & Schlaug, 2004), better auditory spatial skills (Röder et al., 1999; Niemeyer & Starlinger, 1981; Lessard et al., 1998) and more rapid auditory processing (approximately twice as fast, Hugdahl et al., 2004; Kujala et al., 1997b; Niemeyer & Starlinger, 1981; Röder, Rösler & Neville, 2000; Röder et al., 2003), leading to the formulation of the Speed of Processing Hypothesis by Stevens and Weaver (2005).

The advantages found in blind individuals on auditory processing can be related to many different aspects of auditory processing, for instance, auditory perception (e.g. better pitch discrimination, shorter reaction times), auditory spatial perception (e.g. enhanced ability to localize sounds in the lateral peripheral auditory field), and higher cognitive auditory processing, that is, language and memory processing (e.g. faster processing of speech and better phonological working memory functions). With respect to basic auditory processing, the absolute sensory threshold, measured using standard audiometric tests, does not generally reveal any differences between blind and sighted individuals (Hötting & Röder, 2009; Starlinger & Niemeyer, 1981), although Rokem and Ahissar (2009) actually found that congenitally blind do have a slight advantage compared to sighted. The differences between blind and sighted individuals are usually related to, for instance, a more efficient auditory processing of inputs, which, in turn, are likely to contribute to the better performance of blind individuals at higher levels of auditory processing. For example, Hugdahl et al. (2004) used a dichotic listening procedure with a pairwise presentation of CV-syllables under three different conditions: with instructions to pay attention to the right-ear stimulus, to the left-ear stimulus or given no specific instructions regarding attention. The participants were 14 congenitally or early blind adults and 129 sighted controls. The blind participants reported significantly more correct syllables than the sighted overall and also significantly more correct responses when instructed to focus their attention to one stimulus (presented to the left ear) while inhibiting processing of the irrelevant stimulus presented to the other unattended ear. The researchers concluded that blind individuals show enhanced sensitivity in both conscious (the cognitive level of information processing) and automatic (the sensory level of information processing) perception of speech sounds and that this might be the result of reorganization of the auditory modality of the brain.

\(^5\) Absolute pitch: The ability to identify a particular pitch of the musical scale without any reference to tone (Hötting & Röder, 2009).
It is also likely that auditory language processing displays advantages as a result of faster speech processing and better pitch discrimination abilities also found in blind individuals (Hötting & Röder, 2009). Röder, Rösler and Neville (2000) recorded event-related potentials (ERP) in 11 congenitally blind and 10 matched sighted adults while performing an auditory language processing task. The participants listened to 160 sentences and were then asked if they were meaningful or not. Half of the sentences had incongruous final words. The results showed that the blind participants reacted to the incongruous sentence-final words faster than the sighted participants (75 ms compared to 150 ms post-stimulus in the sighted). The results also showed that the electrical brain activity had a different scalp distribution in the blind than in the sighted. The sighted participants had a left-lateralized fronto-central scalp distribution, while the scalp distribution in the blind was symmetric and broad, including higher activation over the occipital cortex. The researchers could not decide from the obtained results whether this broad distribution in both left and right hemisphere reflects a functionally relevant reorganization (i.e. compensatory plasticity). The different scalp distribution does, however, suggest that some language functions may be reorganized in the blind. To explain faster speech processing in blind individuals, the researchers hypothesized that the results show a compensatory adaptation at an early stage in the processing of language, for example, at the level of phoneme discrimination. This could, at least partly, explain both a more rapid auditory processing and a higher sensitivity for speech sounds, which has been found by Hugdahl et al. (2004). For further discussions on auditory language and memory processing, see study I.

It is interesting to note that there are similar neural changes in both blind individuals and other populations, like musicians, known for their pronounced experience of auditory perception and processing, which seem to indicate that the neural changes observed in blind individuals can, at least partly, be attributed to perceptual learning, and not only to innate biological prerequisites (Röder & Neville, 2003). The following paragraphs of the dissertation will discuss which areas of the brain display plastic change, and how they are affected both functionally and structurally. This is followed by a paragraph describing a variety of factors that influence the character of these changes.

It has been suggested that the behavioral compensatory changes, like the ones mentioned above, are mediated by (a) multimodal association areas, (b) the primary cortex of the visual modality and (c) the spared auditory and somatosensory modalities (Noppeney, 2007; Bavelier & Neville, 2002). Multimodal brain areas process and merge sensory inputs from the sensory

---

6 ERP: A method using electroencephalography, in which the electrophysiological reaction of the brain to specific stimuli is tracked over time (Baddeley, Eysenck & Anderson, 2009:15).
organs (visual, auditory and somatosensory), which results in a multisensory integrated experience of the world. This multisensory integration becomes altered due to visual deprivation, showing enhanced processing of input to the remaining modalities, whereby the section of the multimodal association area, usually allotted to vision, is taken over by non-visual stimuli as a result of activity-based competition (Bavelier & Neville, 2002). From studies of visually deprived animals, blind humans, cataract patients and children with cochlear implants, Hötting and Röder (2009) draw the conclusion that multisensory processes are not innate but dependent on multisensory experience early in life, and that vision even might play a crucial role in the development of multisensory functions. It has, for instance, been found that individuals born with dense binocular cataract, deprived of patterned visual input only during the first 5 to 24 months, develop an impaired multisensory interaction (Putzar et al., 2007). This points to the fact that multisensory functions are shaped by experience-dependent plasticity early in life. In a study of auditory-tactile interaction in blind individuals, Hötting and Röder (2009) used a multisensory illusion paradigm testing auditory-tactile interaction. Participants in their study were presented with one to four tactile stimuli in a rapid sequence to the right index finger and asked to report the number of tactile stimuli presented. In most of the trials, the tactile stimuli were accompanied by task-irrelevant tones. Sighted individuals were influenced by the tones, although specifically told to ignore them, while the blind individuals displayed a markedly reduced illusion, especially on items where the discrepancies between the amount of tactile stimuli and tones were large (i.e. one tactile stimuli and four tones). The conclusion drawn by the researchers was that the likelihood of multisensory integration in blind individuals might be lower than in sighted because of their enhanced perceptual ability within the tactile and auditory modality, respectively. In other studies conducted by the same research team this pattern was confirmed in that they showed that visual deprivation reduces and alters interactions between the remaining modalities. Congenitally blind individuals display a reduced multisensory integration, and they are better able to separate simultaneously presented sensory signals from one another than sighted individuals are. Additionally, Hötting and Röder (2009) found that blind individuals are better at splitting their attention to audition and touch to different spatial positions in relation to the body. In the following paragraphs of the thesis, the focus is turned to

---

Visual illusion paradigm: this multisensory paradigm was first introduced by Shams, Kamitani, and Shimojo (2000), whereby sighted participants were presented with a single visual flash accompanied by multiple tones and asked to report the number of flashes. When presented with one flash and more than one tone, participants consistently and incorrectly reported seeing multiple flashes, and the researchers concluded that “what you see is what you hear.”
the visual and auditory cortices, and to the structural and functional reorganization of these modalities.

Compensatory changes are also mediated by the primary sensory cortex, which is associated with the deprived modality; it becomes “colonized” by the remaining modalities (Bavelier & Neville, 2002). This means that in blind individuals, the visual cortex processes, for instance, aspects of auditory and tactile inputs instead of visual input, a phenomenon which has been well documented (Sadato et al., 1996, 2004; Gougoux et al., 2005; Pascual-Leone et al., 2006; Poirier et al., 2006; Burton & McLaren, 2006; Sathian, 2005; Sathian & Lacey, 2007; Kujala et al., 1995, 1997a, 2005; Röder et al., 2002; Ahlo et al., 1993).

This abnormal recruitment or maturation of the visual cortex might also result in an abnormal stabilization of usually transient neural connections in the remaining auditory and somatosensory modalities (Bavelier & Neville, 2002). The neurons in primary visual cortex in sighted individuals show preference for simple and spatial features, while the secondary visual cortex, that is, higher cortical areas, respond to more complex stimulus aspects such as objects of any size and orientation. According to this hierarchically structured organization of the occipital cortex, complex functions, such as language and memory, should not be processed by a primary sensory area, but rather by higher cortical areas like the secondary (extrastriate) visual region (which is also activated). The primary visual cortex does, however, get activated by higher complex cognitive tasks involving language and memory functions in blind individuals (see, for instance, Amedi et al., 2003), while simple sensory tasks, such as passive stimulation or simple motor tasks, do not (Nooppeney, 2007; Bavelier & Neville, 2002). Summarizing existing research on the matter, Büchel (2003) concludes that primary (striate) and secondary (extrastriate) visual cortex in the blind even get activated without sensory input, for instance, when performing tasks involving auditory long-term memory functions (see, for example Raz, Amedi & Zohary, 2005), and he argues that the cortical hierarchy in the occipital cortex of blind individuals is turned on its head, since a primary sensory area is involved in higher cognitive memory functions, rather than in the processing of simple sensory information.

To understand how visual loss affects functional and structural development of the brain, different neuroimaging techniques, such as fMRI, sMRI,

---

8 fMRI stands for functional magnetic resonance imaging, a method of brain imaging that relies on detecting functional changes induced by a powerful magnetic field (Baddeley, Eysenck & Anderson, 2009:15).

9 sMRI stands for structural magnetic resonance imaging, a method of brain imaging that relies on detecting structural changes induced by a powerful magnetic field (Baddeley, Eysenck & Anderson, 2009:15).
and PET,\textsuperscript{10} have been employed. With the help of these techniques, it is possible to find correlations and statistical dependencies between cognitive functions and brain activations, and therefore to define a neurological system sufficient for a particular function. These results do not, however, reveal if the area activated is necessary for a particular task or if it is simply reflecting processing. To discern this and to establish a causal link between the activation of the visual cortex and cognitive functions, lesion methods have been used. Besides naturally occurring lesions (Hamilton et al., 2000), transient or “virtual” lesions can be made using transcranial magnetic stimulation (TMS)\textsuperscript{11}, electrical or pharmacological methods (Pascual-Leone, Walsh & Rothwell, 2000; Noppeney, 2007). Using TMS temporarily disrupts the functioning of a cortical region, making it possible to discern whether that region (in this case the visual cortex) is necessary when a subject performs a given task, for example, when they read braille (Cohen et al., 1997, 1999) or process verbal input (Amedi et al., 2004) (see below for further details).

Confirming what was said above about compensatory changes being mediated by the primary cortex of the lost sensory modality, by spared modalities as well as by multimodal association areas, research on blind individuals has found both compensatory functional and structural changes in primary visual cortex and in the spared auditory cortex. Different cortical activation patterns related to lateralisation has also been found during language processing.

Convincing evidence for a functional role of visual cortical regions in braille reading has been found (Amedi et al., 2003; Büchel et al., 1998; Burton et al., 2002a; Sadato et al., 1996, 1998, 2002). The difficulty is, however, that braille reading is a very complex task that involves the processing of tactile sensory input as well as high level cognitive and linguistic processing, making it hard to pinpoint the functional role of the visual cortex. Researchers therefore turned to memory and language paradigms, where evidence for a functional role of the visual cortex also could be found in, for instance, auditory language and speech processing (Röder et al., 2002), verbal memory processing (Amedi et al., 2003), episodic memory retrieval (Raz, Amedi & Zohary, 2005) and phonological rhyming tasks (Burton, 2003).

Summing up the results from studies of semantic processing in blind individuals, Noppeney (2007) concluded that all participants, congenitally or early blind and sighted, activate core language related areas during semantic

\textsuperscript{10}PET stands for \textit{positron emission tomography}, a method whereby radioactive labeled substances are introduced into the bloodstream and subsequently monitored to measure physiological activation (Baddeley, Eysenck & Anderson, 2009:15).

\textsuperscript{11}TMS stands for \textit{transcranial magnetic stimulation}, a non-invasive stimulation of the brain caused by a rapidly changing electrical current in a coil held over the scalp (Ward, 2010:79).
processing, while early blind individuals also activate secondary (extrastriate) regions of the visual cortices. The activity in both core language areas and secondary visual areas in early blind individuals after the pruning period seems to be an effect of visual deprivation. Usually experience-dependent pruning/synaptic elimination leads to less neural connectivity, a more defined neural architecture and greater functional specification, but this does not seem to be the case in visual loss, since the result is a higher number of neural connections maintained through “over-expressed coupling” of the two areas mentioned. Noppeneye’s (2007) hypothesis was that this is how the secondary (extrastriate) visual regions become connected and incorporated into the semantic retrieval system through the language system, before the pruning periods of the two areas. The functional specialization of the occipital cortex will be exemplified further in the following studies.

Amedi et al. (2003) compared the brain response in ten congenitally blind and five matching controls using fMRI when performing a series of tasks: one tactile braille reading task, one verbal memory task (without sensory input), one verb generation task and one auditory noise task. The researchers found a robust occipital activation in the blind individuals but not in the sighted, and also a reorganization and specialization of the occipital cortex, whereby the anterior regions were activated during braille reading and the posterior regions (including primary visual cortex) during the more cognitively demanding verbal memory and verb generation tasks. They also found that the activation was stronger in the left hemisphere, in accordance with the left lateralization of language processing. The difference between the groups was also mirrored by a superior performance of the blind as a group on verbal memory tasks. The degree of activation of the primary visual cortex during performance of verbal memory tasks also showed a highly positive correlation with the blind individual ability: the higher the scores on the memory task then the greater the activation of the primary visual cortex (no correlation with educational background or IQ was found). The results from this study were further supported in a study by Raz, Amedi and Zohary (2005) using an episodic memory task. Those participants with a better recognition performance had a greater activation of the primary visual cortex compared to poorer performers, and the researchers concluded that the posterior occipital cortex (including primary visual cortex) in blind individuals is likely to be involved in episodic retrieval as well.

Röder et al. (2002) employed functional magnetic resonance imaging (fMRI) to map language-related brain activity in 10 congenitally blind adults and 11 matching sighted controls. The participants listened to sentences with either an easy or a more difficult syntactic structure that were either semantically meaningful or not. The researchers found, besides activity in the classical left-hemispheric language areas, that the blind participants also displayed activity in the homologous right-hemispheric structure and in the
primary visual cortex and other adjacent parts of the brain devoted to vision in sighted individuals (striate and extrastriate cortex), all being parts of the occipital cortex/lobe. The level of activation in the classical/core language areas and the occipital cortex varied as a function of syntactic difficulty and semantic content.

Other research teams have also found visual cortex activation during auditory tasks like discrimination of tones (Alho et al., 1993; Kujala et al., 1995; Röder et al., 1996) and sound localization (Kujala et al., 1992; Weeks et al., 2000). We can conclude from this that there is plenty of evidence showing activation of visual cortex in non-visual tasks, but the next question is whether this activation plays a necessary role in task performance or if it just reflects processing. In looking at results from the following lesion studies, it becomes apparent that it plays a necessary role.

In a tragic experiment by nature reported by Hamilton et al. (2000), it was found that a congenitally blind woman suffering from bilateral posterior artery stroke affecting the occipital cortex was impaired when reading braille, but not when performing simple tactile tasks. The results of this case support a causal link between the occipital functions and the ability to read braille, which means that the occipital cortex is necessary in performing higher order cognitive tasks such as braille reading. The result of this study is further supported by Cohen et al. (1997), who applied repetitive TMS to the occipital cortex in blind and sighted individuals performing a tactile task, where the blind read braille and the sighted embossed Roman letters. In blind participants, but not in sighted, tactile perception was impaired following TMS to the occipital cortex, which supports the findings from the natural experiment of Hamilton et al. (2000).

Amedi et al. (2004) administered TMS to the occipital cortex (including primary visual cortex) to nine blind and nine sighted individuals performing a verbal processing task (verb-generation). The results showed reduced accuracy in verb-generation in blind subjects, but not in sighted. The sighted subjects did, however, show reduced accuracy when TMS was administered to the prefrontal cortex, which is normally active in verbal processing in sighted individuals. The errors were classified as semantic, morphosyntactic or phonological; for example, the errors were classified as semantic if the subject produced “jump” instead of “apple,” as morphosyntactic if the subject produced “green” instead of “apple” and as phonological if “eap” was produced instead of “apple.” Motor output errors were defined as stuttering or the inability to utter intelligible answers within a specific time period (five seconds). Disrupting activity of the occipital cortex in blind (and prefrontal cortex activity in the sighted) in a verb-generation task mostly affected cognitive processes, that is, the semantic component and not the motor component, suggesting a causal link between occipital functions in the blind and semantic processing.
Summarizing the results of the studies presented above it can be concluded that the visual cortex displays functional reorganization as a result of visual loss and that the activation of the visual cortex in a variety of tasks seem to be a necessary prerequisite for task performance.

Recent studies question traditional views that claim that the brain adapts to changes in the environment only through functional reorganization. Structural changes have been found in regional white and gray matter volumes, for instance, in musicians, jugglers and bilinguals (Noppeney, 2007). In a study by Noppeney et al. (2005) that aimed to quantify and statistically evaluate changes in gray and white matter in the brains of blind subjects, it was found that visual deprivation induced both gray and white matter changes within the visual, somatosensory and motor systems. The researchers found a reduction of gray matter volume mainly in the primary visual area but also in secondary ones. They also found a decrease in white matter in afferent parts of the visual system (i.e. in areas containing nerves conveying visual sensory information), but an increase of white matter tracts in somatosensory and motor cortex. This is seen as a result of experience-dependent compensatory plasticity. What was further explored in relation to structural reorganization was the effect of age of onset of blindness. All participants were defined as early blind and had lost their vision before the age of two. The analysis revealed a robust effect of blindness onset on white matter density. Earlier onset was associated with less white matter density in the optic tracts and increased volumes of white matter in primary somatosensory and motor cortex.

Although enhancements related to audition have been found in blind individuals, the auditory cortex, as an intact modality, has received little attention in research compared to the visual cortex. In Elbert et al. (2002), the auditory magnetic response (ERP) was recorded in nine blind and ten sighted participants, when a presentation of pure tones was made. They found, besides shorter reaction times, a structural enlargement (hypertrophy) by a factor of 1.8 in the auditory cortex of the blind subjects compared to the sighted. On the other hand, Stevens (2005), who studied both structural and functional changes (sMRI and fMRI), found no structural changes but did find a substantial functional reorganization of the auditory cortex in seven congenitally blind participants and, to a lesser degree, in five adventitiously blind participants. He discovered that the congenitally blind participants had a decreased metabolic activity in the auditory cortex, when processing auditory stimuli. He suggests that this might be the result of greater efficiency of

---

12 Gray matter: Matter consisting primarily of neuronal cell bodies, i.e. of neurons. White matter: Tissue of the nervous system consisting primarily of myelinated axons and support cells (Ward, 2010:21).
the auditory cortex and/or a result of an expansion of the auditory fields to areas that do not reside within its normal anatomical boundaries.

The main portion of research focusing on auditory cortex in blind individuals has been done by Stevens and Weaver (2005, 2009; Stevens, 2005; Stevens et al., 2007). Stevens and Weaver (2009) examined the response of the auditory cortical areas in seven early blind, five late blind and six sighted individuals while listening to pure tones and frequency modulated stimuli. While no significant differences were found between late blind and sighted individuals, the results of this study suggests that, although the pattern of tonotopic organization is the same in early blind individuals, they process simple (low-demanding) auditory stimuli more efficiently due to plastic changes of the auditory cortex. Stevens and Weaver (2009) drew this conclusion since the blind participants had a decreased signal within the auditory cortex compared to the other groups. They found support for this hypothesis in studies showing that the blind process stimuli faster as shown by shorter latencies of early-evoked potentials using EEG¹³ (Röder et al., 1996; Naveen et al., 1997, 1998; Manjunath et al., 1998) and with reduced metabolic responsiveness using a PET scan (Weeks et al., 2000) while still performing significantly higher results on the tests used. Since this increased efficiency was seen only in the early blind group, the researchers concluded that the plastic alterations in the auditory cortex cannot be characterized as use-dependent, but rather occur before the closure of a critical period in development.

Hötting and Röder (2009) concluded from neurological research on auditory cortex in congenitally and early blind individuals that the enhanced auditory discrimination abilities for basic features, such as timing and duration of sounds, and pitch seem to be a consequence of a reorganization of the auditory cortices.

The character of plastic changes are specific and depends on (1) the nature of the altered experience (e.g. degree of visual loss), (2) the timing of the altered experience (age of onset of blindness) and (3) the particular brain systems that are modified (since different cortical areas have different plasticity profiles, Bavelier & Neville, 2002). These three different factors can partly explain the great variations that exist between blind individuals, since cause of visual deprivation, age of onset of visual deprivation, degree of visual loss, as well as the character of inputs that results from the interaction with the environment and other additional handicaps all influence the neurological development and the compensatory adaptation of the brain (Neville & Bavelier, 2002). The reorganization of the human cortex following visual

---

¹³ EEG stands for electroencephalogram, a device for recording the electrical potential of the brain through a series of electrodes placed on the scalp, by which it detects the electrical activity of the brain (Baddeley, Eysenck & Anderson, 2009: 14–15).
Blindness and Second Language Acquisition
deprivation is, therefore, a product of the dynamic interplay between genetic and environmental factors (Gilbert & Walsh, 2004). Degree of visual loss affects neurological reorganization to a great degree. If an individual suffers a complete loss of vision, the visual cortex can potentially become “colonized” performing tactile, auditory and higher cognitive functions instead, whereas if an individual only suffers from partial visual loss the visual cortex, or parts of it, still process visual signals and cannot become “colonized,” as it does in the case of severe visual loss or blindness. This potential compensatory change is thus largely dependent on the timing of the altered experience, or age of onset of blindness. It is one of the most important factors affecting experience-dependent plastic change in blind individuals, and it has to be taken into account when functional and structural reorganization of the brain is considered (Büchel et al., 1998; Gougoux et al., 2005; Cohen et al., 1999; Sadato et al., 2002). This factor will be discussed in greater detail in the following section. The last factor mentioned above has to do with what particular brain system it is that gets modified, since different brain systems have varying plasticity profiles. Some systems can become reorganized only during a specific sensitive period, whereas other brain systems are modifiable throughout life, as was mentioned above in relation to the visual and prefrontal cortices. This is discussed in greater detail in the next section of the dissertation. But since this study has also both L1 and L2 participants, the matter becomes even more complicated. Looking at it from a second language acquisition perspective, some linguistic aspects are modifiable only very early in life (phonology and grammar), while other aspects are modifiable and, therefore, are also easily learned late in life (vocabulary) (Weber-Fox & Neville, 1996, 1999; Neville & Bavelier, 1998). This also has to be taken into consideration.

2.3.4 Age of onset of blindness

According to Büchel et al. (1998), there is a considerable capacity for functional reorganization of the visual cortex during the first three months after birth. An elevated metabolism in the visual cortex has also been found in the early blind but not in the late blind (i.e. after puberty). Other research teams have, on the other hand, suggested 14 or 16 years of age as the upper limit for functional reorganization of the visual cortex (Cohen et al., 1999; Sadato et al., 2002), while, for example, Kujala et al. (2000), Burton et al. (2002b) and Pascual-Leone et al. (2005) insist that the visual cortex is capable of considerable plastic changes throughout the lifespan.

Pascual-Leone et al. (2005) characterized plasticity as a normal and ongoing state of the nervous system throughout the lifespan, and they speculated that this might also characterize the visual cortex. In a research project by Pascual-Leone and Hamilton (2001), sighted volunteers were
trained on auditory and tactile tasks while blindfolded for five entire days. During this time, the subjects underwent a series of fMRI studies on tactile and acoustic/auditory stimuli. Non-blindfolded control subjects wore blindfolds only during experiments and fMRI studies. The researchers found that the visual cortex became increasingly activated in the blindfolded subjects as the days wore on, compared to the non-blindfolded subjects who showed no such activation. This occipital activation by auditory and tactile stimuli disappeared 12 to 24 hours after the removal of the blindfold. Since functional changes in the occipital cortex occurred after only five days of blindfolding, the researchers drew the conclusion that somatosensory and auditory connections to the visual cortex must already be present in the nervous system, “unmasked” when behaviorally desirable. Pascual-Leone and Hamilton (2001) claimed, however, that the mechanisms involved after only five days of blindfolding are different from those plastic changes that take place in blind individuals that are permanently deprived of visual input. To explain this, the researchers proposed a conceptual framework, in which they found it reasonable to assume that the brain reorganizes itself to be able to exploit the available sensory inputs, and that the identity of the occipital cortex may switch from processing visual information to processing information from other senses. It may also be the case that the occipital cortex inherently possesses the mechanisms necessary for processing non-visual information, being an “operator” of a given function based on the available input. The researchers concluded that two mechanisms, originally suggested by Burton (2003), are inextricably linked. The first is that new sensory associations and connectivity patterns are created as a result of visual deprivation, that is, of cross-modal plastic changes, and the second mechanism is that functions that are inhibited or masked in the sighted become revealed by visual loss (expression of normal physiology, unmasking of silent synapses). The unmasking of pre-existing connections are rapid early-occurring plastic changes, which might be followed by more permanent and slower developing structural changes if sustained and reinforced (Pascual-Leone et al., 2005).

Within modality reorganization is also highly influenced by the timing of sensory deprivation, and it is still uncertain whether reorganization in late onset deprivation is similar to reorganization in early onset deprivation, according to Bavelier and Neville (2002). It is, however, an established fact that an early onset is preferable since the capacity of the nervous system to modify its organization is greater early in life. Sathian (2005:283) concluded that: “Although the precise duration of this critical period remains unclear, it seems safe to conclude that cross-modal plasticity due to blindness that occurs after puberty is more limited than that observed in those who are born blind.” The findings of Veraart et al. (1990) in their study on glucose utilization and metabolic activity in the visual cortex in early and late blind
individuals support this conclusion, but they also shed light on the different prerequisites of early and late blind individuals. The researchers found that early blind individuals display an elevated metabolism in the visual cortex. Elevated levels of glucose utilization and metabolic activity are usually associated with the period of overproduction of synapses observed during cortical development, in all cortical regions, and they are followed by a fall in amount of synapses to adult levels. This rise and fall in synapse formation might control the timing and duration of the sensitive periods (Neville & Bavelier, 2001). Veraart et al. (1990) also found that for the late blind – those who become blind after the completion of visual cortical development – had lower levels of glucose utilization in the visual cortex. These findings suggest that the visual cortex in early blind, but not in late blind, display a higher degree of use-dependent plasticity, even in adults. For a further discussion on the effect of age of onset of blindness on structural development, see Noppeney et al. (2005).
Chapter Three  
General Methodology

In this chapter, the general methodological outline of the whole study will be presented. There are descriptions of the participants and of the study design, the different selection criteria applied, the screening tests used, the participant recruitment procedure, the data collection procedure (with the exception of the foreign accent rating experiment data collection procedure which is described in study III) and of the statistical methods and data management procedures of the study.

3.1 Participants and study design

The total number of participants in this study was 80: 40 L1 speakers and 40 L2 speakers. These two groups were primarily divided into three subgroups each: 11 early blind (EB), 9 late blind (LB), and 20 sighted (S), resulting in a 2 (language background: L1 or L2 speaker) X 3 (visual status: early blind (EB), late blind (LB), sighted (S)) design.

The aim of the study was to investigate the prerequisites for L2 acquisition in blind individuals, and the L2 learners/speakers of the study thus specifically represent the L2-learner group. It was relevant to include both groups, that is, both blind L1 and L2 speakers, to investigate whether they have the same or different prerequisites for acquiring a language, since there might be cognitive advantages associated with second language acquisition and to being an active L2 learner/speaker living in a second language environment. The inclusion of the L2 speaker group was also motivated by the aim of investigating the anecdotal claim that blind L2 speakers produce a more nativelike accent in an L2 than sighted L2 speakers, since accentedness in an L2 was investigated in the study. It should, however, be pointed out that the significance of the L2 factor is not at all clear in relation to the other areas of investigation. The inclusion of both L1 and L2 speakers thus make it possible to discern whether possible group differences could be attributed to the language background factor (i.e. to being an L1 or L2 speaker) and/or to the visual status factor (i.e. to being early blind, late blind or sighted), or to an interaction between both factors. In the latter case, one of the visual status
groups would be more or less advantaged than the other visual status groups because of belonging to either the L1 or L2 speaker group.

All groups were matched on a set of covariates (age, gender, level of education), and sighted and blind L2 groups on mother tongue/s, but differed on the critical variables of interest (language background: L1/L2; and visual status: early blind, late blind, sighted). This matching was performed in order to minimize the risk that any group differences revealed are attributable to the covariables rather than the critical factors examined. Background data on the participants are presented in the following sections. First, the background data of the L1 speakers is presented, which is then followed by a presentation of the background data of the L2 speakers. A section is also devoted to a comparison between the background data of both L1 and L2 speakers.

Since the blind communities (especially the L2 blind community) in the Greater Stockholm, Uppsala and Göteborg areas are small, detailed description of the individual participants has been avoided, in order that the participants cannot be identified. The background details are thus described on a group level. Sometimes information is presented both in writing and in tables or figures. This is done in consideration of blind readers, since they will have to read the information in “black print,” since they cannot read tables or figures on their computers. This also applies to the presentations of results in each substudy.

3.1.1 Background data for the L1 speakers

The variables age, educational background, occupational status, age of onset of blindness and length of blindness are presented in this section, as well as the distribution by sex in the L1 speaker group. The mean age of all L1 speakers was 46.53, SD = 9.93. Table 3.1 presents this information for each visual status group separately. The educational background of the speakers was generally quite high: 1 had some secondary school, 6 had completed secondary school, 6 had some university studies, 26 had completed tertiary/university studies (i.e. Bachelor’s or Master’s degree), and 1 had completed postgraduate university studies (i.e. Ph.D/Doctoral degree). Table 3.1 presents this information for each visual status group separately. The occupational status of the L1 group is presented in table 3.1, and it shows that 31 were working, 2 were unemployed, 4 were retired (early retirement), and 3 were students. In table 3.1 this information is presented for each visual status group separately.

Age of onset of blindness (AOB) naturally differs between the early blind (EB) group and the late blind (LB) groups; this information is presented in table 3.5, where a comparison is made between the L1 and L2 speaker groups. In the EB group, all participants became blind as children, $M = 2.14,$
General Methodology

SD = 3.00, range: 0–7 years of age). In the LB group, all participants became blind as adults, that is, after the age of 18: $M = 33.56, SD = 8.21$, range: 26–50 years of age. The length of blindness (LOB) also naturally differed between the group EB and the LB group: EB, $M = 44.41, SD = 10.70$, range: 29–60 years, and LB, $M = 17.67, SD = 10.49$, range: 6–36 years. The L1 group consisted of 10 women and 30 men. None of the speakers suffered from dyslexia or hearing impairments. Statistical comparisons on all background variables were conducted, and there were no statistical differences, on any variable, between the different visual status groups.

3.1.2 Background data for the L2 speakers

The variables presented in this section are age, educational background, occupation, age of onset of L2 acquisition, length of residence, age of onset of blindness, length of blindness, L1 backgrounds and the distribution by sex in the L2 speaker group. The mean age of all L2 speakers was 48.2, $SD = 8.19$, range 27–61; table 3.2 presents this information for each visual status group separately. The educational background of the speakers was generally quite high: 1 had completed primary school, 10 completed secondary school, 10 had some university studies, 17 had completed tertiary studies (i.e. Bachelor’s or Master’s degree) and 2 had completed postgraduate university studies (i.e. Ph.D/Doctoral degree). This information is presented in table 3.2

Table 3.1. Background data on early blind, late blind and sighted L1 speakers on the variables age, education and occupation. M, SD and range are presented in relation to age, and the number of participants in relation to education and occupation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Visual status</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EB (n=11)</td>
<td>LB (n=9)</td>
<td>S (n=20)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>46.55</td>
<td>51.11</td>
<td>44.45</td>
</tr>
<tr>
<td>$SD$</td>
<td>9.97</td>
<td>8.19</td>
<td>10.36</td>
</tr>
<tr>
<td>Range</td>
<td>34–60</td>
<td>36–62</td>
<td>21–64</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary school</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some secondary</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Secondary school</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Some tertiary</td>
<td>10</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Tertiary (Bachelor/Master)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postgraduate (PhD)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working</td>
<td>10</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Unemployed</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Early retirement</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Student</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

Note. EB = early blind; LB = late blind; S = sighted
for each visual status group. According to the occupational status of the L2 group, 30 were working, 4 were unemployed, 2 were retired (early retirement) and 4 were students. Information for the individual visual status groups is presented in table 3.2.

All L2 speakers had arrived in Sweden after the age of 18, which means that they had an age of onset above 18 (AO<18), and the mean AO was 27.13, SD = 5.88 for the whole L2 group. Table 3.3 presents this information for the individual visual status groups. The average length of residence (LOR) in Sweden was 21.03 years, SD = 7.98, and this information is presented for each visual status group in table 3.3.

The age of onset of blindness (AOB) naturally differed between the early blind (EB) group and the late blind (LB) group. In the EB group, all partici-
pants became blind as children: $M = 2.59$, $SD = 2.60$, range: 0–9 years of age. Nine out of ten became blind before the age of 4.5. In the LB group, all participants became blind as adults after the age of 18, $M = 27.11$, $SD = 7.88$, range: 19–40 years of age. This information is presented in table 3.5. The length of blindness (LOB) differed between the groups: EB, $M = 43.41$, $SD = 11.13$, range: 20.0–58 years, and LB, $M = 16.89$, $SD = 9.62$, range: 8.0–31.0 years.

The L2 speakers had varying L1 backgrounds, and some were monolingual as children and others were successively bilingual; for example, they had Persian, Turkish, Arabic, Sorani, Kurmanji, Amrinja, Tigrinja, Bosnian or Polish as L1/L1s. The L2 group consisted of 11 women and 29 men. Statistical comparisons on all background variables were conducted, and there were no statistical differences, on any variable, between the different visual status groups.

3.1.3 Comparisons between L1 and L2 speakers on background data

This section compares and discusses the background data of the L1 group and the L2 group. As can be seen in table 3.4, there are no major differences between the L1 speaker group and the L2 speaker group in relation to age. The educational level of the L1 and L2 speaker groups differ slightly. Background data on the variable occupation, presented in table 3.4, shows that there are no differences between the two language background groups.

Since there were groups of early and late blind individuals among both L1 and L2 speakers, the variables age of onset of blindness and length of blindness can be compared. As can be seen in tables 3.5 and 3.6, there are no major differences between early blind L1 speakers and early blind L2 speakers or between late blind L1 and late blind L2 speakers.
All differences between L1 speakers and L2 speakers on background data were also compared statistically, and none showed statistical significance.

3.2 Selection criteria

The different selection criteria applied in this project are described below:

Criterion 1, relevant to all participants
Criterion (1), language processing difficulties: no participants suffering from dyslexia or other known difficulties in language processing were selected for the project.

Criteria 2–3, relevant to all L2 participants
Criterion (2), AO of L2 acquisition: all L2 participants were required to have arrived in Sweden after 18 years of age (AO<18). Criterion (3), proficiency level of Swedish: all L2 participants were required to have finished at least secondary school grade level of Swedish.

Another aspect that was considered during the selection process, but was not a specific criterion, was the dialectal aspect of Swedish. The aim was to find as many L2 participants as possible speaking the same dialect of Swedish spoken in or near the Greater Stockholm area, so that the panel of L1 judges of the Foreign Accent Rating experiment would not be confused by both foreign accents and dialectal aspects of Swedish. Unfortunately only 17 blind L2 participants fulfilled all criteria in the Greater Stockholm and Uppsala areas, and 3 blind L2 participants were included from Göteborg, the second largest city of Sweden. In a pilot run of the Foreign Accent Rating
experiment, which was conducted at the Centre for Research on Bilingualism, no dialectal aspects were observed among the speech samples. The judges were researchers employed at the Centre for Research on Bilingualism, and several of them were professional phoneticians. After the experiment, the test leader asked the judges specifically whether any dialectal features had been observed among the samples and, since none of the judges had observed dialectal features, the speech samples from the participants from Göteborg were included in the experiment (study III).

**Criterion 4, relevant to blind L2 participants**
Criterion (4), current visual status: all blind participants were required to have been classified as blind or as severely visually impaired, that is, able to distinguish only between light and darkness.

**Criterion 5, relevant to EB L2 participants**
Criterion (5), age of onset of blindness (AOB): all participants had become blind as children (well before puberty).

**Criterion 6, relevant to LB L2 participants**
Criterion (6), AOB: all participants had to have been able to read enlarged black print until at least 18 years of age, becoming blind or severely visually impaired later in life.

**Criterion 7, relevant to sighted L2 participants**
Criterion (7) matching the blind L2 participants: all sighted L2 participants were selected in order to match the blind L2 participants concerning age, gender distribution, educational background and linguistic background.

The L2 participants had varying linguistic backgrounds, e.g. Persian, Arabic, Turkish, Polish, Amrinja, Tigrinja, Serbian, Bosnian, Sorani and Kurmanji (two Kurdish dialects), and the blind groups and the sighted groups matched each other, even in those participants who became bilingual during childhood, which means that if a blind participant was successively bilingual in childhood (for example, having Sorani as the mother tongue and having learned Arabic at a young age when playing with other children), this participant was matched with a sighted participant who had successively begun learning the same pair of languages during childhood. The first thing that most people think characterizes the speech of an immigrant is that it is accented, and since the accent tends to be influenced by the characteristics of the mother tongue, special concern was taken in order to make the groups well matched for this linguistic aspect, since this study specifically investigated degree of accentedness in L2 speech production. There were five blind successively/sequentially bilinguals that participated in the testing, having
acquired one language at home with the parents and a second language some time after three years of age at school or from friends.

**Criterion 8, relevant to all L1 participants**

Criterion (8), matching the L2 participants: the L1 group was selected in order to match the L2 group concerning age, gender distribution, educational background, visual status and age of onset of blindness.

### 3.3 Initial screening tests

Three different screening tests were used during the selection of participants. One of the tests was used on all participants, while two were used on the L2 speakers and was related to their proficiency level of Swedish. The L2 participants had to be very proficient L2 speakers of Swedish, since some of the tests included in the test battery demanded a high level of Swedish proficiency.

1. A judgment of L2 proficiency level was made by the research leader during initial contacts, when information about the project was provided in Swedish during conversation with the potential participant. If this primary communication was characterized by mutual understanding and fluency in conversation, the potential participant was asked to participate in the project.

2. If the potential participant accepted the invitation to participate in the project, a highly demanding auditory grammaticality judgment test (aGJT, appendix 6) written in Swedish was distributed. Those who scored below the first quartile were later excluded from the project and replaced by another participant. Potential new participants had to score above the same lower quartile value.

The aGJT consisted of 40 Swedish sentences recorded at the Department of Linguistics at Stockholm University. The sentences were spoken by a voice professional mother tongue speaker of Swedish. The aGJT was a simplified and shortened version of the aGJT developed for the project “Age of onset and ultimate attainment in second language acquisition” (good internal consistency, Cronbach's alpha coefficient .8, Bylund, personal communication, April 11, 2014). Half of the sentences were grammatically incorrect, and half were correct. The errors were related to four different grammatical structures/aspects of Swedish that generally present difficulties to someone learning Swedish as a second language: inversions, reflexive possessive pronouns, sentential adverbs in subordinate clauses (relative clauses) and concord/agreement. The original version of the test was simplified and shortened by deleting subordinate clauses from the sentences.
Equipment and procedure: The aGJT was the first test performed during the data collection procedure (see description below). The sentences were presented using E-Prime, version 1.1 (1.1.4.1), Psychology Software Tools (for technical specifications on E-Prime: Schneider, Eschman & Zuccolotto, 2002a, 2002b) and a pair of headphones, namely, the Sennheiser PC 350 model with adjustable volume. The sentences were presented in a fixed randomized order. After each sentence the participants pushed either a button for “right” or a button for “wrong” on a serial response box (serial response box Model no. 200A (serial no. SRB200-06633) Copyright 1993–2003 Psychology Software Tools Inc). The button for “right” was green and marked with a smiling face, and the button for “wrong” was red and marked with a frowning face. For the blind participants, the two buttons were marked with “right” or “wrong” written in braille.

(3) All participants were required to have normal hearing abilities, and an audometric hearing test was therefore distributed as a screening test, as well.

It has generally been found that auditory sensory thresholds of congenitally blind individuals do not differ from those of sighted individuals (Niemeyer & Starlinger, 1981; Starlinger & Niemeyer, 1981; Röder & Neville, 2003), although Rokem and Ahissar (2009) actually found that they have slightly lower auditory sensory thresholds.

3.4 Participant recruitment procedure

The blind participants of the study were located in the Greater Stockholm area, as well as Göteborg. To find suitable participants who fulfilled the selection criteria, different strategies were used:

(1) Advertising in two different newspapers for blind individuals in the Stockholm area: Läns och riksnytt and På tal om Stockholm.

(2) Contacting the national organization for the blind, Synskadades Riks- förbund (SRF), in both Stockholm and Göteborg, and also Stockholms Syncentral and Uppsala Syncentral, sections of the national health care system that assist blind individuals with suitable equipment for daily life as a blind, as well as habilitation/rehabilitation.

(3) Contacting Språkcentrum (Centre for languages) in Stockholm, a subsection of the educational system of Stockholm responsible for mother tongue education.

(4) Personal contacts and by spreading the word about the need for suitable participants for the project.
Primarily, the focus was on finding blind L2 speakers, since there are not many in the Greater Stockholm area that fulfill all selection criteria. Of all the blind L2 speakers asked to participate, only three declined in the Greater Stockholm area. Two participants were also selected from the Uppsala area close to Stockholm. Investigations to find more suitable participants in the rest of the Mälardalen area (where both Stockholm and Uppsala are situated) did not result in finding blind L2 speakers with a high enough level of Swedish proficiency, so the search then continued in Göteborg, the second largest city of Sweden, where the last three participants were located. As the data collection procedure was initiated for the blind L2 participants, matching sighted L2 speakers were located, as well as matching blind and sighted L1 speakers. The sighted L2 speakers were found via personal contacts and by the aid of Språkcentrum. The blind L1 speakers were located via SRF, personal contacts and via the advertisements in the newspapers mentioned above. The sighted L1 speakers were mostly found via personal contacts.

3.5 General data collection procedure

The data was collected at the Centre for Research on Bilingualism, at the home of the participants (only in a few cases and only with blind participants) or at SRF or Syncentralen. The conditions were always quiet, and there was no time limit. The approximate time of data collection was 2 to 2.5 hours for the L2 speakers, and 1.5 hours for the L1 speakers. It took a longer time for the L2 speakers, since recordings of their spoken Swedish were also made for the Foreign Accent Rating experiment.

All participants were informed that they would be treated anonymously, and that they could terminate their involvement at any time that they were so inclined to do so. The L2 participants received a payment of 300 SEK, and the L1 speakers of 200 SEK.

3.6 Statistical methods and data management

Multiple comparisons of continuous data were performed by analysis of variance, ANOVA. If results violated normality (assessed using Kolmogorov-Smirnov), non-parametric and parametric techniques were compared. In those cases where both techniques presented the same significant group differences, the parametric technique ANOVA was selected, and, if not, the non-parametric technique Kruskal-Wallis Test was used in the analysis. In the case of a statistically significant result in the ANOVA, statistical comparisons in order to test differences between groups, post-hoc comparisons, were made by the use of method proposed by Bonferroni to control for multiplicity when comparing the groups (Daniel, 1995; Montgomery, 1991). In
cases where a non-parametric technique was used, post-hoc comparisons were performed using Mann-Whitney. In addition to that, descriptive statistics and graphical methods were used to characterize the data. Rankings of the participants were also made on each test.

The study employed testing of multiple hypotheses, where each hypothesis was analyzed separately and the existence of patterns in and the consistency of the results were considered in the analysis. All analyses were carried out by use of IBM SPSS Statistics, version 21, and the standard 5% level was considered to be statistically significant.

When effect-size statistics were performed, the strengths of associations were interpreted according to the guidelines of Cohen (1988, presented in Pallant, 2013:218) for group comparisons (both eta squared and partial eta squared): .01 = low, .06 = medium, .138 = large, and for correlations (Pallant, 2013:139): small $r = .10$ to .29, medium $r = .30$ to .49, large $r = .50$ to 1.0.
4.1 Introduction

Researchers have found that language processing is closely related to working memory functions, especially the phonological short-term memory functions that have been found to be particularly important to the acquisition of new vocabulary, both in child L1 acquisition and in adult L2 acquisition (Papagno, Valentine & Baddeley, 1991; Baddeley, 2003; Martin, Shelton & Yaffee, 1994; Gathercole & Adams, 1993; Baddeley, Gathercole & Papagno, 1998; Gathercole et al., 1992; Gathercole & Baddeley, 1989, 1990). Forming long-term representations of new phonological material is actually seen as a key component in language development (Papagno, Valentine & Baddeley, 1991). Enhanced phonological short-term memory functions have been associated with language talent (Papagno & Vallar, 1995) and L2 oral fluency gains (O’Brien et al., 2007), as well as with faster acquisition rates and ultimate L2 attainment (Bolibaugh & Foster, 2013). Phonological short-term memory advantages have not only been found in bilinguals (Papagno & Vallar, 1995), but also in congenitally blind children and adults (Hull & Mason, 1995; Röder & Neville, 2003; Swanson & Luxenberg, 2009; Rokem & Ahissar, 2009), something that suggests that experience and use can affect the development of the phonological short-term memory.

It is not only phonological short-term memory functions that have been found to be important to L2 vocabulary acquisition, but also the ability to recognize novel phonological word forms the second time they are heard, a phenomenon that is sometimes called phonological sequence learning (Speciale, Ellis & Bywater, 2004). This ability taps auditory recognition memory (which is classified as an episodic memory function). The ability to recognize new phonological material enables not only vocabulary acquisition, but also the recognition and acquisition of grammatical features such
as morphological variations (Meara, 2005; Granena, 2013; Service, 1992; Service & Kohonen, 1995) and the acquisition of syntax (Papagno & Vallar, 1995). This ability is also seen as a key component in language learning aptitude (Meara, 2005; Granena, 2013). The ability to recognize new phonological material (recognition memory) and phonological short-term memory have actually been found to make additive contributions to receptive and productive L2 lexical competence (Speciale, Ellis & Bywater, 2004). Word recognition memory has also been investigated in congenitally blind adults, and it has been found that they perform superior to sighted individuals in this regard (Röder, Rösler & Neville, 2001; Raz et al., 2005), suggesting that this function can also be improved by extensive training and experience, including, for instance, experience built upon the inability to use the visual sense.

It can be concluded that both phonological short-term memory and word recognition memory are related to the ability to remember or recognize aspects of the sound system of language, that is, to the sound signal itself, but how about a general ability to remember the event of hearing information being presented in the L1 or the L2? In this case, the actual characteristics of the sound signals of the language are secondary, and the focus is instead on remembering events. No prior studies of blind individuals ability to remember events have been found (episodic memory), and it might be hypothesized that blind individuals have developed their episodic memory capacity to a greater extent than sighted, since they are more dependent on their ability to remember things in general than sighted individuals, who constantly are aided by being surrounded by written material in daily life. Written visual information surrounds and supports us to a great extent, complementing auditory and tactile information that might not be as salient as visual information.

In order to investigate phonological short-term memory and recognition memory for novel/foreign phonological sequences – memory functions especially important to L2 acquisition, related to the acquisition of the sound system of language – three phonological short-term memory tests, as well as one test of foreign sound sequence recognition, will be used in the current study. An episodic memory test, measuring the ability to remember the event of hearing facts being presented in either the L1 or the L2, is also included in order to investigate whether the advantages in memory functions found in congenitally blind individuals can be associated with a more general memory advantage or if it mainly seems that they are related to the processing of the sound system of language.

The questions that follow from this introduction are: Do early blind individuals have a better phonological short-term memory performance than late blind and sighted individuals do? Do early blind individuals have a better recognition memory for new sound sequences than late blind and sighted
individuals do? Do early blind individuals have a better episodic memory performance than late blind and sighted do, in this case, the ability to remember the event of hearing information presented auditorily?

4.2 Theoretical background

This section is divided into three areas related to different aspects of cognition. The first section is devoted to phonological short-term memory, which is discussed using the framework of the multi-component working memory model proposed by Baddeley and Hitch (1974). The second section covers recognition memory (a subcategory of episodic memory), and the last section episodic memory. Existing research in relation to both blind individuals and bilinguals/second language acquisition will be presented.

4.2.1 Phonological short-term memory and the working memory model

In recent years working memory has been a major focus in cognitively oriented SLA research, and the multi-component working memory model proposed by Baddeley and Hitch (1974) has been the most influential model in this research (Yilmaz, 2012). The working memory model, presented in figure 4.1, will be used as a framework in the current study as well.

All subcomponents of the model will be presented below, but with a greater focus on the phonological short-term memory subcomponent (the phonological loop), which is of great importance to second language acquisition and investigated in the current study using three different phonological short-term memory tests.

Baddeley and Hitch (1974) proposed a fairly simple system capable of handling a wide range of cognitive abilities. This multi-component model was based on existing research findings on short-term memory and the memory system/s responsible for short-term memory that form a part of working memory. Unlike short-term memory, which is a simple and temporary storage of small amounts of information (which can only be tested immediately or after a short delay), the working memory also manipulates this information.

The original three-component version of the model consisted of an attentional control component and two temporary short-term storage components: one processing verbal information and one responsible for visuo-spatial information. These components are seen as processes and storage systems that are tightly interlinked within the separate modules and more loosely linked between the modules, also being remotely connected to long-term memory and perception systems. The central controller was termed the
Blindness and Second Language Acquisition

“central executive”; the verbal system initially termed “the articulatory loop” but later, and currently, called “the phonological loop”; and the last component “the visuo/spatial sketchpad.” The model has continued to evolve during the 40 years since it was first proposed, and it should still be considered as “a relatively loose theoretical framework, rather than a precise model that allows for specific predictions” (Baddeley, 2012:7). The phonological loop component was studied first, based on early research on verbal short-term memory. This research was focused on, for instance, the acoustic similarity effect of similar sounding sequences of letters and words. The acoustic similarity effect is a tendency for immediate serial recall of verbal material to be reduced, when items are similar in sound (Baddeley, 2012). For more details on research related to the phonological loop, see below. The very complex central executive component, responsible for attentional control of action, was further developed by the incorporation of the Norman and Shallice (1986) model describing attention to action (see below). Many years later Baddeley (2000) added a fourth component, “the episodic buffer.” This component was added to account for the integration of codes from different subsystems, for example, the integration and combination of visual and phonological information particularly evident in language processing, through a common storage.
In the following sections, the different components of the working memory model will be presented, as well as existing research from SLA and on blind individuals, investigating these components.

4.2.1.1 Central Executive

The central executive is seen as the most complex part of working memory, able to do all the processes that are not handled by the other subcomponents of the working memory. In the original version of the model, it was thought to be like “a man in the head.” The tasks that have been used in research on the central executive have generally been designed to interrupt the central executive, by being attentionally demanding, involving simultaneous performance of more than one task. There is an example provided in Baddeley (2012) in which counting backwards in threes from a number such as 271 is thought to be loading on the central executive, while simple repetition of the digits 271 is not. In going into greater detail on the different functions of the central executive, it is thought to be able to (a) focus attention, (b) have the capacity to divide attention between two simultaneous streams of information, (c) switch between tasks, and (d) have the capacity to interface with long-term memory. Bilinguals have typically been found to outperform monolinguals on measures of executive functions, and this advantage seems to persist throughout the lifespan (Bialystok et al., 2004; 2005; Stocco et al., 2014). A variety of different executive tasks have been used, for instance, the Simon task, task-switching paradigms and tasks where the participant has to manage internal response conflicts (for references related to different types of tasks, see Stocco et al., 2014). Factors that have been found to influence bilingual executive functions are the amount of bilingual experience and the ability to control the use of the two languages. Three important components of executive functioning have been described: inhibition (inhibiting one language in favor of another, language selection), shifting (switching between languages) and updating (continuous monitoring and deletion of content from working memory) (Stocco, et al., 2014; Miyake et al., 2000), and the former two have been associated with better inhibitory control and switching processes in bilinguals.

Interestingly enough, in a study of high-level language proficiency (Linck et al., 2013), it was found that high-level L2 attainment was not associated with high scores on executive functioning, but rather with phonological short-term memory performance, associative learning and implicit learning.

In a study by Swanson and Luxenberg (2009), the working memory model was used as a framework to capture differences in performance between blind and sighted children. The researchers focused on short-term and working memory in blind children, and their results suggest that there are domain specific aspects in the central executive system. This conclusion was drawn from results showing that blind children were superior to sighted
children on measures on phonological short-term memory but not on measures of working memory. The advantages in blind children were seen on tests related to the phonological loop functions: sentence repetition, serial word recall (both tests are subtests of the Detroit Test of Learning Aptitude, version 3) and forward and backward digit span, but not on the working memory tests that were used in order to measure executive functions. In Rokem and Ahissar (2009), on the other hand, auditory backward digit span was used to measure CE functions in congenitally blind adults, since backward repetition presumably requires conscious control of the repetition process.

In another study on adult blind monolinguals (Finnish) and bilinguals (Finnish/Swedish), the attention control in relation to perception of syllables was investigated using a dichotic listening paradigm, whereby two different sounds were presented at the same time, one in each ear. The stimuli were often CV syllables and a so-called “right ear advantage” was usually found as participants typically reported more correct items when paying attention to the sounds in their right ear. This was interpreted as a left hemisphere dominance for speech perception (speech perception is located in the left hemisphere of the brain), and the magnitude of the right ear advantage was associated with the degree of hemispheric specialization (Hugdahl et al., 2004). Of the 14 blind participants, 6 were congenitally blind, and 8 had been blind for 25 to 55 years. Their age of onset of blindness was, however, not discussed, so it is not clear if these participants became blind during childhood or as adults. The mean age of the blind participants was 48.64 (SD 9.17). The controls consisted of 129 sighted Finnish-speaking individuals. In their study, interest was not on the aspect of mono- or bilingualism, so no investigation of possible group differences in relation to mono- and bilingualism was conducted. But the results of the dichotic listening paradigm showed that the blind participants outperformed the sighted in three different conditions: (1) a non-forced attention condition, (2) a forced-right (FR) condition (participants were told to focus/pay attention to the right ear stimulus and ignore the stimulus presented in the left ear) and (3) a forced-left (FL) attention condition (which is the opposite of the FR condition). In sum, the blind individuals showed enhanced attentional ability perceiving and identifying speech sounds, which suggests an advantage in central executive functions in blind individuals in relation to verbal material and phonetic processing, that is, in relation to the sound system of language.

4.2.1.2 The phonological loop

4.2.1.2.1 Characteristics and functions of the phonological loop component

According to Baddeley, Gathercole and Papagno (1998), the phonological loop is the subcomponent of the working memory model that has been most
extensively studied. It is specialized for retaining phonological information over short periods of time and comprises two different functions: (1) a phonological store that holds information in phonological form (temporal capacity about 2 seconds) and (2) a vocal or subvocal rehearsal process, which maintains decaying information in the phonological store through rehearsal. The phonological loop processes are rapid and require minimal attention (Baddeley, 2012). Although generally discussed in relation to storage of heard and spoken material, some research suggests that the phonological loop is activated by other types of language-related processes, such as sign language processing (Rönnberg, Rudner & Ingvar, 2004). Its role in other types of non-linguistic auditory information processing, for instance, in relation to environmental sounds, is not very well explored. In a study comparing the performance of memory on verbal and musical sequences, the results suggest that there is a limited correspondence between verbal and musical processing in auditory short-term memory (Williamson, Baddeley & Hitch, 2010).

Research findings have shown that the capacity of the phonological loop can be diminished when the list of items to be repeated consist of (a) many syllables (the word length effect is a tendency for the verbal memory span to decrease when longer words are used; Baddeley, 2012), (b) have similar sounding items (the phonological similarity effect is a tendency for immediate serial recall of verbal material to be reduced, when the items are similar in sound; Baddeley, 2012), (c) when participants have to continuously utter a word like “the” during repetition of the items (the articulatory suppression effect, which is a technique for disrupting verbal rehearsal by requiring participants to continuously repeat a spoken item; Baddeley, 2012) and (d) when irrelevant speech or music is presented simultaneously (irrelevant sound effect is a tendency for verbal STM to be disrupted by concurrent fluctuating sounds, including both speech and music, and both perception and recall becomes impaired, according to Baddeley, 2012). For more information on the four different effects, see Baddeley, Thomson and Buchanan (1975), Conrad and Hull (1964) and Murray (1967).

These findings have led to the following conclusions about the characteristics of the phonological loop. The phonological similarity effect has led to the conclusion that some kind of phonological storage is involved. This conclusion was based on the finding that the phonological similarity effect appears only when there is a brief delay between perception and recall, but not when there is a longer delay, suggesting different effects on different types of storage (acoustic vs. semantic storage, Baddeley & Ecob, 1970). In Baddeley, Thomson and Buchanan (1975), a study in which immediate recall of words was used to study the word length effect, participants repeated as many words as they could repeat in approximately two seconds, which was then assumed to be the upper time limit of the phonological short-
term store component. When articulation was suppressed, using an *articulatory suppression* paradigm, the word length effect remained if items were presented auditorily but not when items were presented visually, leading to the conclusion that the store was phonemically based. Based on these findings the researchers suggested that auditory presented or spoken material gains immediate access to the phonological short-term store component, since a phonological code is already available through the verbal signal. Written material, on the other hand, first has to be subvocalized in order to access the phonological short-term component. Baddeley and colleagues thus concluded that there was a phonemically based short-term store, which handled approximately two seconds of verbal material (Baddeley, Lewis & Vallar, 1984).

Conclusions on the characteristics of the second of the subcomponents of the phonological loop, the vocal or subvocal rehearsal process, were drawn from the finding that performance on the immediate recall of sequences of five words of varying length (one to five syllables) declined systematically with word length. It was assumed that the rehearsal process occurred in real time, that is, the actual time it takes to articulate a word, and that rehearsal of longer words resulted in more trace decay and poorer results (Baddeley, Thomson & Buchanan, 1975). The conclusion drawn was that the rehearsal process and short-term forgetting are affected by trace decay, rather than interference (Baddeley, 2012).

In a study by Colle and Welsh (1976), it was found that immediate serial recall was disrupted by irrelevant speech noise\(^{14}\) (which consisted of a spoken foreign language) but not by white noise.\(^{15}\) Salamé and Baddeley (1982) also demonstrated that it did not matter if the irrelevant speech consisted of nonsense words or real words as the disruptive effect was the same. Vocal music and tones of varying pitch has also been found to have the same interruptive effect on serial recall, provided that there is a fluctuation in pitch (Jones & Macken, 1993). It seems as if the irrelevant sound effect disrupts both the process of perception and impairs recall, whereas white noise only disrupts the perceptual process (Baddeley, Eysenck & Anderson, 2009). An interesting hypothesis proposed by Page and Norris (2003) suggests that it is the serial order mechanism that is interrupted by irrelevant speech, rather than the actual phonological short-term store component. It can be concluded that despite a fair amount of research, the question of how serial order is retained by the phonological loop and why it becomes interrupted by irrele-

\(^{14}\) Irrelevant speech noise consists of multiple voices, also called “babble noise” and “cocktail speech” noise. In the remaining sections of the dissertation, this is referred to as “babble noise.”

\(^{15}\) The audiosignal of white noise sounds like a hissing sound resembling the /SH/ sound of the word “ash” with audible sounds between 20 and 20 000 Hz. (https://www.princeton.edu/~achaney/tmve/wiki100k/docs/White_noise.html)
vant speech or fluctuating sound has not been clearly sufficiently answered. This means, for instance, that there is no explanation for how it is possible that items are sometimes recalled correctly but in the wrong position in the list (Hitch, Flude & Burgess, 2009).

Another aspect that has not been explained fully by the working memory model is its connection to long-term memory and learning. This link has been explored in relation to a clinical case, that of a woman called “PV” (Baddeley, Papagno & Vallar, 1988), and in studies trying to illuminate the role of the phonological loop in vocabulary acquisition in children (for example, in Gathercole & Baddeley, 1989; for more references, see Gathercole & Baddeley, 1993). The clinical case PV suffered from a very specific deficit in the phonological short-term memory, with an auditory digit span of only two digits. Her other intellectual abilities were otherwise preserved. The researcher wanted to investigate the role of the phonological loop in new long-term phonological learning, by requiring PV both to learn words of a foreign language and to remember word-pairs in the L1. Her ability to remember word pairs in the L1 was normal, whereas she failed to acquire any of the words in the foreign language even after ten trials, a time at which the controls performed perfectly. PV was unable to form new long-term phonological forms, that is, to learn new words, leading the researchers to conclude that they had found the function of the loop and also finding proof of a direct link between the loop and the long-term memory (Baddeley, Papagno & Vallar, 1988; Baddeley, 2012).

In research conducted by Gathercole (2006) and Masoura and Gathercole (2005) on vocabulary acquisition in children, it was concluded that the working memory plays a significant role at the initial stages. It was, for instance, found that the immediate recall of nonwords was facilitated if the items had letter structures similar to L1 word forms than if they did not. This wordlikeness effect suggested that information flows not only from the phonological short-term memory, but also in the reverse direction, that is, from the phonological representations in long-term memory to the phonological short-term memory.

4.2.1.2.2 The role of the phonological loop in second language acquisition

The phonological loop mechanism has been studied in a variety of populations in relation to the acquisition of new words, for instance, in normal adults and children (Service, 1992; Service & Kohonen, 1995; Gathercole & Baddeley, 1990; Papagno & Vallar, 1992), in neuropsychological patients (for example, PV, reported on in the former section), in talented language learners (Papagno & Vallar, 1995) and in L2 learners (Nguyen, 2011). The phonological loop has also been studied in relation to the acquisition of syn-
tax (Papagno & Vallar, 1995), where the researchers proposed that the phonological loop might play a crucial role in the acquisition of syntax as well.

It is commonly believed that the phonological store is active as soon as children start to develop their language abilities, while the subvocal rehearsal process is an ability that emerges around the age of seven. Since children use their phonological memory while acquiring vocabulary under the age of seven, Baddeley, Gathercole and Papagno (1998) and Gathercole and Adams (1993) drew the conclusion that it is the phonological store, and not the subvocal rehearsal process, that mediates long-term phonological learning, that is, the learning of new words, in young children.

The subvocal rehearsal process does, however, play a role in L2 learning in adults, according to Papagno, Valentine and Baddeley (1991). In this research, an articulatory suppression paradigm was used in order to explore the role of the phonological loop in L2 vocabulary acquisition. Articulatory suppression is thought to impair performance by minimizing the subvocal rehearsal process but not preventing phonological encoding. It was found that articulatory suppression disrupted the acquisition of foreign vocabulary, but not the learning of L1 word-pairs. Papagno, Valentine and Baddeley (1991) concluded that the phonological rehearsal process plays a role in foreign language vocabulary acquisition, a conclusion supported by subjects reporting difficulties in remembering the sounds of the foreign words when the rehearsal process was impaired. It is further suggested that the function of the phonological loop is to learn novel phonological forms of new words, that is, learning the *sounds* of new words that we are exposed to in our environment. Thus, Papagno, Valentine and Baddeley (1991) proposed that the phonological loop has evolved as a part of human cognition devoted to the processing of novel sound patterns. The phonological loop’s use in retaining already familiar words, for instance, L1 words, is secondary. Its primary purpose is to store these unfamiliar sound patterns while more permanent memory records are being constructed in long-term memory. The phonological short-term store is the mechanism of the phonological loop that is linked to long-term representations. Forming long-term representations of novel phonological material is thus thought of as a key component of language development.

In a research project conducted by Papagno and Vallar (1995), comparisons of different types of memory functions and long-term learning tasks in multilingual adults were performed. They compared adults who spoke at least three languages fluently to adults who had only studied one foreign language at school as children (all participants lived in their L1 environment). The parents of the participants were not bilingual or multilingual. There were no differences between the groups on nonverbal skills, visuospatial short-term memory span, visuospatial learning or on measures on general intelligence. There were, however, differences between the groups
on the two tests on phonological short-term memory functions: auditory digit span and nonword repetition, tests on which the multilingual participants outperformed the control group. Multilinguals were also able to learn more nonwords in a paired-associate learning task (considered to be an experimental analogue of vocabulary acquisition), and the researchers concluded that the better performances of multilinguals are the result of a phonological memory advantage. Baddeley, Gathercole and Papagno (1998:166) commented on the results of Papagno and Vallar (1995) and pointed out that “Once again, good phonological memory performance shares a highly specific link with fast and efficient learning of unfamiliar phonological material [...].” From the study, they drew the conclusion that gifted language learners may have developed a natural talent for language learning because of excellent phonological loop function. Conversely, it has been found that decreased digit span and difficulties in repeating nonwords (two tests measuring phonological loop functions) have been related to failure in L2 acquisition (Ardila, 2003). Ardila (2003) confirmed the crucial role of the working memory in L2 acquisition and concluded that the ability to repeat words in an unknown language predicts success in L2 acquisition.

Speidel (1993) performed a longitudinal study of phonological short-term memory functions in two bilingual siblings, a girl and a boy, during the acquisition of their two mother tongues. While the girl had a normal linguistic development, sounding like a native in both languages, the boy had great difficulties in speaking both languages, which lasted until the age of 12:6, when he still produced simpler sentences in the stronger language and spoke a deviant language in the weaker language, sounding like a foreigner. There were no differences in quality or quantity of language input or general intelligence between the children. There was, however, a difference between the siblings in phonological short-term memory capacity. According to Speidel, it is commonly believed among researchers that children need to have a corpus, that is, a storehouse in the long-term memory, of adult language patterns to be able to acquire adult syntax and grammar. In order to develop such a storehouse of phrases in long-term memory, the child must first process them in the phonological short-term memory, and if the phonological short-term memory capacity is limited, it can be expected that children with this limitation will have greater difficulties and need more trials of the input in order to form long-term knowledge. Children with a limited phonological short-term memory capacity would then have to form sentences from single words or sound units, having no “word order-unit” or ready-made patterns of speech available in long-term memory. This would mean that the limitations of the phonological short-term memory also limit the first language development in relation to vocabulary and lexical acquisition. Interestingly enough, blind children have been found to use imitative speech, verbal routines and formulaic speech, that is, ready-made adult patterns, to a
larger extent than sighted children (Pérez-Pereira, 1994; Pérez-Pereira & Castro, 1992, 1997; Peters, 1994), which would thus support the idea that vocabulary acquisition is done through the creation of a corpus or storehouse of adult ready-made patterns of speech in long-term memory.

Another team of researchers (Speciale, Ellis & Bywater, 2004) studied the relationship between phonological sequence learning (learning of “new word” forms), short-term store capacity and vocabulary acquisition in adult L2 learners, and suggested that the limits of the phonological short-term memory also limit the rate in which an L2 is and can be acquired. This conclusion was also supported by Bolibaugh and Foster (2013), who suggested that the capacity of the phonological short-term memory limit both rate and ultimate L2 attainment.

O’Brien et al. (2007) studied the relationship between phonological short-term memory and L2 fluency gains in adult L1 speakers of English learning Spanish as a foreign language or as an L2 in an immersion context. The results showed that phonological short-term memory, as measured by a nonword repetition task, predicted initial L2 oral fluency (general overall oral ability and fluency) development over time (13 weeks).

Lastly, it should be mentioned that research has indicated that the phonological loop also is of major importance to spoken L2 production, that is, L2 pronunciation, primarily at earlier stages of L2 acquisition, but is not as important in L2 pronunciation at advanced levels of L2 attainment (Hu et al., 2012).

4.2.1.2.3 The phonological loop and blindness

Neuropsychological studies of blind individuals’ verbal short-term memory functions do not generally use the working memory model as a framework. They do, however, use the same tests, as have been used to study phonological loop functions, that is, digit span and nonword repetition. In the study of cognitive perceptual systems that is done in this field of research, most studies have been devoted to verbal long-term memory functions (for instance, Röder, Rösler & Neville, 2000; Amedi et al., 2003; Raz, Amedi & Zohary, 2005) and relatively few on verbal short-term memory functions. A few studies should, however, be mentioned that specifically test the phonological short-term memory functions using digit span measures.

In a study by Hull and Mason (1995) comparing congenitally blind children, children with low vision and sighted children on auditory forward digit span, it was found that congenitally blind children performed significantly higher results than the other two groups. Röder and Neville (2003) compared 11 congenitally blind adults and 11 matched sighted on auditory word and digit spans (both forward and backward). They found that blind subjects scored significantly higher than the sighted controls, confirming the results of Hull and Mason (1995).
Rokem and Ahissar (2009) studied the interaction of cognitive and auditory abilities in congenitally blind adults by employing a variety of tasks that measured short-term memory functions (auditory forward digit span and immediate serial recall of sequences of nonwords from one to five items long, with and without noise), executive memory functions (auditory backward digit span), speech perception (of nonword sequences from one to five items long, with or without babble noise) and two-tone frequency discrimination (same/different and high/low discrimination). Their aim was to find out whether the advantages found in blind individuals on memory and perceptual tasks reflect two separate compensatory mechanisms (that is, both a memory capacity advantage and a stimulus encoding advantage) or just one (a stimulus encoding advantage that, in turn, leads to a better memory performance). The blind participants were superior to sighted on the auditory forward digit span task (3 SDs better), and also on nonword repetition span, that is, on all measures of phonological loop functions relevant to this discussion. When comparing the results on forward and backward digit span, the researchers concluded that when required to manipulate and repeat the digits backwards, the performance was hampered in comparison to forward digit span, and they proposed that the short-term memory advantage results from a better stimulus encoding at an early stage of processing, before the stage at which the stimulus is manipulated. They further proposed that it is the ability of blind individuals to sequence or chunk together speech signal information that supports and leads to memory encoding advantages. As was pointed out above, many blind children use ready-made chunks of adult speech to a larger extent than sighted children (Perez-Pereira & Conti-Ramsden, 1999), which seems to support this argument in relation to linguistic behavior.

Raz et al. (2007) also tested serial recall, as well as recognition memory, in 19 congenitally blind and 19 matching sighted controls. In the serial recall test, the subjects were asked to recall and repeat lists of 20 familiar L1 nouns (everyday objects and places that could be perceived both visually and tactualy, with the list comprising 10 abstract nouns and 10 concrete nouns) in the correct serial order, that is, in the order of presentation. List presentation followed by immediate serial recall was repeated four times. The results showed that the blind participants were remarkably superior to the sighted participants, and the researchers speculated that the ability to remember information (in this case words) in a “route-like” sequential manner is a serial memory function that becomes more well developed in blind individuals due to necessity, being required to remember for instance spatial information while orienting themselves.

In a study by Swanson and Luxenberg (2008) comparing congenitally blind and sighted children on both phonological loop functions and executive functions, it was found that the blind children performed better than
sighted children on the test measuring phonological loop functions, but not on the test measuring executive functions.

4.2.1.3 The episodic buffer

The episodic buffer component of the working memory model was added in the year 2000 (Baddeley, 2000). It holds integrated multidimensional episodes or chunks of information emanating from the other subsystems of the working memory model (the phonological loop and visuospatial sketchpad). It has a limited storage capacity of approximately four chunks. Initially, it was hypothesized that information from the phonological loop and the visuospatial sketchpad had to pass through the central executive, which controlled the access to the buffer component, but in a series of studies (referred to in Baddeley, 2012) aimed at clarifying the linking mechanism between the components and the buffer, it became clear that this was not necessarily the case. In studies aimed at clarifying the linking mechanism between the buffer and the visuospatial sketchpad, that is, the visual binding mechanism, it was found that the linking mechanism was not disrupted by a concurrent task that was heavily demanding to the central executive, leading to the conclusion that information did not have to pass through the central executive in order to get to the buffer component, but instead passed directly from the visuospatial sketchpad to the episodic buffer. The role of the central executive and the buffer in verbal binding, specifically, in this case, the binding of words together into chunks during retention of spoken sentences, was also studied and, as with visual binding, it was found that the binding process was not interrupted by concurrent tasks. The binding together of sentences is therefore assumed to operate automatically within the long-term memory. The conclusion from these studies of visual and verbal binding in working memory produced evidence that contradicted the original hypothesis stating that the binding processes are achieved within the buffer component. Instead, the buffer is now regarded as a passive component in which different types of bindings, achieved elsewhere, become integrated. The buffer also links working memory to long-term memory and perception. Conscious awareness is needed in order to retrieve information from the buffer.

To this author’s knowledge, there is no research on the episodic buffer in bilinguals or in blind individuals.

4.2.1.4 The visuospatial sketchpad

The visuospatial sketchpad is a temporary storage of visual or spatial information, and there is research to support that the storage of visual working memory and spatial working memory information is separate. It is probable that the visuospatial sketchpad also process tactile information, but very little is currently known about these different short-term memory aspects, and a
hypothesis is that information from all these sensory channels can be related to the sketchpad. The exact nature of the visuospatial rehearsal process is currently unclear, but a suggestion was made by Logie and Pearson (1997) stating that there is a temporary visual cache for storing visual information and an inner scribe that temporarily retains spatial information. To my knowledge, there is no research comparing spatial abilities between L1 and L2 speakers.

Spatial abilities in blind individuals have been a matter for research in a variety of studies, and the essential question has been whether the visual sense contributes in a unique way to the establishment of spatial representations or if haptic and auditory cues are sufficient in this respect. The paradigms used have involved manipulation by hand in “table-top” tasks and tasks that require movement (locomotion). No firm conclusions have been drawn from existing research, and it is still an open question as to whether blind individuals display spatial impairment, have any specific difficulties in relation to spatiality or if they have equal skills as sighted individuals in this respect (Röder & Neville, 2003).

4.2.1.5 The link between working memory and long-term memory

Baddeley’s (2012) current view on the link between long-term memory and working memory is that it is a complex linking system between these two aspects of memory. Working memory works as the interface between cognition and action, and incoming information is processed by the different components of the working memory, which are all influenced by long-term memory, and which all influence long-term memory. The working memory and the long-term memory are, however, seen as separate systems that serve different functions (Miyake & Shah, 1999).

4.2.1.6 Working memory – a constant trait or susceptible to training? Or even an expression of volatile and temporary plasticity?

According to Klingberg (2010), working memory has been viewed as a constant trait, rather than a function susceptible to extended training effects. In a review of existing research on working memory training, he concluded that earlier studies using explicit training in, for instance, digit span, had shown that improvements were possible, but also are highly associated with and limited to the specific task used in the training paradigm. What characterized this training was that it taught the participants to use explicit strategies to help them handle the material of the task, for instance, through rehearsal, chunking or conscious association of the material to already existing long-term memories. Current research, using an implicit working memory training program developed by Klingberg and colleagues, has shown that working memory capacity improvements are possible and that they are also trans-
Blindness and Second Language Acquisition

ferable to working memory subcomponents other than the one specifically trained by the task. This is exemplified by the findings of Thorell et al. (2009), where preschool children received working memory training of the visuospatial working memory subcomponent, which led not only to advantages in visuospatial functions, but also to significant advantages on a verbal working memory task. The conclusion drawn is that implicit working memory training programs, which use perceptual training methods, leads to general and durable working memory advantages.

This is particularly relevant in relation to blind individuals, who inevitably and implicitly train and use the auditory perceptual system, involving, for instance, the phonological loop subcomponent during speech perception. This could potentially lead not only to advantages in the phonological loop functions, but also to advantages in other subcomponents of the working memory as well, that is, as long as the same brain structures are employed during task performance. On the other hand, it has been found that early blind individuals, who have advantages associated with phonological short-term memory functions, do not display the same advantages in executive functions that are not related to the sound system of language (Rokem & Ahissar, 2009; Swanson & Luxenberg, 2008; advantages in executive functions related to the sound system have been found in Hugdahl et al., 2004). This highlights the fact that there are limitations to how much advantages in one subcomponent of working memory can result in advantages in other subcomponents, and it might thus be explained in terms of activation of different brain structures of the working memory.

In a recent article, Lansner et al. (2013) proposed an abstract neurocomputational model, an Attractor Network Model, which is able to reproduce data from immediate free recall of word-list data from the Betula Project.\(^\text{16}\) It is suggested that the key cellular mechanisms underlying working memory encoding, reactivation and recall are even less constant by nature and are rather expressions of rapid and volatile synaptic plasticity, adjustable intrinsic excitability and neuronal adaptation between the different working memory subcomponents. This results in a network characterized by dynamically changing activity, spontaneously hopping between different components or units of the working memory. The model is able to unify short- and long-term forms of memory, explaining recency, primacy\(^\text{17}\) and contiguity effects.\(^\text{18}\)

---

\(^{16}\) http://www.betula.su.se/en/

\(^{17}\) The primacy effect can be explained by the repeated reactivations of the words presented. Already during the encoding phase, previously presented items become reactivated in between later presented items (the rehearsal process, according to Baddeley, 2012). This strengthens the synaptic trace, that is, the synapses in the reactivated pattern, enforcing encoding and also the likelihood of item recall during the recall phase. Newly presented items eventually overwrite previously stored items, resulting in forgetting, thus resulting in greater
4.2.1.7 Auditory memory versus phonological short-term memory

Many models of hearing have ascribed an important role to a sensory memory store in integrating auditory information over short periods of time (a few seconds). Auditory memory is likely to be involved in all kinds of heard material. It should, however, not be confused with the verbal short-term memory, which is concerned specifically with speech (Ward, 2010).

4.2.2 Recognition memory

Recognition memory is a subcategory of declarative or explicit long-term memory, and in the literature it is generally called “episodic memory.” In the current study, however, it is relevant to emphasize the aspect of recognition. It is the ability to recognize, for instance, previously encountered people, events and objects. It is a process of memory retrieval. It is commonly believed to consist of two different components: (1) familiarity, or “knowing”; and (2) recollection or “remembering,” according to the dual-process model proposed by Mandler (1980). The difference between the two processes can be described with an example: Imagine that you pass someone on the street and immediately sense that something is very familiar about that person. You know that you have met this person before somewhere. This process is context-independent and immediate. After a while you start to remember where you actually met the person. This latter process of recollection is slower, controlled and context-dependent.

According to Ward (2010), there is some controversy over whether these two processes have separate neural substrates in the brain, or if the difference between them is merely a difference in depth-of-processing (Craik & Lockhart, 1972), whereby familiarity is a weaker form of recollection. The strength of the memory depends on a variety of factors, for instance, on whether full attention was devoted to memorizing the information (intentional), or if it was learned only passively, if it was related to previous experiences or if the person was motivated to learn and remember.

To test recognition memory, two types of tests have been used: yes/no recognition tests, which mixes old and new items and then presents one item at a time to participants and asks them to respond ‘yes’ or ‘no’ on whether they recognize them or not, and the other test type, known as forced-choice recognition, in which participants have to choose which of two presented items has been previously presented (Baddeley, Eysenck & Anderson, 2009).

\[\text{18}\] Contiguity effects: Words are more likely to be recalled together if they are presented closer together in a list.
There are different modalities in which recognition memory can be assessed: visual, auditory, olfactory, tactile and recognition of taste. The modality that is relevant to this study is auditory recognition memory.

4.2.2.1 Recognition memory and second language acquisition

In SLA research, there is currently a strong interest in language learning aptitude (Granena, 2013), and the ability to recognize new word forms has been suggested as an important factor affecting L2 acquisition talent (Speciale, Ellis & Bywater, 2004). The ability to recognize phonological regularities, sometimes referred to as phonological sequence learning, in a new language is seen as an important precursor to vocabulary acquisition, both in infants and in adults (Speciale, Ellis & Bywater, 2004). The ability to recognize phonological patterns in spoken language is a key memory skill in language ability, since it enables the individual to acquire new words and syntax, as well as to recognize subtle morphological variations that many languages use to signal grammatical function (Speciale, Ellis & Bywater, 2004; Meara, 2005; Granena, 2013; Service, 1992; Service & Kohonen, 1995; Papagno & Vallar, 1995).

Since the ability to recognize foreign sound sequences is seen as a key component in L2 language learning aptitude, a test of phonological sequence recognition, called Llama D, was included as a subtest in the Llama Language Aptitude Test battery (Meara, 2005), a test battery frequently used in SLA research (this subtest is used in the current study; for a list of other studies using Llama D, see Granena, 2013). It is an explicit test (i.e. participants are instructed to recognize words) of recognition memory. A study by Granena (2013) found that Llama D predicted early (AO 3–6 years) and late (adult) L2 learners’ grammatical sensitivity to gender, number and person agreement in a word monitoring task, which supports the above discussion on the ability to recognize grammatical features and endings.

In a study on high-level proficiency in late L2 acquisition by Forsberg Lundell and Sandgren (2013), a strong positive correlation between the ability to produce L2 French collocations\(^\text{19}\) and performance on Llama D was found. A growing body of evidence shows that L2 collocations present a specific challenge to L2 acquisition and that difficulty in the mastery of collocations is found even at near-native levels. These results, again, suggest that high scores on Llama D, measuring the ability to recognize foreign sound sequences, is related to language learning talent. In a validation study of the Llama Language Aptitude Tests performed by Granena (2013), Llama D was found to be the only subtest that required automatic use of L2 knowledge, an ability found in highly advanced L2 learners.

\(^{19}\) Collocations are a kind of formulaic speech, for example, “do justice” (Forsberg Lundell & Sandgren, 2013).
In two different studies, Speciale, Ellis and Bywater (2004) examined individual cognitive differences that affect the acquisition of L2 word forms (both studies are reported in the same article). In order to do so, they tested both the auditory recognition memory and the short-term phonological memory in 38 undergraduate students of psychology who had English as their L1. They tried to ascertain what limited learners’ vocabulary development: the capacity of the phonological short-term store or the ability to learn new phonological sequences of language (which taps the auditory recognition memory), or if these two capacities are inextricably entwined through experience and therefore not separable processes in vocabulary development. The first experiment included two vocabulary tasks, one devoted to foreign language vocabulary learning of German and a second lexical-decision task with low-frequency English words, measuring the breadth of native lexical knowledge. The second experiment was a longitudinal 10-week field experiment during which participants acquired Spanish vocabulary in a novice-level course. The researchers used nonword repetition tasks as an index of phonological short-term store capacity (low wordlikeness) in both experiments, in addition to a nonword repetition task with Spanish-like items in the second experiment. In both experiments, they also used a measure called the Phonological Sequencing Index (PSI) to determine individual differences in ability to learn phonological sequences. This task involved the auditory recognition memory and required participants to distinguish between phonological sequences of two to four syllables that occur once and those that recur. The results, in relation to auditory recognition memory (as measured by PSI), showed that there was a lack of correlation between nonword repetition results and PSI, and the researchers concluded that the measures were fairly pure and unrelated measuring separable cognitive components. Drawing their conclusions from the results of both experiments, the researchers argued that phonological sequence leaning, that is, auditory recognition of foreign sound sequences, and phonological short-term store capacity make additive contributions to productive and receptive foreign language lexical competence, and that the combined effect of the two abilities contribute more to foreign language competence than the capacity of the phonological short-term store alone.

\[ r = .39, \ n = 77, \ p = .001. \]

20 In the current study, however, there is a medium strong correlation between the phonological short-term memory measures and Llama D test scores (correlated using a summarized z score from the three phonological short-term measures and the Llama D score transferred to z scores), \( r = .39, \ n = 77, \ p = .001. \)
4.2.2.2 Recognition memory and blindness

Auditory word recognition in blind individuals was studied by Röder, Rösler and Neville (2001) using ERP\(^{21}\) and a yes/no recognition test. One of the goals of the study was to determine which memory functions – encoding and/or retrieval – might be altered in blind individuals. An incidental learning paradigm was used, in which participants were not instructed during the first stage of the experiment, the study phase, on what they later would be asked to perform in the actual test phase. ERP measures were made both during the study phase and during the actual test phase. During the study phase, the participants of the study listened to 80 sentences that ended with either an appropriate or an inappropriate sentence-final word and were instructed to indicate whether the sentences they heard made sense or not. After the study phase, the participants were instructed that they would hear all sentence-final words of the sentences again intermixed with 80 new words and indicate whether they recognized the words from the previously presented sentences or not. The results showed that the auditory word recognition ability of the congenitally blind participants was superior to that of the sighted controls and that the previously presented words elicited a more pronounced ERP, especially over the right hemisphere. During the study phase, the incongruent sentence final words (that later would have to be recognized) elicited a more pronounced ERP in the blind and the ERPs were also of shorter onset (i.e. they processed and reacted to the incongruency significantly faster). A more pronounced ERP was only found, but to a lesser degree, in the sighted participants with the highest memory performance. Interestingly, there were no differences between the blind and sighted groups in their accuracy judgments of the sentences during the study phase, which indicates that all participants paid attention to the stimuli. The researchers concluded that the superior behavior performance on the recognition test and the more pronounced left-lateralized ERP\(^{22}\) during the study phase in the blind implies that the blind participants used a more efficient semantic coding strategy than the sighted. This also enabled them to recognize the relevant items to a larger extent than the sighted controls.

In an fMRI study by Raz, Amedi and Zohary (2005), nine congenitally blind adults performed a long-term auditory recognition task in which lists of words, previously recalled by heart by the participants one year before the

---

21 ERP: event-related potential is a measure of electrical signals generated by the brain through electrodes placed on the scalp. Changes in electrical signals are associated with cognitive processing. The measure is instantaneous, which makes this method particularly useful in measuring the relative timing of cognitive events (Ward, 2010).

22 According to the HERA (Hemisphere Encoding Retrieval Asymmetry) model, there is a link between processes of episodic encoding and the left hemisphere, and between retrieval and the right hemisphere (Tulving et al., 1994).
study, had to be recognized. In the study performed one year earlier, during which the participants learned the words to be recognized in the study, the blind participants outperformed sighted on a verbal memory task. For this reason, the sighted controls were not included in this follow-up study. Raz, Amedi and Zohary (2005) found that better recognition performance activated the visual cortex to a larger extent than poor performance and concluded that the visual cortex is likely to be involved in episodic retrieval. This conclusion cannot be generalized to all types of episodic retrieval, but only specifically to auditory recognition retrieval of verbal material.

In a study of auditory voice-recognition ability in 92 blind and 22 sighted individuals, it was found that blind individuals were significantly better than sighted, irrespective of IQ, aptitude in auditory capabilities, age of onset of blindness (AOB), degree of blindness (totally blind, light perception ability or residual/goodish sight) and length of blindness (LOB) (Bull, Rathborn & Clifford, 1983). However, it was not reported how many of the blind participants that were totally blind, had light perception abilities or had residual/decent sight (maybe because the results between the groups did not differ). Most studies that include individuals with residual vision have found that these individuals generally perform worse than both their blind and their sighted peers (Stankov & Spilsbury, 1978). Röder, Wolber and Neville (unpublished, presented in Röder & Neville, 2003) replicated the results of Bull, Rathborn and Clifford’s (1983) study with 18 congenitally blind and 18 matched sighted in a test of voice recognition.

Auditory recognition memory for environmental sounds in congenitally blind, late blind and sighted was studied by Röder and Rösler (2003), who found that both congenitally blind and late blind individuals were significantly better than sighted and concluded that compensatory changes in long-term memory functions in both blind groups, irrespective of AOB, provide evidence of a high adaptive capability in the human cognitive system.

Based on the findings presented above, it seems as if age of onset of blindness might not affect results when recognition memory is investigated.

4.2.3 Episodic memory

Episodic memory is classified as a declarative long-term memory. The concept of episodic memory was first introduced by Endel Tulving (1972), when he distinguished episodic and semantic memory from one another as two separate memory systems. The crucial feature about episodic memory is the capacity to remember specific events or episodes. Episodic memories concern things that happen in a specific place at a specific time, and answers

\[2 + 3 = 5\] and "Stockholm is the capital of Sweden,"
the questions “what,” “where” or “when.” This type of memory gives us our capacity to recollect specific experiences, which we can use for mental time travel to ask such question as “What did you do at 11:00 am yesterday?” “What is your earliest memory?” “What did I have for dinner last night?” “Where will I go tomorrow?” – a capacity that is not observed in nonhuman animals. It is the awareness of subjective time and our ability to re-experience, in our mind, previous occurrences (Tulving, 2002). This type of memory is dependent on our ability to encode, store and later retrieve/recall these events and experiences from memory. The contents in episodic memory are constantly changing, since information gets lost when new information is processed (Tulving, 2002; Nyberg et al., 1996). These processes are affected by their levels-of-processing, as deeper processed material facilitates recall. Craik and Lockhart (1972) even challenged the theory of two separate short- and long-term memory stores, suggesting that there is only a matter of difference in the level-of-processing. More deeply coded material has thus been processed more elaborately and actively forms associations with previously stored memories and schemas, and are therefore easier to recall. Deeper and more elaborate coding is suggested by Craik and Tulving (1975) to involve semantic encoding.

Episodic memory can be applied to a broad range of memory phenomena, ranging from single words to autobiographical memories. At one end of the spectrum, episodic memory can consist of simple words learned from a list or facts recalled from a short story during an experimental setup, and, at the other end of the continuum, it can consist of episodes related to complex personal experiences and events (Schrauf, Pavlenko & Dewaele, 2003). It is easy enough to understand that the latter is an expression of episodic memory, since what we consider to be “our memories” are of this sort, but it is more difficult in the former case. The former case can be explained by the fact that the individual him/herself has experienced hearing the list of words or the story during a fairly recent personal past experience, which he or she is then later asked to recall.

4.2.3.1 Episodic memory and second language acquisition

While there are several good theories about bilingualism and semantic memory, which generally are concerned with lexical access to semantic memory, there are far fewer theories or models on bilingualism and episodic memory. Where episodic memory has been discussed in research on bilingualism, it has mainly served to shed light on semantic aspects of the L2 memory system (Schrauf, Pavlenko & Dewaele, 2003). There are studies on autobiographical memory, which is an aspect of episodic memory, and bilingualism (for a list of references, see Schrauf, Pavlenko & Dewaele, 2003) and the results show that the retrieval of memories is language-specific and related to the language that was spoken at the time of encoding. Auto-
biographical bilingual memory needs, however, to be integrated into a larger theory of bilingual episodic memory, and the researchers have stressed the need for a model that also takes cultural frameworks into consideration. Schrauf, Pavlenko and Dewaele (2003) argue that “one need not be committed to a strong Whorfian relativism to admit that we pay selective attention to the physical and social world that surrounds us, and that what we pay attention to is largely shaped by the culture(s) we inhabit” (p. 229–230). The researchers thus specifically emphasize the importance of including the cultural framework into a model of bilingual episodic memory, and this argument is based on the research findings of van Hell et al. (2003), for instance. These researchers explored the influence of cultural background knowledge on the ability to retell, complete and finish three story beginnings: one story related to the cultural background of the participants concerning Ramadan, a second related to the L2 cultural background in the Netherlands, and a third not related to cultural background but to the everyday life experiences of all participants. The participants were bilingual ethnic minority children from immigrant families of Islamic background and the control group consisted of monolingual Dutch children. The results showed that both qualitative and quantitative characteristics of the stories were influenced by the cultural background of the participants. Cultural familiarity with a topic resulted in both longer and more coherent stories and also in more connective ties.

It is not always easy to separate semantic and episodic memory from each other, which is seen in the discussion above. Culturally shared knowledge is generally considered to be an aspect of semantic memory, that is, a part of our general knowledge of the world (Tulving, 1972), and we have more information in semantic memory in areas that are of special interest to us. It might be that episodic memory performance gets boosted, or stored at a greater depth, by culturally shared semantic memories in the case of bilinguals, when the episodic memory tests used draw on personal cultural background knowledge. If episodic memory abilities are better in bilinguals, as a result of using two languages simultaneously, it would also be apparent in tests that do not favor one participating group over the other. This is seen in Kormi-Nouri, Moniri and Nilsson (2003), which is referred to below. It is obviously important to be careful when selecting test material when testing bilinguals in order to avoid a cultural bias.

In a doctoral thesis by Moniri (2006) that adopts a life-span approach to bilingual memory, two studies were performed on episodic and semantic memory processing, both in bilingual children (120 primary school pupils from grades 2, 4 and 6, in which 60 participants were Persian-Swedish bilinguals; Kormi-Nouri, Moniri & Nilsson, 2003) and in younger and older adults having learned English as a foreign language in formal settings (334 participants using English as a foreign language on a daily basis were compared to 170 monolingual Swedish L1 speakers, with ages ranging from 35
to 50, 55 to 65 and 70 to 80; Moniri, de Frias & Nilsson, unpublished manuscript). In the study on bilingual children that focused on episodic memory functions, it was found that these children were better at both free and cued recall than monolingual children. It was also found that episodic action memory was better in the bilingual children than in the monolingual children. This was not seen, however, in the verbal memory task, which suggests that the bilingual children displayed a better episodic integration for action memory. The research suggested that the bilingualism effect could be observed more under automatic or implicit processing conditions, which are thought to characterize action memory, rather than under the explicit processing conditions of verbal memory performance. In the second study on adults who regularly used a foreign language, it was found that they performed significantly better than those adults who used only the L1 (monolinguals), on all episodic memory tests (nine recall tests and three recognition tests); it was also found that episodic memory in both groups was impaired in older adults (70–80 years old), although less so in the group using more than one language on a daily basis. This suggests that using more than one language might delay age-related episodic memory impairments.

In a longitudinal study by Ljungberg et al. (2013), the use of more than one language was shown to result in advantages on episodic memory recall, verbal letter and categorical fluency during the trajectory of life. The participants belonging to the bilingual group were L1 speakers of Swedish who had learned a foreign language in formal school settings. Eighty percent of the bilinguals spent from 0 to 2 hours per day reading, writing, speaking or listening to the foreign language. The participants of the monolingual group used only Swedish on a daily basis but had the same language educational background as the bilingual group. It should be pointed out that the tests used were all performed on Swedish (the L1) and foreign language performance was, thus, not investigated. The results showed that the regular use of more than one language resulted in an advantage in verbal episodic recall and that this advantage persisted across ages (35–85 years).

---

24 The participants classified in this study as bilinguals would be classified as foreign language speakers if the study would have been conducted in the field of SLA. Ljungberg et al. (2013) thus compared monolinguals using only the L1 with individuals who, besides the L1, used at least one additional foreign language on a daily basis, despite living in the L1 environment. In the current study, none of the participants could be classified as monolingual speakers, as both L1 and L2 speakers use more than one language on a daily basis; the L1 speakers use their mother tongue and at least one additional foreign language, while the L2 speakers use at least their L1 as well as their L2 on a daily basis, as they live in the L2 environment.
4.2.3.2 Episodic memory and blindness
In measuring episodic long-term memory functions in the blind, different aspects of auditory recognition memory have commonly been tested. To the author’s knowledge, no studies of other aspects of episodic memory in blind individuals have been reported.

4.3 Research questions
Based on the theoretical background that has been presented, the following research questions were formulated:

1) Do early blind individuals have a better phonological short-term memory performance than late blind and sighted individuals? (See section 4.5.1.)

2) Do early blind individuals have a better recognition memory for new sound sequences than late blind and sighted individuals? (See section 4.5.2.)

3) Do early blind individuals have a better episodic memory performance than late blind and sighted, in this case specifically, a better ability for remembering the event of hearing information presented auditorily? (See section 4.5.3.)

4.4 Method

4.4.1 Participants
Both L1 and L2 speakers performed on the tests. The participants are described in chapter 3.

4.4.2 Tests and predictions
Five different memory tests were used in this substudy: three phonological short-term memory tests (also called serial recall tests), one recognition memory test (classified as an episodic memory test in the field of psychology) and one episodic memory test. A description of all the tests is presented below. Predictions concerning possible findings were made for each test in relation to a) the visual status variable, b) the language background variable and c) the possible interaction between the two variables, and these are also presented below.

4.4.2.1 Phonological short-term memory tests
In their discussion of different tests of phonological short-term memory, Baddeley, Gathercole and Papagno (1998) suggested that the ability to repeat
series of digits taps the fundamental capacity of humans to generate longer representations of brief and novel speech events, that is, to generate new words. Another frequently used test in studies on phonological short-term memory and long-term learning is nonword repetition tests, and the researchers suggested that the nonword repetition tests might actually be more sensitive to phonological loop functions than digit span measures. In discussing the relationship between nonword repetition and vocabulary acquisition further, Baddeley, Gathercole and Papagno (1998) concluded that it is oversimplistic to claim a unidirectional relationship between the phonological loop and vocabulary acquisition. Rather, they argued that there is an interactive relationship between vocabulary knowledge, phonological loop capacity and nonword learning. This argument is based on findings that children are more accurate at repeating nonwords that are rated as having a high degree of wordlikeness, since knowledge can be drawn from the already existing long-term phonological forms. This contribution of long-term knowledge in repetition is thought to reduce the contribution of the phonological loop, and therefore lessens the effect of constraints in phonological loop capacity. The phonological loop mediates the long-term phonological learning, according to Baddeley, Gathercole and Papagno (1998). The possibility of using existing vocabulary knowledge, due to the wordlikeness of nonwords, also explains why nonword repetition is more highly correlated with vocabulary acquisition than digit span measures.

In the current study, three different phonological short-term memory tests were used: a digit span test and two nonword repetition tests (CNRep and Lat A).

4.4.2.1.1 Digit span

In 1887, the first digit span test was devised and used by Jacobs (1887). According to Baddeley, Gathercole and Papagno (1998), the digit span measure provides information on the short-term memory capacity and, more specifically, the phonological loop capacity. In its basic version, which is used in this project, it reflects short-term memory span. The digit span test measures the longest sequence of digits that can be held for a short period of time before recollection (Juffs & Harrington, 2011). For most people, the digit span is limited to about six or seven digits, but there is considerable individual variation. Individuals who have large spans are able to process or repeat more sounds in two seconds (the time limit of the phonological short-term store) than those with shorter spans. Longer spans also correlate with higher scores on IQ tests (Kroll & de Groot, 2005). Digit span requires that one (a) remembers the right items and (b) remembers the order in which they were presented. Baddeley, Gathercole and Papagno (1998) argued that the ability to repeat series of digits also taps the fundamental capacity of humans.
to generate longer representations of brief and novel speech events, that is, to generate new words.

To an L1 speaker, the digits from one to nine are very familiar, which makes the test mainly one of memory of order. For an L2 speaker, however, the test becomes more complex, since there is an L2 component involved, and thus, the digits also have to be remembered in the L2. It has been found that the digit span in an L2 is shorter than in the L1 (Cook, 1977, 1979; Ellis & Hennelly, 1980) and that more advanced L2 learners have larger spans than less advanced L2 learners (Cook, 1977). According to da Costa Pinto (1991), digit spans performed in the L1 are always superior to those performed in an L2, and their spoken duration is also much reduced in the L1 compared to the L2. A natural question is why execution of digit span test in different languages would make a difference to the span, and it seems as if the time of spoken duration might at least be a part of the answer to the question. It has been found that serial recall performed in, for instance, in digit span or nonword repetition, is affected by the time of spoken duration, since the articulatory rehearsal process is thought to take place in real time. Even when the number of syllables and phonemes are held constant, the memory span for words or digits that take a short time to articulate is greater than for words that take a longer time to articulate, according to Ellis and Hennelly (1980), and if time of articulation generally takes a longer time in an L2, it also shortens the length of the span. Naveh-Benjamin and Ayres (1986) found that speakers of English, a language that has short words for digits, have larger digit spans than speakers of languages with long words for digits, as Arabic has. Ellis and Hennelly (1980) also found that the digit span in Welsh children (average spoken duration of 385 ms per digit in Welsh) was significantly smaller than in English children (average spoken duration of 321 ms per digit in English), which is explained by the bilingual word-length differences. This is further supported in a study by Chincotta and Underwood (1997) comparing native speakers of six different mother tongues on digit span with and without articulatory suppression. They found that the differences in span between the languages were eliminated using the articulatory suppression paradigm, and they concluded that cross-linguistic differences in digit span can be attributed to variation in the articulatory duration.

The auditory digit span test used in this study is based on a standardized test of Auditive Sequential Memory in the *Illinois Test of Psycholinguistic Abilities* (Kirk, McCarthy & Kirk, 1990), which is commonly used by speech therapists in Sweden and was also used in a research project performed by Hedman (2009) (Appendix 1). The participants in this study were presented with up to 20 items consisting of 2 to 8 digits. They were asked to repeat the item directly after it was presented. The difficulty level of the digit span increased successively. If the participant did not manage to repeat the
Blindness and Second Language Acquisition

item after the first auditory presentation, a second presentation of the same item followed. If the participant failed to repeat two consecutive items, the experiment was terminated. Although there was an upper limit to the span, only one participant scored at the ceiling. The scoring used in this study followed the practice of Hedman (2009), whereby one point was given for every correctly repeated series of digits.

In the current study, the internal consistency of the scale was good, with a Cronbach’s alpha coefficient of .89.

It was predicted that early blind individuals would have an advantage compared to late blind and sighted on digit span. This prediction was based on the findings of improved phonological short-term functions in early or congenitally blind individuals compared to sighted (Hull & Mason, 1995; Röder & Neville, 2003; Rokem & Ahissar, 2009) and on the assumption that late blind individuals do not have the same advantages associated with early blind individuals, because of a lesser degree of plasticity in relevant parts of the nervous system in adulthood (e.g. the visual cortex, Veerart et al., 1990). It was also predicted that L1 speakers would perform better compared to L2 speakers, since the test is in Swedish. It was further predicted that there would be no interaction effect, since the effects of these factors were expected to be independent and additive, which means that it was not predicted that one specific visual status group would be more or less advantaged due to being L1 or L2 speakers.

4.4.2.1.2 Nonword repetition tests

The nonword paradigm has been widely used by psychologists since the beginning of the 1980s. These types of tests investigate the capacity of the verbal component of working memory, the phonological loop (Baddeley & Hitch, 1974). It has generally been used on populations suffering from low reading ability, dyslexia, general developmental language problems and acquired language processing disorders, populations in which poor nonword repetition generally has been found. In these populations, impairments have also been found in conventional phonological short-term memory tests like digit span, and according to Gathercole et al. (1994), there is a strong association between nonword repetition tests and other phonological memory measures.

One reason for using this type of test in this project on blind L2 learners with no language impairments is that the link between nonword repetition ability and phonological working memory skill is well established. Another reason is that exposure to unfamiliar phonological forms is present in everyday life for an L2 learner, and nonword repetition tests thus provide a “convenient laboratory analog of imitation in natural language situations” (Gathercole et al., 1994:104) that is especially common in an L2 environment.
Service (1992) found, for instance, that nonword repetition ability was an excellent predictor of vocabulary acquisition proficiency in nine-year-old Finnish children learning English as a foreign language. Gathercole et al. (1994) also conclude that the link between nonword repetition ability and the ability to learn new words extends into adulthood.

A variety of cognitive processes that can be related to perception and production of languages are involved in the execution of nonword repetition; aspects of the phonological working memory are activated as well as long-term vocabulary knowledge. Phonological analysis and output/production processes are also involved. For instance, the nonword has to be perceived correctly and analyzed into its phonological constituents, a process of phonological segmentation. The spoken auditory form of the nonword has obligatory access to the phonological short-term store of the phonological loop as a phonological code and is then refreshed and kept from decay by the rehearsal process (Gathercole et al., 1994).

The last process in nonword repetition is the output or production process. During this process a plan of how to articulate stored phonological sequences is made and executed. This process is a potential source of individual variation, since it is affected both by memory constraints and speech motor programming. According to Gathercole et al. (1994), children by the age of four or five, unless suffering from known speech motor deficits, have developed sufficient productions skills to produce nonwords. It can, therefore, be expected that the limitations in nonword production in this study are set by memory constraints, at least for the L1 speakers, rather than articulatory deficits. In an analysis of the Children’s test of Nonword Repetition (CNRep), it was found that those words that had sound structures similar to already familiar words were repeated more correctly. The long-term memory contribution to nonword repetition is therefore stronger for familiar sound structures and less for unfamiliar sound structures (the wordlikeness effect). This is commented on below in relation to the differing prerequisites of the L1 and L2 speakers of the project.

Specific predictions concerning the results are presented in relation to each test below.

**CNRep**

The test used here is a translation of CNRep, that is, the Children’s test of Nonword Repetition, developed by Gathercole et al. (1994). Scores on CNRep and on auditory digit span, the most commonly used tests for measuring verbal short-term memory, are closely related. According to Gathercole et al. (1994), both digit span and nonword repetition tests measure phonological memory skills, but they concluded that scores on the CNRep are more effective in discriminating vocabulary knowledge than digit span during early school years. This reasoning is in line with the fin-
Blindness and Second Language Acquisition

ings of Service (1992), who measured phonological short-term memory in children (of nine-year-olds) using a nonword repetition test. It was found that the test was a good predictor of learning English as a foreign language over a period of three school years. In Service and Kohonen (1995), it was concluded that phonological memory may be specifically related to foreign vocabulary learning.

The version of the test used in the current study was adapted to Swedish phonology and syntax, and with regard to syllable quantity and phonological patterns, only minor changes from the English version needed to be made (developed by Hedman, 2009, appendix 2). The phonological and morphological properties of the words make them sound like Swedish words, and the L1 speakers of Swedish in the current study may thus have a greater contribution from similar phonological long-term structures.

The test consisted of 40 nonwords of 2 to 5 syllables each. The test contained 10 2-syllabic words, 10 3-syllabic words, 10 4-syllabic words and 10 5-syllabic words. In the analysis, the repetitions of the two first words were not given points, since they were considered trial words. The subjects heard a single word at a time, for example, “loddernapisk,” which they immediately repeated. The repetitions were recorded. One point was given for every correctly repeated item, with the possibility of a maximum score of 38 points.

The test-retest reliability score of the original version of the CNRep is high, between 0.77 and 0.80 (Gathercole et al., 1994). The internal consistency of the CNRep in the current study was good, with a Cronbach’s alpha coefficient of .86.

It was predicted that early blind individuals would have an advantage compared to late blind and sighted on the CNRep. This prediction in relation to visual status was motivated by the same research findings that were presented in relation to the digit span test discussed above. A prediction related to the language background factor was that L1 speakers might have an advantage compared to L2 speakers, since the items are adapted to Swedish phonology and syntax. It was also predicted that there would be no interaction effect, since the effects of these factors were expected to be independent and additive.

Lat A

The second nonword repetition test that was used is Lat A, a subtest of the Swansea Language Aptitude Tests Swansea LAT (v.2.0, Meara, Milton & Lorenzo-Dus, 2003), which is a computer-based aptitude test battery. The five subtests are loosely based on the first constructed test battery devoted to language aptitude: Modern Language Aptitude Tests (MLAT; Carroll & Sapon, 1959). The subtest Lat A, in its original version, is a self-judgment test of phonetic memory. The participants hear unfamiliar/exotic multi-
syllabic soundstrings, which they immediately repeat. The test consists of 25 multisyllabic soundstrings, ranging from 1 to 13 syllables (with no 9-syllabic soundstrings included).

There are great similarities between Lat A and the CNRep nonword test, since both of them consist of nonwords and tap the same cognitive memory function: the phonological short-term memory. There are, however, some differences as well. Unlike the CNRep, which has items that are Swedish-sounding, the items of Lat A are foreign and exotic sounding to all participants, that is, not similar to any already-known language stored in long-term memory. It can, therefore, be expected that the test will present the same challenges to both L1 and L2 speakers because of the low degree of word-likeness for both groups. Another difference between the CNRep test and Lat A is the number of syllables of the items. While the CNRep test contains items with 2 to 5 syllables, Lat A contain items with 1 to 13 syllables. Since 15 of the 25 items of Lat A contain more than 5 syllables, which is the upper limit of the CNRep test, Lat A is more demanding to the phonological loop capacity than the CNRep, also minimizing the risk of ceiling effects.

The original version of this test was a self-judgment test, but it was excluded from the test battery because of low validity, since it did not actually measure the participant’s ability to repeat the items, but the participant’s ability to judge his or her own ability to repeat the items. It is not hard to imagine that if people are not able to repeat a nonword correctly, they might also have difficulties in judging the quality of their own production. For this reason and to make this test a valid measure of the ability to repeat nonwords, recordings of the repetitions were made, and the responses were as mentioned transcribed and analyzed by the test leader.

Every item was divided into syllables, and one point was given for every syllable repeated correctly in the right serial order. This means that the scores were between 1 and 13 points for each item, depending on the number of syllables it contained (appendix 3).

By correlating the scoring from the analysis reported here, namely a “strict” scoring procedure (where item syllables had to be repeated correctly in the right serial order) with a more “lenient” scoring procedure (where one point was given for every correctly repeated syllable, not necessarily in the right serial order, not reported here because very similar results between the two analyses were obtained), a very high intra-rater reliability score was received: \( r = .95, n = 77, p < .001 \). The internal consistency of Lat A items (correctly repeated syllables in the right serial order) was good, with a Cronbach’s alpha coefficient of .88.

It was predicted that early blind individuals would have an advantage compared to the late blind and sighted. This prediction was motivated by the same research findings presented above in relation to the other two tests. Another prediction in relation to Lat A was that there would be no signifi-
cant difference between the results of the L1 speakers and the L2 speakers, since the items were language neutral. It was also predicted that there would be no interaction effect, since the effects of these factors were expected to be independent and additive.

4.4.2.2 Recognition memory test Llama D

Primarily, a comment will be made here concerning terminology, highlighting the fact that recognition memory tests measure aspects of episodic memory, and is therefore generally called episodic long-term memory tests in the literature from the field of psychology.

The recognition memory test Llama D is a subtest of the Llama Language Aptitude Tests (Meara, 2005), which is a more recent version of the Lat-series mentioned above. The Llama test battery is also computer-based and contain four subtests that measure sound-symbol association, grammatical inferencing, vocabulary learning and sound recognition (free for download at www.lognostics.co.uk/tools/llama/index.htm). The test is language-independent, since the items are very exotic sounding and not similar to any previously heard languages. The subtest Llama D, the only non-visual subtest in the test battery, is not based on any of the subtests that appear in the first language aptitude test battery created by Carroll and Sapon (1959). This test is loosely based on work by Service (1992; Service & Kohonen, 1995). Llama D is a test of memory for unusual sound sequences, a sound recognition test in which previously heard sound sequences are to be identified among novel sound sequences. It is suggested that a key skill in language ability is the ability to recognize patterns of spoken language, and that it is an advantage if a pattern of sounds are recognized and familiar the second time that it is heard, since that would benefit vocabulary acquisition (Meara, 2005; Speciale, Ellis & Bywater, 2004).

In a study conducted by Speciale, Ellis and Bywater (2004), a test similar to Llama D was used to measure the ability to learn phonological sequences, something that together with the phonological short-term store capacity, as measured by a nonword repetition test, was found to contribute to productive L2 vocabulary acquisition. The test of phonological sequence learning predicted receptive L2 vocabulary learning. The researchers also found that the phonological store capacity, measured by the nonword test, was unrelated to phonological sequence learning ability which was measured by the test similar to Llama D. Speciale, Ellis and Bywater (2004) concluded that this was a consequence of using nonword repetition items that had extremely low wordlikeness (as in the Lat A test in this study) and, therefore, very little support from long-term phonological knowledge. They further concluded that individual differences in the ability to learn phonological sequences influence an individual’s aptitude in L2 vocabulary acquisition. The same
ability would also aid in recognizing small variations in a new language, like endings, that signal grammatical features (Meara, 2005).

There is yet another facet of Speciale, Ellis and Bywater (2004) that holds relevance not only to L2 vocabulary acquisition but also to other aspects of L2 acquisition. They argue that if word recognition and production relevant to L2 lexical development is automatized, attentional resources instead can be freed up for semantic and syntactic processing.

The stimuli of the tests used in this study are based on a dialect of an Indian language spoken in North West British Columbia in Canada. The words are the names of flowers and natural objects, and the sounds have been synthesized using AT&T Natural Voices (French). These sound sequences are generally perceived as very exotic, since they differ from already familiar languages. This makes the test language-independent. The words or sound sequences that are presented in the test are between two and five syllables long; twelve words are two-syllabic, thirteen are three-syllabic, three are four-syllabic and two are five-syllabic. The words mostly consist of CV syllables and sound like, for example, /dilisa:k/, /niklik/ and /kakiljak/ (to hear all items presented, download the program). The participants primarily listen to 10 target words which, immediately after presentation should be identified among 30 words. Among these 30 items, 10 are the target items previously heard in the first presentation, 5 of those target items are also repeated a second time (i.e. repeated twice), and 15 items are novel and unfamiliar (i.e. distractor words). The items are presented in a fixed quasi-random order. The test takes approximately 3 to 3.5 minutes to complete, and the result is presented as a final score, where the maximum result is 75. The result file does not present hits, false alarms/distractors, correct rejections and mistakes in relation to the items, making it impossible to ascertain if there is a difference in hit-rate between target items presented only once and those presented twice.

Granena (2013) performed an exploratory validation study that assessed the reliability of the Llama aptitude test battery, as well as the validity exploring its underlying structure by means of exploratory factor analyses. The study had 186 participants from 3 different L1 backgrounds (Chinese, \(n = 142\); Spanish, \(n = 41\) and English, \(n = 3\)). In order to evaluate the reliability of the test, separate audio recordings were obtained from 74 of the participants performing the subtests, making it possible to register hits, false alarms/ distractors, correct rejections and mistakes, and to evaluate test reliability.

---

25 According to the manual, the maximum result should be 100, and the score results interpreted according to a nominal scale: 0–10 = “a very poor score,” 15–35 = “an average score, most people score within this range,” 40–60 = “a good score,” 75–100 = “an outstanding score. Few people manage to score in this range” (Meara, 2005). The maximum score is actually 75 and not 100, and the missing part of the nominal scale (65–75) can be given the interpretation of 75–100, if the nominal scale is used.
The reliability of the subtests was evaluated using two measures: internal consistency and test-retest reliability. The internal consistency, that is, the degree to which the results were stable across items, was assessed by means of Cronbach’s alpha, and the internal consistency of Llama D \( (k = 30) \) was acceptable \( (\alpha = .64) \). Test-retest reliability, that is, stability over time, was assessed with a subsample of 20 participants who were measured twice with a time interval of 2 years. The correlation between Time 1 and Time 2 was \( r = .60 \) \((p < .01)\), a fairly strong correlation. The two exploratory factor analyses showed that the four subtests measure two different dimensions of aptitude. These two dimensions were interpreted as analytic ability, which is relevant for explicit language learning, and sound sequence learning ability, relevant for implicit language learning. Llama D loaded on the latter aptitude component, unlike the other three subtests, which all included a study phase, a rehearsal phase and the opportunity to use problem-solving strategies. According to Granena (2013), Llama D taps an underlying cognitive ability that is relevant for implicit learning, and which does not rely on central executive processing. Attention control was found inversely related to the cognitive ability underlying Llama D. It was also found that test scores were independent of the participants’ L1 and gender.

The participants were told to memorize the 10 target words first presented and that they would have to recognize those 10 target words among 30 words in a later presentation. Since half of the participants in this study are blind, the test administrator pushed the yes/no buttons on the computer for all participants, who gave the answers orally.

It was predicted that early blind individuals would have an advantage compared to late blind and sighted on recognition memory performance, although studies of word recognition have only reported the performance of congenitally blind in comparison with sighted individuals and found congenitally blind superior to sighted (Röder, Rösler & Neville, 2001). There is one study of recognition memory for environmental sounds, where both early and late blind individuals outperformed sighted (Röder & Rösler, 2003), so the prediction is made with some caution in relation to the late blind group. It was also predicted that this advantage in recognition memory performance would not be associated with the language background variable as the test is language neutral, and that both L1 and L2 groups would have individuals displaying greater language aptitude in relation to this specific memory component than others. A further prediction was that there would be no interaction effect between the two variables visual status and language background as it is expected that the factors make independent and additive contributions to the result.
4.4.2.3 Episodic memory test Alomba

In the current study, a short story about a fictional country called Alomba was presented auditorily to the participants (appendix 4). The story consisted of 173 words and revealed much information about the country. The information revealed was not tied to any specific cultural or religious background (or linguistic for that matter). The participants were told to remember as many details from the story as possible and that they, immediately after the presentation, would be given as much time as they needed for recollection. In this test, the participants were not told to pay specific attention to the speech signal by, for instance, trying to repeat it. Unlike in the other tests, there is not a maximum score, since recollection did not have to be verbatim. The amount of information presented and correctly recalled would result in a maximum score of approximately 45 points.

It was predicted that early blind individuals would have an advantage on episodic recall compared to late blind and sighted individuals. Another prediction was that the L1 speakers would have an advantage compared to the L2 speakers, since the language used in the test was Swedish. It was also predicted that there would be no interaction effect, since the effects of these factors were expected to be independent and additive.

4.5 Results

The main test results are presented in tables, but for those readers who prefer figures, all test results of the study are presented in figures in appendix 7.

When data is normally distributed, parametric techniques are used, and when data is not normally distributed, non-parametric techniques are used, unless the parametric technique and the non-parametric technique displayed similar results, in which case the parametric technique was preferred and selected. The statistics were run on raw scores except in the case of Lat A, where a different type of analysis was performed (see above).

4.5.1 Phonological short-term memory tests

4.5.1.1 Digit Span

In relation to the language background variable, it was predicted that L1 speakers would receive a higher result than the L2 speakers, since the test was in Swedish. In relation to the visual status factor, it was predicted that early blind individuals would receive a higher mean result than late blind and sighted groups, and that late blind and sighted would receive similar
results. The last prediction, in relation to a possible interaction effect between the two variables, was that there would be no interaction effect, since the effect was rather expected to be additive.

Table 4.1 shows that data seem to support the prediction in relation to the language background factor, and a 2 (language background: L1 speaker or L2 speaker) x 3 (degree of vision: EB, LB, S) ANOVA analysis revealed that the main effect of language background was significant, $F(1, 74) = 23.09, p = .001$, and effect size was large: partial eta squared .24, which indicates that the mean of the L1 speakers ($M = 15.55, SD = 3.37$) was significantly higher than the mean of the L2 speakers ($M = 12.34, SD = 2.99$). There was also a statistically significant main effect of visual status (EB, LB, S), $F(2, 74) = 11.75, p = .001$, and effect size was large: partial eta squared .24. This also supports the prediction and is further explored in the post-hoc analysis presented below. Also, in line with the prediction in relation to interaction, the statistical analysis revealed that there was no interaction between visual status and linguistic background, $F(2, 74) = 0.55, p = .582$.

Post-hoc analysis using Bonferroni showed that the EB group ($M = 16.34, SD = 3.29$) scored significantly higher than the other two groups: LB ($M = 13.78, SD = 2.86$), $p = .017$, and S ($M = 12.70, SD = 3.37$), $p = .001$, and that the scores of the LB and S groups did not differ significantly. The statistical analysis thus supported the prediction in relation to the visual status variable, as well, which means that all three predictions were supported.

A ranking of all participants on digit span using z-scores showed that 17 participants had results that were better than approximately 1 standard deviation above the mean (from 1 to 1.68), and, of those, 12 participants were early blind (10 L1 speakers, 2 L2 speakers), 1 was a late blind L1 speaker, and 4 were sighted L1 speakers.

### 4.5.1.2 CNRep

It was predicted that the L1 speakers in the study might obtain higher results than the L2 speakers on the CNRep, since the nonwords in the test were

<table>
<thead>
<tr>
<th>Language background</th>
<th>EB</th>
<th>LB</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>18.45 (0.85)</td>
<td>15.00 (3.18)</td>
<td>14.20 (3.42)</td>
<td>15.55 (3.37)</td>
</tr>
<tr>
<td>L2</td>
<td>14.23 (3.50)</td>
<td>12.56 (1.99)</td>
<td>11.20 (2.61)</td>
<td>12.34 (2.99)</td>
</tr>
<tr>
<td>Total</td>
<td>16.34 (3.29)</td>
<td>13.78 (2.86)</td>
<td>12.70 (3.37)</td>
<td>13.94 (3.56)</td>
</tr>
</tbody>
</table>

*Note: EB = early blind; LB = late blind; S = sighted*
adapted to Swedish phonology and syntax. It was also predicted that the early blind would receive higher results than the late blind and sighted and that late blind and sighted groups would not differ. It was further predicted that there would be no interaction effect between the language background variable and the visual status variable.

As illustrated in table 4.2, the data seem to support all three predictions. Normality was assessed using Kolmogorov-Smirnov, and the result showed that normality was violated. A comparison between parametric and non-parametric techniques was performed, and it showed that both techniques revealed the same significant group differences. For this reason, the parametric technique, rather than a non-parametric technique, was chosen to test the interpretations made of the data.

A 2 (language background: L1 speaker or L2 speaker) x 3 (degree of vision: EB, LB, S) ANOVA was conducted to evaluate the CNRep data, and the results revealed that the main effect of language background was significant, $F(1, 74) = 4.23, p = .043$, effect size was small (almost medium): partial eta squared .05, which suggests that the actual difference between the groups in terms of the mean score is not great. This finding, nevertheless, supports the prediction. There was also a statistically significant main effect of visual status (EB, LB, S): $F(2, 74) = 6.63, p = .002$, effect size was large, partial eta squared .152. This finding also supports the prediction and is further evaluated in the post-hoc analysis. The statistical analysis also supported the prediction in relation to interaction, since there was no interaction between visual status and linguistic background: $F(2, 74) = 1.74, p = .182$.

Post-hoc analysis using Bonferroni revealed that the EB group ($M = 34.68, SD = 3.66$) scored significantly higher than the other two groups: LB ($M = 30.22, SD = 5.20$), $p = .009$, and S ($M = 30.70, SD = 5.15$), $p = .005$, and that the scores of the LB and S groups did not differ significantly, which is in line with the prediction. The statistical evaluation thus supported the predictions in relation to the language background variable, the visual status variable and in relation to a possible interaction between the variables, but it also showed that the actual difference in mean score between L1 and L2 speakers, albeit significant, is not great. This highlights the fact that the

<table>
<thead>
<tr>
<th>Language background</th>
<th>EB</th>
<th>LB</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>35.55 (3.70)</td>
<td>30.33 (7.42)</td>
<td>33.05 (4.67)</td>
<td>33.13 (5.37)</td>
</tr>
<tr>
<td>L2</td>
<td>33.82 (3.57)</td>
<td>30.11 (1.54)</td>
<td>28.35 (4.57)</td>
<td>30.25 (4.40)</td>
</tr>
<tr>
<td>Total</td>
<td>34.68 (3.66)</td>
<td>30.22 (5.20)</td>
<td>30.70 (5.15)</td>
<td>31.69 (5.09)</td>
</tr>
</tbody>
</table>

Note: EB = early blind; LB = late blind; S = sighted
items are after all nonwords and not the L1 of any participating group, although items are adapted to Swedish phonology and syntax.

A ranking of all participants on the CNRep using z-scores showed that 16 participants had results that were better than 1 standard deviation above the mean (from 1 to 1.24). Of those 16 participants, 11 were early blind (8 L1 speakers, 3 L2 speakers), 2 were late blind L1 speakers and 3 were sighted L1 speakers.

4.5.1.3 Lat A

Lat A is the only serial recall test in the current study that has items that are language-neutral, since the sound sequences to be repeated do not resemble already known languages. This means that the items are equally difficult to repeat for both L1 and L2 speakers, and also that the participants have less help from already stored phonological long-term memory representations.

The following analyses will be presented here: (a) amount of correctly repeated syllables repeated in the right serial order; (b) the collapsed 1–4 syllable-levels, the 5–8 syllable-levels and the 10–13 syllable-levels; and (c) phonological short-term store capacity. These analyses are described below. In raw scores, the maximum result is 25, since the test contains 25 items of differing lengths (appendix 3).

(a) Correctly repeated syllables in the right serial order

Analysis a) is not based on raw scores, unlike analysis b) and c). Analysis a) can be seen as the main analysis of Lat A, and analyses b) and c) present additional information. In this analysis, all items were divided into syllables, and 1 point was given for every correctly repeated syllable in the right serial order. This transformation of raw scores was made because of the relative degree of difficulty between the items. It is far more demanding to repeat 13-syllable items in the right serial order than 1-syllable items (in raw scores both achievements give 1 point), and a participant who managed to repeat items containing many syllables, thus received more points than those participants who did not manage to do this. This analysis was chosen so that those participants who have developed the ability to repeat really long items in the right serial order could be distinguished from those who could not. All participants' responses were recorded, and the items were transcribed and divided into syllables.

It was previously predicted that early blind individuals would receive higher scores than both late blind and sighted, and that the results of late blind and sighted would not differ. It was also predicted that there would be no difference between L1 and L2 speaker results on this test, since the items are language neutral. Lastly, it was predicted that there would be no inter-
action effect between the visual status factor and the language background factor, as the effect is expected to be additive.

As shown in table 4.3, the L2 speakers do receive a slightly higher score than the L1 speakers, but this difference in mean score is not significant according to the result of a 2 (language background: L1 speaker or L2 speaker) x 3 (visual status: early blind, late blind, sighted) ANOVA. The analysis thus revealed that the main effect of language background was not significant, $F(1, 71) = 2.82, p = .097$, which was in line with the prediction in relation to language background. There was, however, a statistically significant effect of visual status (EB, LB, S), $F(2, 71) = 13.82, p = .001$. Effect size was large, partial eta squared = .28. This finding is also in line with the prediction, and it is further explored in the post-hoc comparisons. The statistical analysis also support the prediction made concerning interaction, as there was no interaction between visual status and linguistic background, $F(2, 71) = 0.74, p = .480$. This shows that the effect of the two variables was additive.

Post-hoc analysis using Bonferroni revealed that the EB group ($M = 113.73, SD = 20.68$) scored significantly higher than the other two groups: LB ($M = 90.18, SD = 18.03$), $p = .001$, and S ($M = 88.45, SD = 18.16$), $p = .001$, and that the mean scores of the LB and S groups did not differ. So, in this test, which presented the same challenge to all 80 participants (since it was not similar to any previously known languages), and which was the most demanding serial recall test of all three phonological short-term memory tests, the early blind group outperformed the late blind and sighted, and late blind and sighted groups did not differ. This finding also supports the prediction in relation to visual status, which means that all three predictions were supported.

Interestingly, and impressively enough, when a ranking was made of all participants using z-scores on Lat A strict scoring, the best 11 participants were all early blind: 6 L1 speakers and 5 L2 speakers. This means that half of all early blind participants in the whole study received a higher score than all other participants. The best early blind participant, ranked number 1, received a score 2.45 standard deviations above mean, and the 11th early

### Table 4.3

<table>
<thead>
<tr>
<th>Language background</th>
<th>EB</th>
<th>LB</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>111.73 (24.97)</td>
<td>81.75 (21.30)</td>
<td>86.89 (18.33)</td>
<td>93.16 (23.96)</td>
</tr>
<tr>
<td>L2</td>
<td>115.73 (16.32)</td>
<td>97.67 (10.91)</td>
<td>89.85 (18.37)</td>
<td>98.73 (19.46)</td>
</tr>
<tr>
<td>Total</td>
<td>113.73 (20.68)</td>
<td>90.18 (18.03)</td>
<td>88.45 (18.16)</td>
<td>96.05 (21.78)</td>
</tr>
</tbody>
</table>

Note: EB = early blind; LB = late blind; S = sighted
blind received a score 1.06 standard deviations above mean. The participant ranked number 12 was a sighted L2 speaker, who received a score 1.01 standard deviations above mean, and participant 13 was a sighted L1 speaker who also had a score 1.01 standard deviations above mean.

(b) Syllable levels collapsed and analyzed

This analysis is based on raw scores, where one point was given for every correctly repeated item, irrespective of the length on the items (which otherwise varied between 1 and 13 syllables). The levels 1–4, 5–8 and 10–13 were then collapsed and the statistics were run on these figures. This analysis was chosen because it shows the advantage in phonological short-term memory functions not only in the early blind group, but also in the late blind group, an advantage not visible on an analysis of overall score. Figure 4.2 displays the results of this analysis, and the collapsed raw scores were transformed into percent of correctly repeated items on the collapsed 1–4, 5–8 and 10–13 levels. As illustrated for the lower collapsed levels 1–4, both early blind and late blind groups presented higher results than the sighted group. On the levels 5–8 and 10–13, the same pattern appears as in the other phonological short-term memory tests where early blind presented higher results than the other two groups, and late blind and sighted presented similar results. The statistical analyses, presented later in the paragraph, support this interpretation of data. Figure 4.2 presents L1 and L2 speakers as one
Study I: Memory, Blindness and Second Language Acquisition

group, since the difference between these groups of speakers on Lat A were not significant, as shown in analysis (a), presented earlier.

A two-way between groups analysis of variance was then performed on the 1–4 syllable levels, and the analysis revealed that there was a statistically significant main effect for degree of vision/visual status (EB, LB, S), $F(2, 71) = 7.41, p = .001$. Effect size was large, partial eta squared = .17. There was no main effect for language background (L1: $M = 6.03$, $SD = 1.52$, L2: $M = 6.28$, $SD = 1.40$), $F(1, 71) = 1.7, p = .202$, which shows that both L1 and L2 speakers had the same prerequisites to perform the test, as was expected. There was no interaction between visual status and linguistic background, $F(2, 71) = 1.20, p = .306$.

Post-hoc analysis using Bonferroni revealed that the EB group ($M = 6.73$, $SD = 1.49$) did not score significantly higher than the LB ($M = 6.76$, $SD = 1.30$), $p = 1.0$, but significantly higher than the S group ($M = 5.55$, $SD = 1.27$), $p = .005$. The scores of the LB were significantly higher than the S group, $p = .008$. On the collapsed 1–4 syllabic level, both EB and LB scored higher than S. It can be hypothesized that the better performance of the phonological short-term memory in both the early and late blind is seen in the performance of this lowest collapsed level.

At the five- to eight-syllable levels, however, the usual pattern appears. The analysis revealed that the effect of language background was not significant (L1: $M = 2.81$, $SD = 2.22$, L2: $M = 3.00$, $SD = 2.02$), $p = .54$. There was a statistically significant main effect for degree of vision/visual status (EB, LB, S), $F(2, 71) = 8.55, p = .001$. Effect size was large (partial eta squared = .19). The effect of language background (L1 or L2 speaker) was not significant, $F(1, 71) = 0.38, p = .542$. There was no interaction between visual status and linguistic background, $F(2, 71) = 0.07, p = .936$.

Post-hoc analysis using Bonferroni revealed that the EB group ($M = 4.36$, $SD = 2.15$) scored significantly higher than the LB ($M = 2.35$, $SD = 1.73$), $p = .006$, and the S group ($M = 2.31$, $SD = 1.86$), $p = .001$, but the scores of LB and S did not differ significantly. On this more difficult level, the usual pattern appears where EB outperformed the other two groups.

At the 10–13 syllable levels, statistical methods were not used, since very few participants managed to repeat any items with this many syllables. Only 11 participants managed to perform at these levels: 9 of them were early blind, 2 of them were sighted, and none were late blind.

(c) Short-term store capacity

The third analysis of phonological short-term store capacity was performed due to congenitally blind individuals being found to perform better on tests of phonological short-term store capacity (e.g. Röder & Neville, 2003; Rokem & Ahissar, 2009), and because Lat A had supraspan length items that
exceeded the phonological short-term store capacity of approximately two seconds of spoken material (Baddeley, 2012).

In order to investigate the possible differences between the groups in ability to store spoken material, group comparisons were performed on the items in Lat A that took approximately two seconds or more to repeat, and the raw scores on those items were used in the statistical analysis.

At the five-syllable level, the difference between the groups (EB, LB, S) were not significant. At the six-syllable level, where average item length was 1.8 seconds, the difference between the groups was significant. The two-way between groups ANOVA revealed a statistically significant main effect for degree of vision/visual status (EB, LB, S), $F(2, 71) = 3.94, p = .024$. Effect size was moderate (partial eta squared = .10). There was no significant main effect for language background ($F(1, 71) = 2.07, p = .16$) and no interaction between visual status and language background ($F(2, 71) = 2.30, p = .11$). Post-hoc analysis using Bonferroni revealed that the score of the EB group ($M = 1.00, SD = 0.82$) was not significantly different from the score of the LB group ($M = 0.47, SD = 0.62$), $p = .078$, but significantly higher than the S group ($M = 0.50, SD = 0.73$), $p = .035$. The difference between the LB and S was not significant.

At the seven-syllable level, where average item length is 2.09 seconds, the same pattern appears. The two-way between groups ANOVA revealed that there was a statistically significant main effect for degree of vision/visual status (EB, LB, S), $F(2, 71) = 7.75, p = .001$. Effect size was large, partial eta squared = .18. There was no significant main effect for language background ($F(1, 71) = 0.92, p = .34$) and no interaction between visual status and linguistic background ($F(2, 71) = 0.80, p = .45$). Post-hoc analysis using Bonferroni revealed that the score of EB group ($M = 1.32, SD = 0.78$) was not significantly different from the score of the LB ($M = 0.76, SD = 0.75$), $p = .066$, but significantly higher than the S group ($M = 0.55, SD = 0.69$), $p = .001$. The difference between the LB and S groups was not significant.

At the eight-syllable level, where average item length is 2.42 seconds, a new (albeit familiar) pattern appears. The two-way between groups ANOVA revealed a statistically significant main effect for degree of vision/visual status (EB, LB, S), $F(2, 71) = 9.61, p = .001$. Effect size was large, partial eta squared = .21. There was no significant main effect for language background ($F(1, 71) = 0.03, p = .87$), and no interaction between visual status and linguistic background ($F(2, 71) = 0.67, p = .52$). Post-hoc analysis using Bonferroni revealed that the score of EB group ($M = 1.45, SD = 0.96$) was significantly higher than the score of the LB ($M = 0.53, SD = 0.87$), $p = .003$, and significantly higher than the S group ($M = 0.53, SD = 0.73$), $p = .001$. The difference between the LB and S groups was not significant.
The same pattern appears at the ten-syllable level (unfortunately the test does not contain any 9-syllable items), where average item length is 3.012 seconds. The two-way between groups ANOVA revealed a statistically significant main effect of visual status (EB, LB, S), \( F(2, 71) = 6.89, p = .002 \). Effect size was large, partial eta squared = .16. There was no significant main effect for language background (\( F(1, 71) = 0.64, p = .80 \)), and no interaction between visual status and linguistic background (\( F(2, 71) = 0.08, p = .92 \)). Post-hoc analysis using Bonferroni revealed that the score of EB group (\( M = 0.27, SD = 0.46 \)) was significantly higher than the score of the LB (\( M = 0.00, SD = 0.00 \)), \( p = .009 \), and significantly higher than the S group (\( M = 0.03, SD = 0.16 \)), \( p = .004 \). The difference between the LB and S groups was not significant.

At the 11-, 12- and 13-syllable levels, no significant group differences appear. In sum, it can be seen that EB became better than S at the six-syllable level and above, that is, from 1.8 seconds of spoken material up to 3.012. At the six- and seven-syllable levels, the LB score was not significantly different from any other group, and results for that group were between the EB and the S group. This suggests that the LB group has advantages in phonological short-term storage capacity, but not enough for it to reach significance when storage requirements are approximately two seconds or more (it was, however, seen for the collapsed one- to four-syllable level in the former analysis).

It has been found that congenitally and early blind individuals process speech twice as fast as sighted individuals (e.g. Stevens, 2005), and these findings seem to indicate that congenitally and early blind individuals not only process twice as much speech during the same timeframe as sighted, but also that their actual timeframe, that is, their storage capacity, is greater. In this study, early blind were significantly better than the late blind up to 3.012 seconds of spoken material, which suggests that the storage capacity is increased by approximately 50% compared to the two-second limit proposed by Baddeley (2012). This storage capacity advantage would thus be a result of early blindness.

4.5.1.4 Summary of phonological short-term memory test results
The digit span test results showed that early blind individuals were significantly better than the other two groups and that the late blind and sighted groups did not differ significantly. The L1 speakers also scored significantly better than the L2 speakers. The results also revealed that there was no interaction between the language background factor and the visual status factor. These findings were all in line with the predictions.

The statistical analysis of the CNRep scores showed that the same pattern appeared again: the early blind scored significantly better than the late blind and sighted, and the late blind and sighted groups did not differ significantly.
Also in this test, the L1 speakers scored higher than the L2 speakers, but the actual difference in mean score was not great. As with the digit span test, the results revealed that there was no interaction between the language background factor and the visual status factor. These findings were also in line with the predictions.

The statistical analysis of Lat A correctly repeated syllables in the right serial order analysis (not based on raw scores) showed that the usual pattern appeared again where the early blind group performed significantly better than the late blind and sighted, and that the results of the late blind and sighted did not differ. In this language neutral test, there was no significant difference between the L1 and the L2 speakers. The analysis also revealed that there was no interaction between the language background factor and the visual status factor. These findings were also in line with the predictions.

Two additional analyses were also performed on the Lat A data, and these were based on raw scores. The analysis of the collapsed 1–4, 5–8 and 10–13 levels (the test contained items with 1 to 13 syllables) revealed additional information not visible in analyses of overall score results. This analysis displays the advantage not only of the early blind individuals, but also of the late blind individuals on the one- to four-syllable levels, compared to sighted. On higher levels (five to eight), however, the usual pattern appears, in which the early blind outperform both the late blind and sighted, which do not differ significantly. No significant differences appeared on the 10–13 levels, since very few participants scored at these levels. It is noteworthy, however, that among those very few 11 participants who managed to score on these levels 9 were early blind.

The last analysis based on raw scores investigated the phonological short-term store capacity of the different groups. According to Baddeley (2012), the upper limit of the phonological short-term store capacity is approximately two seconds of spoken material. Significant group differences appeared from the six-syllable level, where the average item length was 1.8 seconds, and here the early blind outperform the sighted, and this pattern was also found at the seven-syllable level, where the average item length was 2.09 seconds (late blind did not differ significantly from the other groups on these levels, and thus scored in between the other two groups). At the eight- to ten-syllable levels, where the demand on the phonological short-term store capacity was on average 2.42–3.01 seconds, the early blind performed significantly better than both late blind and sighted. In the early blind group, the phonological short-term store capacity advantage is thus 1.01 seconds (i.e. approximately 50%) greater, as a consequence of becoming blind early in life. The advantage in phonological short-term store size could not be calculated for the late blind group, as the advantage found at the six- and seven-syllable levels did not differ significantly from the results of the sighted.
Based on the results of the Lat A test, (which is language neutral), it seems as if there is no general L2 advantage, that is, an advantage as a result of being an L2 speaker. This is discussed further below.

When rankings of all participants were made (z-score) for all phonological short-term test results, it becomes clear that some participants consequently received either a low or a high score on these tests. For instance, five early blind and one sighted participant consistently received scores one standard deviation or more above the mean. The same tendency can also be seen among the low scores, where four participants consequently received a score one standard deviation below the mean or lower on all three tests, one of who was late blind and three sighted. This shows that there are some individuals who are more talented and have developed this memory function to a greater degree, and in this case most of them are early blind; whereas other individuals have not developed this memory function to a great degree (in this test illustrated by one late blind and three sighted individuals).

The general finding, in relation to the rankings made of the phonological short-term memory test results, is that the majority of participants who scored higher than one standard deviation above the mean, were early blind.

### 4.5.2 Llama D

The results of Llama D test are shown in table 4.4. It was predicted that early blind individuals would receive a better result than late blind and sighted, and that late blind and sighted group results would not differ, that is, there would be the same pattern of results as was found in the phonological short-term memory tests. It was also predicted that the language background factor would not be significant, since the items are language neutral. A last prediction was also made in relation to a possible interaction effect, and it was predicted that there would be no interaction effect.

Normality was assessed using Kolmogorov-Smirnov, and the result showed that normality was violated. For this reason, non-parametric and parametric techniques were compared, and since the results did not present the same significant group differences, the non-parametric technique was used. A Mann-Whitney $U$ test revealed that there was no significant diffic-
Blindness and Second Language Acquisition

difference between L1 (M = 35.63, SD = 14.51) and L2 (M = 34.13, SD = 15.44) speakers, which supported the prediction in relation to the variable language background. The analysis using a Kruskal-Wallis test, however, revealed that the difference in Llama D scores between the different visual status groups was significant (EB, n = 22; LB, n = 18; S, n = 40) \( \chi^2(2, n = 80) = 19.57, p = .001 \), which supports the prediction, and this was further explored using Mann-Whitney. It was also predicted that there would be no interaction between the variables language background and visual status, and a two-way between-groups ANOVA was conducted to investigate this, which showed that there was no interaction between the variables, \( F(2, 74) = 1.27, p = .29 \), which is in line with the prediction.

A Mann-Whitney U test revealed that the difference in mean score between EB (M = 45.45, SD = 14.30) and LB (M = 36.94, SD = 12.96) was not significant, \( U = 135, z = -1.73, p = .08 \). This finding does not support the previous prediction. It should, however, be noted that the L1 and L2 speaker groups behaved somewhat differently, since the results of the L2 speaker group actually seem to support the prediction that early blind would outperform the other two groups and that the other two groups would not differ significantly. The difference between EB and S (M = 28.13, SD = 12.44) was, however, significant, \( U = 168.00, z = -4.03, p = .001 \), large effect size: \( r = .51 \), which was in line with the prediction. The difference between LB and S was significant, \( U = 196.50, z = -2.78, p = .005 \), large effect size: \( r = .36 \). This finding does not support the prediction, since the late blind performed higher than the sighted.

It can be concluded that the pairwise comparisons between the groups revealed that both EB and LB performed significantly better than the S participants, and that this test (as well as the collapsed 1- to 4-syllable levels and the Lat A) seemed to capture the advantage in performance not only of EB but also of LB. Another possible explanation is that some late blind L1 speakers were particularly talented at recognition of new word forms and raised the mean of the late blind L1 speaker group, thus changing the predicted pattern for the whole group (L1 and L2 speakers as one group).

A ranking of all participants on Llama D using z-scores shows that 16 participants had results that were better than 1 standard deviation above the mean (from 1 to 2.36 standard deviations above the mean). Of those 16 participants, 12 were early blind (5 L1 speakers, 7 L2 speakers), 3 were late blind (L1 speakers) and 1 was a sighted (L2 speaker).

This test thus taps a cognitive long-term memory function that develops in blind individuals in general, and perhaps especially in those individuals who exhibit high language aptitude related to auditory recognition memory for new words.
4.5.3 Alomba

Table 4.5 shows the mean results of all participating groups on the episodic memory test Alomba. According to the prediction in relation to the language background variable, L1 speakers would score higher than the L2 speakers, since the test was in Swedish. It was also predicted in relation to the visual status variable that the early blind would perform better than the late blind and sighted, and that late blind and sighted would not differ between them. The last prediction was that there would be no interaction effect between the visual status variable and the language background variable.

In order to test the predictions statistically, a two-way between-groups ANOVA was conducted to investigate the impact of language background and visual status on episodic memory as measured by the episodic memory test Alomba. The results showed that the main effect of language background was significant $F(1, 74) = 6.44, p = .013$. Effect-size was moderate (partial eta squared .08). The mean of the L1 speakers ($M = 17.41, SD = 5.61$) was significantly higher than the mean of the L2 speakers ($M = 14.31, SD = 4.12$), which is in line with the previous prediction. There was, however, no statistically significant main effect for visual status (EB, LB, S), $F(2, 74) = 0.122, p = .89$, and this result does not support the previous prediction concerning the visual status factor, since early blind did not receive a significantly higher result than the other two groups. There was no interaction between language background and visual status, $F(2, 74) = 0.051, p = .95$, which is in line with the prediction related to a possible interaction between the two variables.

A ranking of all participants on Alomba using $z$-scores shows that 14 participants had results that were better than 1 standard deviation above the mean (from 1 to 3.14 standard deviations above the mean): 4 early blind (3 L1 speakers, 1 L2 speaker), 2 late blind L1 speakers and 8 sighted L1 speakers. Compared to the previously made rankings in relation to the other memory tests, it can be seen that there is a fairly even distribution between blind and sighted individuals who are highly ranked. In the other memory tests, the early blind individuals dominate among highly ranked individuals.

<table>
<thead>
<tr>
<th>Language background</th>
<th>EB</th>
<th>LB</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>18.00 (4.69)</td>
<td>16.78 (7.23)</td>
<td>17.38 (5.53)</td>
<td>17.41 (5.61)</td>
</tr>
<tr>
<td>L2</td>
<td>14.59 (4.02)</td>
<td>14.33 (5.08)</td>
<td>14.15 (3.91)</td>
<td>14.31 (4.12)</td>
</tr>
<tr>
<td>Total</td>
<td>16.30 (4.61)</td>
<td>15.56 (6.19)</td>
<td>15.76 (5.00)</td>
<td>15.86 (5.13)</td>
</tr>
</tbody>
</table>

Note. EB = early blind; LB = late blind; S = sighted
4.6 Discussion

The three memory aspects that were investigated are discussed separately in this section, and each discussion ends with a paragraph discussing methodological aspects of the specific testing for each.

4.6.1 Phonological short-term memory

The answer to the question of whether early blind individuals have a better phonological short-term memory performance than late blind and sighted seems to be yes based on the cross-sectional data collected. All three phonological short-term memory tests revealed that early blind were significantly better than late blind and sighted individuals in terms of overall scores. The analysis of phonological short-term memory storage capacity also revealed group differences. According to Baddely (2012), the upper limit of the phonological short-term store is approximately two seconds of spoken material, and as the demand on the storage capacity is close to the upper limit, the early blind group performed significantly better than the sighted individuals. The significant difference in storage capacity emerges at 1.8 seconds of spoken material, and it persists until the length of spoken material is 3.012 seconds, that is, when the processing demand on the phonological short-term store is approximately one second above the upper limit of the store. This is an advantage in processing capacity of approximately 50%. Previous research has also found that congenitally and early blind have improved their rate of speech processing by approximately 50%, understanding ultra-fast speech rates up to 25 syllables per second in the L1 compared to sighted individuals, whose maximum performance is approximately 8–10 syllables per second (Hertrich et al., 2009). Taken together, these findings suggest that congenitally and early blind not only process more than twice as much spoken material during the same time frame as sighted, but also that the actual timeframe, that is, the phonological storage capacity, might be approximately one and a half times greater than that of the sighted.

The findings also showed that when the demand on phonological short-term store exceeded 3.012 (on 11- to 13-syllable levels on Lat A strict scoring), very few participants managed to repeat the items. In fact, only 11 participants managed to do this, and of those individuals 9 were early blind and 2 were sighted.

A ranking was made of the participants’ results on Lat A strict scoring (the phonological short-term test, which placed the greatest demand on phonological short-term storage capacity containing supraspan length items), and it showed that the 11 first-ranked participants were all early blind. This means that half of all early blind participants of the study (six L1 speakers and five L2 speakers) performed higher results than the remaining partici-
pants, and they all scored better than one standard deviation above the mean when scores were transformed into z-scores.

According to Gathercole (2006), both new word learning and nonword repetition rely on the phonological storage capacity, and these abilities are constrained and determined by auditory and phonological processing (perception) and on speech-motor output processes (production). Gathercole also emphasizes that the phonological storage capacity is particularly important during the early stages of language acquisition (in the L1) but that it remains as a support for new word learning throughout the lifespan of the speaker.

The current finding of phonological short-term memory advantages in early blind compared to sighted is in line with findings provided by other researchers (e.g. Röder & Neville, 2003; Hull & Mason, 1995; Swanson & Luxenberg, 2009; Rokem & Ahissar, 2009). No previous studies have investigated the phonological short-term memory performance of late blind L2 speakers. The advantages of the late blind individuals in the current study could be seen on lower levels (the collapsed one- to four-syllable levels on Lat A), rather than on higher levels or on overall score. Possible advantages in phonological short-term store capacity in late blind could not be calculated since the differences found compared to early blind and sighted, above two seconds of store capacity (from seven-syllable to ten-syllable levels), did not reach significance.

The next question, then, is wherein lies the advantage of congenitally and early blind individuals that result in a better phonological short-term memory performance. In the study by Rokem and Ahissar (2009), where phonological short-term memory advantages in early blind were found, it was suggested that it is not an advantage of the phonological short-term memory function per se that results in a memory advantage, but rather a compensatory mechanism at the level of perceptual encoding. This advantage in perceptual encoding in turn leads to a better memory performance. Rokem and Ahissar (2009) suggested that, specifically, it is the ability to chunk remembered items that make congenitally blind individuals better at phonological short-term memory functions.

The same connection between phonological short-term memory advantage and the ability to chunk verbal material was made in a longitudinal study by Speidel (1993) that compared bilingual development in two siblings. In that study, it was found that the sibling who had good phonological short-term memory function sounded like a native in both languages, while the other sibling with poor phonological short-term memory performance sounded like a native in one language but like a foreigner in the other language. Speidel (1993) argued that a poor short-term memory capacity leads to less ready-made patterns or chunks of imitated speech in long-term memory, which in turn leads to the difficulty of having to construct sentenc-
ces from single words or sound units, having no “word-order-unit” support from long-term memory.

In earlier research on L1 development, it was found that blind children use more ready-made patterns of speech. They learn and repeat adult speech as models or chunks of speech to a larger degree than sighted children (Pérez-Pereira 1994; Pérez-Pereira & Castro, 1992, 1997; Peters, 1994), and it might be suggested that this behavior develops the phonological short-term store capacity as well as the amount and size of stored models of ready-made chunks of adult speech stored in long-term memory. This would, as a consequence, benefit L2 acquisition. Interestingly enough, Raz et al. (2007) also explains the better performance of the congenitally blind at serial recall of word lists (measuring phonological short-term memory) with the ability to learn in a “route-like” sequential manner.

Phonological short-term memory advantages are of importance to many aspects of L2 acquisition. According to Papagno, Valentine and Baddeley (1991), the function of the phonological loop is to learn the new sounds of new words acquired, and its primary purpose is to store these unfamiliar sound patterns while more permanent long-term representations are being established. This forming of long-term memory representations is also regarded as a key component in language development. Baddeley, Gathercole and Papagno (1998) also concluded that a good phonological short-term memory is related to fast and efficient learning of unfamiliar words, and they concluded that individuals with a good phonological short-term memory capacity have the prerequisites for developing a natural talent for learning languages. These findings are further supported by findings and conclusions drawn by other researchers. Bolibaugh and Foster (2013), for instance, drew the conclusion that the capacity of the phonological short-term memory limits both the rate of L2 acquisition and ultimate L2 attainment.

The phonological short-term memory has also been found to be of importance to the acquisition of other aspects of language. Papagno and Vallar (1995), for example, found that the phonological short-term memory is important to the acquisition of syntax. Additionally, O’Brien et al. (2007) found that phonological short-term memory predicted L2 oral fluency development over a 13-week period, during the initial stages of L2 acquisition. This aspect of oral fluency gains at early stages of L2 acquisition seems to support the experience of a teacher of Swedish as a second language who taught the blind and claimed that these individuals had a better L2 pronunciation (see introduction to study III), since oral fluency would affect the overall impression of speech production. Phonological short-term memory has, in fact, also been found to be of major importance to the development of L2 pronunciation during the earlier stages of L2 acquisition (Hu et al., 2012), but less so during later stages as the contribution from long-term representations increase (Masoura & Gathercole, 2005).
These findings thus suggest that the phonological short-term memory advantages found in early blind individuals are very important to many aspects of second language acquisition, no matter if the language is acquired early or late in life, and that it is especially important during early phases of L2 acquisition, but also that it remains as a support for new word learning, the acquisition of syntax, the rate of L2 acquisition and ultimate L2 attainment throughout the lifespan.

Unlike the visual status factor, the language background factor does not seem to be of any major importance in relation to phonological short-term memory functions, at least not in this study. Based on the results of the Lat A test, which is language neutral, it seems as if there is no advantage as a result of being an L2 speaker, although L2 speakers have the opportunity to use the phonological short-term memory to a greater degree on a daily basis, encountering new vocabulary to a greater extent than L1 speakers. Two comments, however, should be made. The first one is that there is a trend which shows that all three L2 groups received higher results than their respective L1 groups, and there is a possibility that an advantage in this specific memory function would have emerged if the test had contained more items with supraspan length or more participants. The second comment is that the participants of the current study were experienced L2 speakers, who presumably encounter less new word forms than a person who has just started to learn a new language, and that there might be L2 advantages at earlier stages of the L2 acquisition process, since the phonological short-term memory is particularly important at earlier stages of L2 acquisition (Gathercole, 2006; O’Brien et al., 2007, Hu et al., 2012), which are not captured in the current study.

In relation to methodological aspects, it is assumed that all three phonological short-term memory tests have high validity, since the common practice, when measuring phonological short-term working memory functions, is to use immediate serial recall tests like digit span and nonword repetition. Both the digit span test and the CNRep test used in the study are standardized tests. Lat A, in its original version, had very low reliability scores (and was excluded from the later developed Llama series), since the participants themselves judged their own performance. An analysis other than the one presented in the dissertation was also performed by the test leader (a more lenient scoring of correctly repeated syllables, not presented because of similar results), which was mentioned above, and there was a very high intra-rater reliability score between the strict scoring presented and the lenient scoring: $r = .95$, $n = 77$, $p < .001$. The internal consistencies of the scales measuring phonological short-term memory tests were also high with Cronbach’s alpha coefficients between .86 and .89.

Another finding that seems to support the reliability of the phonological short-term memory tests is that the results from all three tests display the
same general pattern. Also the statistical analyses seem reliable, since the effect sizes observed were generally large.

It might be argued that it would have been preferable if the digit span and CNRep tests had contained items with supraspan length (as the Lat A did) in order to avoid the risk of ceiling effects. It would also have been preferable to have included semantic memory tests in the study.

4.6.2 Recognition memory

The answer to the question of whether early blind individuals have a better recognition memory for new sound sequences is no, since it is not only the early blind group that receives a higher score than the sighted, but also the late blind group. There thus seem to be a general advantage of blindness in relation to recognition memory capacity. This finding is in line with the findings of previous research in which recognition memory is investigated in blind individuals (Bull, Rathborn & Clifford, 1983; Röder & Rösler, 2003), where both early and late blind individuals outperformed sighted on recognition memory tasks. The tasks in Bull, Rathborn and Clifford (1983) and Röder and Rösler (2003) were, however, not specifically testing recognition of words, but recognition of voices and environmental sounds; nevertheless, these also indicated that late blind individuals have the ability to develop the recognition memory ability to a larger extent than sighted individuals. This also indicates that recognition memory, at least in relation to audition, might maintain a high degree of plasticity later in life as well (discussed further below). It should be pointed out that the result pattern of the L2 group resembled the result pattern found in the phonological short-term memory tests in which the early blind outperformed the other two groups, but analyzed as a whole group (both L1 and L2 speakers) the pattern just presented appeared.

Recognition memory tasks are less demanding than phonological short-term memory tasks, which require that the items have to be recalled and subsequently also produced. In recognition memory tasks, on the other hand, the participant is not asked to produce the items, but are instead presented with the items that only have to be recognized the second time they are presented (Ward, 2010). This fact might also contribute to the performance of the late blind, making them as able as the early blind at recognition memory performance.

Speciale, Ellis and Bywater (2004) investigated whether the ability to recognize and learn new phonological sequences was related to the phonological short-term store capacity, or whether these processes made separate and additive contributions to vocabulary development. The researchers found that these two processes were separate but important complementary processes that together made a greater contribution to foreign language competence.
than the capacity of the phonological short-term store alone, as they found no correlation between the results of the two tests. The current results, unlike the results of Speciale, Ellis and Bywater (2004), showed that these two capacities are correlated (highly significant and medium strong, $r = .40, n = 77, p = .001$). The results of the current study thus suggest that these processes are inextricably entwined and inseparable processes in language acquisition: one of the processes related to receptive language competence (recognition memory), and the other to productive language competence (phonological short-term memory).

The ability to recognize new phonological sequences has been associated with different aspects of language learning talent, for instance, in relation to the abilities to acquire new vocabulary, to recognize grammatical features and to acquire L2 collocations (Granena, 2013; Meara, 2005; Forsberg Lundell & Sandgren, 2013). These findings, together with the findings of the current study, imply that blind individuals, irrespective of age of onset of blindness, have developed better prerequisites for learning a second or foreign language than sighted individuals. This is even further supported by the findings from the phonological short-term memory tests in blind individuals. As can be seen in the presentation of the Lat A results, the late blind also display some advantage in phonological short-term memory capacity compared to sighted individuals at less demanding levels of the test (collapsed levels 1–4). The early blind displayed, however, an impressive advantage in phonological short-term store capacity (productive language competence), which, together with better performance on auditory recognition memory for new words (receptive language competence), give them obvious benefits in relation to the sighted when it comes to second language acquisition.

As was mentioned in the presentation of the test Granena (2013) evaluated the Llama test battery on 186 participants from 3 different linguistic backgrounds and received a mean score on the Llama D of 30.27 (SD = 15.72), approximately the same as for the sighted groups of the current study. The fact that the mean scores of sighted individuals are comparable between studies suggests a good reliability of the test. Granena (2013) also evaluated internal consistency, which was acceptable, and test-retest reliability, which was great.

That the Llama D test measures the ability to recognize novel word forms or sound sequences is not doubted, and none of the participants had had any previous experience with the Canadian Indian language that was used. Further, the statistical measures performed in the current study showed that the effect sizes were either medium or large. Taken together, these different measures demonstrate that the test results of Llama D cannot be disregarded due to low validity or reliability.
4.6.3 Episodic memory

The answer to the question of whether early blind individuals have a better episodic memory performance than late blind and sighted is no, since there were no significant differences between the groups of different visual status. That is, they have no advantages compared to the late blind and sighted in remembering an event in which many facts are presented to them. In other types of episodic memory tests, like auditory recognition tests (Röder & Rösler, 2003; Röder, Rösler & Neville, 2001; Raz et al., 2005; Bull, Rathborn & Clifford, 1983; Röder, Wolber & Neville, unpublished but presented in Röder & Neville, 2003) both early and late blind individuals perform significantly better than sighted. This was also found in the current study, but in the case of remembering the event of hearing many facts being presented, the same advantage was thus not observed.

It is interesting to note that in the cases of phonological short-term memory and auditory recognition memory, the advantages found in blind individuals are associated with the ability to register the characteristics of the speech signal or of the sound signal. The episodic memory test Alomba, however, requires the recall of the event of hearing facts being presented, rather than the registering of sound or speech signal characteristics. This implies that the advantages found in blind individuals are primarily associated with the processing of auditory information. This is further supported by the finding of Rokem and Ahissar (2009), who investigated whether the phonological short-term memory advantages found in congenitally blind individuals were the result of an actual memory advantage, or if the better memory performance of congenitally blind was based on auditory processing advantages. Their results showed that it was the required auditory processing of the speech signal, underlying the memory performance, that was favored rather than the actual memory performance per se. It can thus be concluded that being early or late blind does not seem to be an advantage compared to being sighted on episodic memory performance requiring recollection of the event of hearing facts in an auditorily presented story in either an L1 or L2.

In discussing methodological aspects, it should be mentioned that inter- and intra-rater reliability measures were not performed, which is a limitation of the study.
Chapter Five

Study II:
Speech Perception in Noise and Blindness

5.1 Introduction

It has been shown that the prerequisites for perceiving speech in quiet listening conditions are very similar for L1 and L2 speakers (Rogers et al., 2006; Mayo, Florentine & Buus, 1997). In noisy environments, however, the prerequisites differ greatly between them. It has, for instance, been found that L2 speakers receive much poorer results on measures of speech perception in noise, especially when the noise consists of speech or babble, and even when the age of onset of L2 acquisition is as low as two years of age (McAllister, 1997; Rogers et al., 2006; Mayo, Florentine & Buus, 1997; Crandell & Smaldino, 1996), indicating that nativelike speech perceptual abilities develop very early in childhood. These findings are in line with the findings of McAllister (1997), who developed the notion of “perceptual foreign accent,” which states that even near-native adult L2 speakers, that is, L2 speakers who are indistinguishable from L1 speakers in everyday communication, suffer from a “hidden” disadvantage or inability when perceiving speech in noisy environments.

Speech perception in blind L1 speakers has been investigated in both quiet and noisy environments. It has been found that congenitally blind L1 speakers have proven to have the same auditory sensory threshold in quiet environments as sighted individuals (Röder & Neville, 2003; Niemeyer & Starlunger, 1981) or only a minor advantage (Rokem & Ahissar, 2009).

Since blind individuals do not have access to extralinguistic information like facial expressions, gestures, etc., it might be hypothesized that blind individuals are disadvantaged compared to sighted individuals when they perceive speech and interpret a message. This might, however, not be the case, according to Röder, Rösler and Neville (2000), who suggest that extralinguistic information, such as facial expressions, is also transferred re-
Blindness and Second Language Acquisition

dundantly in parallel in the form of auditory cues in the speech signal. These auditory cues are thus only perceived by blind individuals, as sighted individuals have not developed the ability to perceive them and instead rely on visual cues. Other advantages associated with auditory perception in blind individuals have also been found. It is, for example, a well-established fact that early blind individuals process speech much faster than sighted individuals (approximately twice as fast: Hertrich, Dietrich & Ackermann, 2013; Hugdahl et al., 2004; Niemeyer & Starlinger, 1981; Röder, Rösler & Neville, 2000; Röder et al., 2002; Röder et al., 2003), and thus process more speech material within the same timeframe (for instance, the timeframe of the phonological short-term store) compared to sighted. It was also found in the current study (study I) that the size of the phonological short-term store is greater in early blind individuals than in late blind and sighted individuals (approximately 50% greater), and both these advantages (i.e. the improved speed of speech processing and the larger size of the phonological short-term store) might be an advantage when longer stretches of speech, for example, sentences rather than single words, have to be perceived, due to the greater demand this places on the phonological loop capacity.

These findings suggest that blind individuals, especially congenitally and early blind individuals, have advantages compared to sighted that are associated with different aspects of speech perception. However, what happens when the speech signal is degraded by noise? The results from studies of the perception of speech in noise by blind individuals are mixed, some suggesting that blind individuals perform lower results than sighted in perturbed environments (Stankov & Spilsbury, 1978), while the results of other studies suggest that congenitally blind individuals have an advantage compared to sighted individuals (Rokem & Ahissar, 2009; Muchnik et al., 1991; Niemeyer & Starlinger, 1981). No definite conclusions can be drawn from this research because different noise sources have been used in different studies. The only study of speech perception in noise in blind L2 speakers is a small-scale study of Kjellberg Smeds (2008), and the findings from that study suggested that blind individuals suffered from a disadvantage compared to sighted when they perceived words in babble noise but not when they perceived sentences in white noise. This suggests that different kinds of speech material and different kinds of noise affect blind individuals differently than they do sighted individuals. Based on contradictory findings in that study, however, no conclusions could be drawn, and it is still an open question whether early blind L2 speakers have the same advantages as congenitally and early blind L1 speakers when they perceive speech in noise, which was found to be the case in previous research (Rokem & Ahissar, 2009; Muchnik et al., 1991; Niemeyer & Starlinger, 1981), or if this depends on the language background factor, that is, on the fact that they are L2 spea-
kers and not L1 speakers, or on the character of the noise or on the type of linguistic material to be perceived.

Based on this introduction, the following questions arise: Are early blind individuals advantaged compared to late blind and sighted when perceiving speech in noise, or does their perceptual performance depend on (a) if the person is L1 or L2 speaker, or on (b) the noise source (white noise versus babble noise), or on (c) the length of the item to be perceived (single words versus sentences)?

5.2 Theoretical background

The theoretical background presents relevant research in relation to speech perception, both in L1 and L2 speakers, in quiet and noisy environments and in blind and sighted individuals. All these aspects of speech perception are discussed in relation to a model of speech processing that is used as a framework for the discussion.

5.2.1 Speech perception

For speech perception, the signals are directed mainly along the “what” pathway of the auditory cortex in the left hemisphere. A question that Ward (2010) and other researchers, such as Wernicke (see Ward, 2010), have asked themselves, is at what stage of processing, if any, does the brain start to treat speech differently from other sounds? Usually the answer is when it becomes lateralized to the left hemisphere of the brain, the hemisphere associated with language processing. It has been found that both speech and sounds are treated bilaterally, by both hemispheres, in the primary auditory cortex, and this finding suggests that divergence takes place at a later stage in the cortical hierarchy. Results show that a greater activation of the left hemisphere, that is the lateralization associated with language processing, begins to appear along the so-called “what” route in the secondary auditory cortex, mentioned above. Wernicke speculated that the left hemisphere advantage arose because of its connection to the motor-speech system, which is also located in the left hemisphere and called Broca’s area, which is activated during speech production. Wernicke’s area, also situated in the left hemisphere, close to the auditory cortex, is associated with the understanding of written and spoken speech, that is, it is the speech perception system. Interestingly, research on blind individuals has shown that both blind and sighted individuals demonstrate this left lateralization of language and speech processing, but some studies have found this to be less pronounced in blind individuals (Röder, Rösler & Neville, 2000), since the left-hemisphere advantage seems to vanish as blind individuals learn to read braille (Röder & Neville, 2003). Instead, a broader activation occurs in blind individuals when
speech is processed that involves both hemispheres of the brain (Röder, Rösler & Neville, 2000). Interestingly enough, extremely talented second language learners have also been found to activate the right hemisphere to a greater degree than the less talented, bypassing the established first language processing mechanisms associated with the left hemisphere. This then leads to an additional right hemisphere based flexibility for second language processing, and thus a greater utilization of the cortex compared to untalented language learners, resulting in a more symmetrical activation. In fact, Schneiderman and Desmarais (1988) even suggest that a non-left lateralization for language is an essential element in the neuropsychological profile of a talented language learner.

It was mentioned above that there are two routes for speech signals as they pass the primary auditory cortex: one for perceiving speech (“what”) and one for production of speech (“how,” the same route as speech location “where”). The “what” route is based on lexical-semantic processing, and it is probably based on the acoustic aspects of speech. This speech perception route eventually reaches the semantic memory structures of the brain identifying the content, that is, the “what” of speech (what is being said), before ending at Broca’s speech production area. The other “how” route is based on auditory-motor correspondence (how something is to be articulated). It also starts at the primary auditory cortex and leads to a part of Wernicke’s area that links together auditory and motor (and visual) aspects of speech. This area has been shown to become activated by silent articulation. It has been suggested that the “how” route, connecting this area with Brocha’s area of speech production, is the neuroanatomical basis of the phonological loop (Baddeley & Hitch, 1974; Baddeley, Lewis & Vallar, 1984), that is, the short-term memory for verbal material, which is refreshed by subvocal articulation. The existence of two routes suggests that there are two different ways in which speech can be repeated. The “what” route would be successfully repeating already familiar words, whereas the “how” route is used when the words are either novel or familiar but consisting of phonemes already existing in the articulatory repertoire (Ward, 2010).

Perception of speech presents a great challenge to the auditory system, which simultaneously handles a multitude of auditory cues (for instance, vowels and consonants, which are related to voicing, manner and place of articulation) and prosodic features (characterized by rhythm, intonation and dynamic characteristics; Kjellin, 1998) that have to be recognized by the listener, while speech is processed.

26 Semantic memory: a person’s stored information about the world and a person’s stored language system (Smith, 1993: G18).
5.2.2 A model of speech processing

In this section, a model of speech or language processing is presented. This model will then be used as a framework for discussing speech perception, comparing the different prerequisites of L1 and L2 speakers, of sighted and blind individuals, both with and without noise. There are different models describing speech processing, but only the model chosen here will be described in detail. This model, shown in figure 5.1, was developed by Lindblom (1987:12).

McAllister (1997) presented and used this model of speech and language processing in relation to second language speakers. According to the model, the understanding of an utterance is supported by two different psychological processes in the listener. The first process is passive, stimulus driven and signal-independent. The other process is active, hypothesis driven and signal-dependent. These two processes occur simultaneously and complement each other as the listener interprets an utterance. Signal-dependent information is the actual information contained in the speech signal – the “acoustic cues” or raw material on which the perceptual process is based. Signal-independent information refers to knowledge of the language spoken, of the communication situation that the person is in, of the world, and also non-linguistic cues like gestures and body language. This information creates expectations, on behalf of the listener, and also creates a frame for
the possible meanings conveyed by the speech signal. In order to reach the ideal level of speech comprehension, as indicated by the dotted line, the amounts of signal-dependent information and signal-independent information have to complement each other in order to reach full understanding. If the signal-dependent information (the linguistic raw material) is insufficient, for instance, when noise disturbs the signal, the listener has to rely more on signal-independent information to be able to perceive and understand the speech signal. In other words, when the speech signal is degraded, the listener makes active hypotheses about what is being verbally expressed, based on the situation, former experiences of different kinds, facial expressions and lip movements, etc. This is supported by the findings of other researchers. For instance, when Binnie (1974) tested speech perception in sighted individuals in a noisy environment, the results showed that the lower the speech discrimination score, the greater the visual contribution to the results. The opposite case is also common and occurs, for instance, when the listener has fairly little knowledge of the subject (signal-independent information) that is being conveyed by the speaker.

5.2.3 Speech perception in L2 speakers, with and without noise

Using the model presented above as a framework for understanding speech perception in L2 speakers, it can be concluded that they are disadvantaged in terms of signal-independent information. According to McAllister (1997), L2 learners have access to a reduced number of “top-down” strategies, associated with signal-independent processing, compared to native speakers. As an L2 speaker, one might, for example, have insufficient knowledge of the language or of how to interpret the situation or other non-linguistic cues such as the facial expressions of speakers. With respect to signal-dependent information, it might seem as if L2 speakers would have the same prerequisites for hearing the linguistic cues of the speech signal. This is, however, not the case. It has been shown that there are deviations and shortcomings in the way a new sound system is learned, even among competent L2 speakers. As was mentioned in the introduction, the reduced perceptual capacity found in even near-native L2 speakers is a “hidden” inability that only becomes obvious in perturbed listening environments. In noisy environments, characterized by a reduction in the redundancy of information, the L2 speaker is more adversely affected than the native speaker. This reduced perceptual capacity is referred to as “perceptual foreign accent” (McAllister, 1997, 1998).

McAllister (1997) performed experiments to investigate the existence of reduced comprehension capacity due to a “perceptual foreign accent” in proficient L2 users. The participants in this study were four proficient L2
speakers and four L1 speakers. The linguistic material that was used was (1) continuous speech, and (2) simple questions based on the Helen Task (developed by Ludvigsen, 1975, as reported in McAllister, 1997). These questions are easy to answer for both L1 and L2 speakers, e.g. “What color is a lemon?” “What number comes after three?” The linguistic material was presented in two types of noise; babble noise/cocktail speech noise and Hagerman noise. When listening to the material without noise, the listeners were primarily asked to report when they "just barely" could follow the content of the recorded material. This “just barely” level was then used as the listener’s threshold. In the second listener response, the comprehension threshold was found by the participant when answering simple questions, exemplified above. After these baseline recordings, noise was added. When the participant answered the question correctly, the noise was raised by 1 dB, and when the question was incorrectly answered or when the question was not heard, the noise level was decreased by 1 dB, resulting in an individual average signal-to-noise ratio. The results showed that the mean threshold of comprehension was higher for the L2 listeners than for the L1 listeners, which means that the items needed to be presented at a louder volume to the L2 speakers. When noise was added, L1 listeners performed significantly better than L2 listeners under three listening conditions: the threshold method in babble noise and in Hagerman noise, and the Helen method in babble noise. The group differences were not significant when using the Helen method and Hagerman noise, which was not discussed further. McAllister and Dufberg (1989) and McAllister (1997, 1989) concluded that when the speech signal is masked by noise, L1 speakers can tap their reserve of signal-independent information and experience, while the L2 listeners lack this ability. McAllister (1997) also concluded that babble noise seem to be a somewhat better masker of speech than Hagerman noise. As illustrated, even advanced late bilinguals, that is, bilinguals who acquired the L2 as adults, experience pronounced problem in perceiving speech in noisy environments, especially if the noise consists of babble noise.

To further investigate the importance of the age of onset of L2 acquisition (AO) and the ability to perceive speech in noise, Mayo, Florentine and Buus (1997) performed an experiment with monolingual and bilingual adults using a speech perception in noise-test. The groups were nine monolingual English speakers (“monolinguals”), three bilinguals who learned English as an L2 from birth (having one parent speaking English and one parent speaking Spanish, that is, “infant bilinguals”), nine who had Spanish as their L1 and learned English as an L2 before the age of 6 (“toddler bilinguals”), and nine who had Spanish as their L1 and learned English as an L2 after the age of 14.

---

27 Hagerman noise is a low-frequency, modulated noise with approximately the same long-term average spectrum as male speech (McAllister, 1997).
Blindness and Second Language Acquisition

Participants were all perfectly fluent in English, using their L2 at the university on a daily basis. All had normal hearing. The items consisted of 50 sentences in English presented in babble noise. In the analysis, “infant bilinguals” and “toddler bilinguals” were treated as one group. The results showed that all participants performed with native-like proficiency in quiet conditions. In noisy conditions, however, the monolinguals performed significantly better than the other groups, and the early bilinguals significantly better than the late bilinguals. The findings indicate that learning an L2 at an early age is important for high-level processing in noisy environments.

Crandell and Smaldino (1996) also studied speech perception in babble noise in children with English as an L2. The participants were 20 children with English as their L1 and 20 children with English as their L2, and they ranged in age from eight to ten years. The children in the latter group had all started to learn and speak the L2 at around the age of two and, according to their parents, they spoke English approximately 50% of the time. The items were English sentences. The results showed that the children with English as an L2 performed significantly poorer than the children with English as an L1.

In a more recent study by Rogers et al. (2006), the findings of previous studies were confirmed. The study investigated monosyllabic word recognition in quiet, in noise and in noise with reverberation (i.e. with an echo) by comparing performances by 15 monolingual speakers of American English and 12 Spanish-English bilinguals who had learned English as an L2 before six years of age and spoke English without a noticeable accent. The finding was that the early bilinguals received significantly poorer scores in noise and in noise with reverberation, but equal results under quiet conditions.

Summarizing the studies presented above, it is clear that L2 speakers are disadvantaged perceiving speech in environments in which many people are talking at the same time, even when the age of onset of L2 acquisition is as early as two years of age. It can be concluded that there is a dual disadvantage for L2 speakers in speech perception, in relation both to signal-dependent and signal-independent processes. These disadvantages are further enhanced when there is noise in the surrounding environment, degrading the signal-dependent information (the acoustic cues) even more.

5.2.4 Speech perception in blind L1 speakers, with and without noise

Investigations of auditory sensory thresholds in congenitally blind L1 speakers as revealed by standard audiometry (e.g. differences in thresholds for
frequencies, interaural time difference\textsuperscript{28} or amplitude modulations), do not generally reveal any differences between blind and sighted individuals (Röder & Neville, 2003; Niemeyer & Starlinger, 1981, Starlinger & Niemeyer, 1981), although minor advantages were found by Rokem & Ahissar (2009).

It is thus suggested that blind L1 speakers have more or less the same prerequisites for basic speech perception in non-perturbed environments compared to the sighted, although their basic prerequisites for speech perception are very different from those of sighted individuals. According to the model presented above, blind L1 speakers have, for example, less input from signal-independent information like facial expressions and support from the surrounding environment. As was mentioned more briefly in the introduction, Röder, Rösler and Neville (2000) suggested that the acoustic cues (e.g. prosodic cues) actually convey the extra linguistic information usually expressed by facial expressions, such as affective and other pragmatic information. This information is thus simultaneously, and redundantly, transferred through facial expressions, voice cues and body language, which is available only to the sighted listener. To blind listeners, however, only auditory cues (signal-dependent information) are available, and Röder, Rösler and Neville (2000) speculate that blind individuals are able to make extended use of and/or process these cues, which are to sighted individuals “hidden” auditory cues, that characterize the speech signal, enabling them to understand the message that is communicated to them. Relating this line of reasoning to the model described above, the auditory cues, that is, the signal-dependent information, actually redundantly conveys signal-independent information such as facial and affective expressions, as well. While sighted individuals primarily use visual cues that are presented by the speaker, the blind individual receives the same information but provided solely by the auditory signal. It can also be speculated that the ability to detect this signal-independent information from the speech signal is an ability that is improved in congenitally and early blind individuals, but maybe not in the late blind, since they have been using visually presented signal-independent information, just as sighted individuals, during childhood and adolescence, and therefore have not developed the ability to perceive this “extra linguistic” information from the speech signal (i.e. the signal-dependent information). This might be explained in terms of plasticity. The rise in synapse formation of the auditory and visual cortices, which are most likely involved in speech processing in blind individuals (Hertrich, Dietrich & Ackermann, 2013), takes place early in life – between 4 and 12 months of age – and has already

\textsuperscript{28} Interaural time difference: The difference in arrival time of a sound between two ears, which is important in sound localization (http://courses.washington.edu/psy333/lecture_pdf/Week9_Day2.pdf). 2014-09-09.
Blindness and Second Language Acquisition

fallen to adult levels between 2 and 4 years of age (at least in sighted individuals, Ward, 2010). During these sensitive periods, late blind individuals still use their visual sense, and recruitment of the visual cortex for functions other than vision is, therefore, not possible.

It was mentioned previously that blind L1 speakers also have the ability to perceive speech at a much higher rate than sighted individuals (25 syllables/second vs. 8–10 syllables/second), and researchers have found that this engages the central auditory system, the left frontal gyrus (known to be involved in phonological processing) and the visual system (Hertrich et al., 2009). An interesting observation is that blind individuals increase the speed of auditory presentations on their technical aids, like mobile phones and computers, when they listen to messages or auditorily presented documents. Before these technical aids were developed, they used, for instance, sped-up tapes, which were constructed by omitting the pauses between words, in order to increase the speed of presentation (Röder & Rösler, 2003, personal communication with Röder, November 2012). The ability to perceive speech at a greater rate can be explained by (a) enhanced auditory stimulus encoding ability (Elbert et al., 2002; Stevens & Weaver, 2009; Röder, Rösler & Neville, 2001; Rokem & Ahissar, 2009), which comprises advantages related to auditory processing, and/or by (b) a functional cross-modal contribution from the visual cortex in non-visual tasks (Alho et al., 1993; Gougoux et al., 2005; Röder et al., 2002; Sadato et al., 1996).

In the former section, it was shown that even near-native L2 speakers suffer from a “hidden” inability to perceive speech in noisy environments, and the next issue to be discussed here is how speech perception in blind individuals is affected by noise. There have been few studies of speech perception in noise with blind L1 speakers, but the results have been inconclusive. Some studies report a better performance in the blind, whereas other studies report the opposite. Stankov and Spilsbury (1978), for instance, compared 30 blind, 30 sighted and 30 children with low vision (10–15 years), on 26 different auditory tests, related to temporal tracking, discrimination among sound patterns/sound pattern recognition, speech perception in noise, and maintaining and judging rhythm. On most of these tests, groups of blind and sighted children obtained similar results, but blind children were better at tests of tonal memory, on tests where they had to recognize sound patterns, and on Rapid Spelling and on Letter Span. They performed, however, worse on tests in which they had to maintain and judge rhythm, and also on the two tests of speech perception in noise. In the latter, participants were asked to pick out single words from a continuous background of babble noise (irrele-
vant speech noise) or another type of background noise that was not specified.29

Opposing results in relation to speech perception in noise have been reported in an often cited article by Niemeyer and Starlinger (1981), where different aspects of speech perception in 18 blind and 18 matched sighted adults were investigated using a variety of tasks. The researchers used a dichotic listening experiment and four speech audiometric tests (speech on different semantic levels, both with and without noise, type of noise not specified), and also elicited auditory evoked cortical responses to record the speed of processing. No significant differences between blind and sighted on the dichotic listening experiment were found (such differences were found, however, by Hugdahl et al., 2004), but differences were found on all speech audiometric tests and also on speed of processing. The researchers found that the reaction times were significantly shorter in the blind participants, a finding that has been confirmed by many other studies (Hugdahl et al., 2004; Kujala et al., 1997b; Röder, Rösler & Neville, 2000; Röder et al., 2003; Stevens & Weaver, 2005). They also found that the blind participants were superior on speech perception on all semantic levels, especially on sentence discrimination with and without environment-simulating noise. The character of this noise is not described in more detail.

Muchnik et al. (1991) studied central auditory skills in blind and sighted individuals and used a speech perception in noise test in which native words were presented in an unspecified type of noise at a fixed level. Both the stimuli and noise were delivered at 40 dB (signal-to-noise ratio 0.). The results showed that the blind participants were significantly better than the sighted.

Rokem and Ahissar (2009) used different kinds of speech perception in noise tests than the studies mentioned above. Speech perception was tested both with and without noise. Stimuli consisted of a set of ten disyllabic nonwords designed to resemble L1 phonetics and phonology. Primarily, participants were asked to repeat the presented nonwords, and the eventual level, at which the stimulus was played, was at the end of the task at ~80% correct stimulus identification. The task was performed both in a quiet background and in babble noise at 60dB, and it tapped the perceptual threshold. The results showed that blind individuals were better at identifying nonsense words at lower signal levels, both with and without babble noise. It should be clarified that the noise level was held constant while the pitch level of the items was manipulated. The researchers also used babble noise in a verbal

29 On all tests, children with little vision obtained lower results than the other groups, which the authors attribute to possible cognitive and/or personal problems. This explanation might, however, not be sufficient, since the neurological mechanism would also have to be considered for a more compete understanding of the prerequisites of these individuals. This was, however, not methologically possible at the time when those studies were conducted.
memory task, where participants were asked to repeat one- to five-item long sequences of nonwords under three different conditions. The first two conditions required participants to (a) repeat the sequences that all were presented above the threshold intensity, and (b) repeat items presented on the individual ~80% level of intensity. In the third condition (c), babble noise was added to the ~80% level of individual intensity. The results on verbal memory span showed that blind individuals were better in the first supra-threshold condition, an advantage that was eliminated as soon as items were presented at the individual ~80% level of intensity. The researchers therefore suggest that the advantages found in blind individuals reflect a compensatory mechanism at the level of perceptual encoding, which, in turn, leads to a better memory performance (retention and retrieval), rather than a compensatory memory advantage. This was further supported when noise was added, since the advantage of the blind was eliminated in this condition as well. The memory performance of blind individuals, thus, seems to be hampered by babble noise, or, rather, the advantage found in blind individuals in terms of verbal memory performance becomes diminished by babble noise. These findings are in line with previous results on the irrelevant speech effect, which indicates that babble noise not only disrupts perception, but also impairs recall (in contrast to white noise, which only disrupts perception; Baddeley, Eysenck & Anderson, 2009).

Summarizing the results presented above, it becomes clear that it is not possible to draw any firm conclusions on speech perception in noise by blind individuals. That might be explained by a variety of factors. The participants of the first study cited above are children, and the participants of the other studies are adults, and it is not clear whether the compensatory mechanisms found in blind adults, in relation to auditory processing, is fully developed in children. Another, perhaps even more important, factor is the character of the noise. In one study, Stankov and Spilsbury (1978) used babble noise and another type of noise which, unfortunately, they did not describe in great detail. This problem is shared by Niemeyer and Starlinger (1981), who did not describe “environmental sounding” in much detail. This was also the case with Muchnik et al. (1991), where there is no description of the characteristics of the noise that was used. Rokem and Ahissar (2009), on the other hand, provided a very clear description of the noise that was used, but it is nevertheless impossible to compare their results with the results of other studies.

5.2.5 Speech perception in noise in blind L2 speakers
In a small-scale study performed by Smeds (reported in Kjellberg Smeds, 2008) on blind L2 learners, white noise and babble noise were used under two different and not quite comparable conditions. One of the tests, which is
also used in the current project with two types of noise (both babble and white noise; for a detailed description, see the methods section), measured perception of common disyllabic Swedish words in babble noise. On this test, blind participants received a significantly lower result than sighted participants. The other test presented sentences in white noise. The result of this test painted a different picture, as no significant group differences were found, although there was a tendency for blind individuals to perform better.

The study by Kjellberg Smeds (2008) seems to indicate that different kinds of noise affect blind and sighted individuals differently, and in this case babble noise presented a greater challenge to perception in blind individuals. Conversely, in Rokem and Ahissar’s (2009) carefully performed study on L1 speakers cited above, babble noise seemed to reduce the great advantage of the congenitally blind in silent conditions, although they still obtained higher results on this test than the sighted did.

5.3 Research question
Based on the theoretical background presented above, the following research question was formulated:

Are early blind individuals advantaged compared to late blind and sighted when perceiving speech in noise, or does the perceptual ability depend on (a) if the person is L1 or L2 speaker, or on (b) the noise source (white noise versus babble noise), or on (c) the length of the item to be perceived (single words versus sentences)?

5.4 Method
5.4.1 Participants
All 80 participants (for a detailed description of the participants, see chapter 3, General Methodology) of the project performed the speech perception in noise tests.

5.4.2 Speech perception in noise tests
In this study, speech perception of words and sentences were tested in both white noise and babble noise.

5.4.2.1 Speech material
The first type of speech material used was common disyllabic Swedish words for a test that was developed by McAllister and Brodda (reported in McAllister, 2002). The phoneme distribution in the word material reflects the distribution of phonemes in Swedish, according to the original idea of
“phonetic balancing.” A list of 100 disyllabic words was selected in the following manner. The phoneme and word frequency data was drawn from a database constructed at the Department of Speech, Music and Hearing at the Royal School of Technology, and it consists of 150 million words from various resources. Five hundred of the most common Swedish words were primarily selected from this database. In the next selection process, the Spoken Language database (Talspråksdatabasen), compiled by Allwood and colleagues, was used (for more detail, see McAllister, 2002). The final list reflects the word and phoneme frequency in Swedish. The words are not of uniform prosodic or morphological form. The words have both accent 1 and 2, reflecting the general proportion of accent occurrences in Swedish, and they are presented in their most common morphologically inflected forms.

The second type of speech material consist of sentences, or to be more exact, so called Helen questions (also described briefly above), which were constructed for the development of the test. The questions are simple to answer for both L1 and L2 speakers, e.g. “What number comes after 18?” “What day comes before Friday?” “How much is 3 + 9?” “What is the opposite of small?” The questions were recorded in an anechoic chamber at the Department of Linguistics at Stockholm University. The speaker was a female voice professional.

5.4.2.2 Noise sources

The first type of noise used was babble noise (in the literature also called cocktail speech noise and irrelevant speech noise), constructed by McAllister and colleagues at the Department of Linguistics (McAllister & Dufberg, 1989). They constructed the noise by recording continuous speech 24 times onto the same tape, without erasing previous recordings, and to eliminate any remnants of understandable speech, they played it backwards. The resulting noise sounds like many Swedish people speaking at the same time, as at a cocktail party.

The second type of noise was white noise. It has a uniform continuous spectrum, which has a hissing sound, resembling the /sh/ sound of the word “ash.”

5.4.2.3 Speech perception of words in noise, a test with a phonological distance metric

The original version of the test, which consists of disyllabic words presented in babble noise, was developed by McAllister and Brodda (McAllister, 2002). In each test run, the program randomly selects 40 words from the list of 100 words, described above. Ten dummy stimuli are first introduced, so that the participant gets accustomed to the procedure before noise is added. During the presentation of the dummy words, the volume could be adjusted
to a comfortable level by the participant. The test stimuli are presented in a carrier phrase “Nu hör du....” (“Now you will hear...”) via earphones, and the participant is asked to repeat the word presented. After the first ten words, the noise is added to the signal at a signal-to-noise ratio of +30dB. For every correctly repeated word, which is registered by the test leader, the noise level increases. For every unsuccessful repetition the noise volume decreases. This adaptive procedure is followed through the rest of the test, and the final signal-to-noise ratio is the test result.

The test measures the phonological distance between the target word and the word spoken by the participant. This measure is a product of an algorithm developed by Brodda (McAllister, 2002), based on experiments performed between 1967 and 1970 in a consultation for the Swedish Patent Office (for further discussion, see McAllister, 2002). The measurement of phonological similarity is used when the participant does not repeat the target word correctly. The answer provided by the participant is transcribed by the test administrator, and the provided word is then compared, by the program, to the target word. The phonological distance is presented as a number between 0 and 1, and this figure controls the subsequently presented signal-to-noise ratio.

Based on the construction features of the test, McAllister and Brodda (McAllister, 2002) argued that the test has a high degree of construct validity, and their aim was to judge its validity through a comparison with other speech perception tests run on the same subjects as was given the test in 2002. No published data has, however, been found evaluating the validity of the test further.

In the current study, a second version of this test was also distributed with white noise. The volume level (dB) of the last correctly repeated word was used in the analysis.

5.4.2.4 Speech perception of sentences in noise, the Helen Task

The Helen Task was chosen to measure speech perception of sentences in noise, since it does not involve any subjective impression of perception. The Helen Task consists of simple questions that everyone can answer, irrespective of language background (appendix 5, in Swedish). The task measures a participant’s ability to perform the task, which is to answer the question. If the participant does not hear the question because the noise is too loud, the chance of guessing the right answer is minimal, and if the question is perceived, it is also easily answered (high validity). In a study comparing three different speech perception methods (the threshold method, the Ramp method and the Helen method/task), McAllister and Dufberg (1989) considered the Helen Task to be the most promising one, irrespective of noise source.
The computerized Helen test program used in this study was developed by Anders Branderud for the current project. The Helen questions were presented at a fixed volume level that was adjusted to present the same level of the sounds (signal volume 0.90586 RMS [RMS is root-mean-square of the noise voltage signal, and it is a commonly used metric for the value of a signal]) and of the noise as in the speech perception of the word-test previously described. The noise presented was adjusted according to the answers of the participants. When a correct answer was given, the noise level was raised by 0.15 RMS, and it was decreased by 0.15 RMS when the answer was incorrect. The increase/decrease of noise was made in a stepwise manner. The test contained 18 trials, and the correct result/answer with the highest noise level was used in the analysis. The Helen questions were presented in both white noise and babble noise, and the participants were instructed to answer the questions.

5.4.3 Predictions

Instead of presenting repetitive predictions for each test, the general predictions in relation to speech perception in noise are presented here. First, it was predicted that L2 speakers would be disadvantaged, since perception in noise is a “hidden” inability of even highly proficient L2 speakers (McAllister, 1997). It was also predicted in relation to the visual status variable that all blind individuals (both early blind and late blind) would have a greater disadvantage perceiving both words and sentences in babble noise compared to sighted individuals. This prediction was based on the earlier findings of Smeds (2008), which showed that blind individuals are greatly disturbed by talkative environments and that babble noise not only disturbs perception but probably also interrupts the chunking-mechanism that seems to be of particular importance to blind individuals during speech processing (Page & Norris, 2003; Perez-Pereira & Conti-Ramsden, 1999; Speidel, 1993; Rokem & Ahissar, 2009; Raz et al., 2005). This prediction is, however, not applicable to speech perception in white noise, which only disrupts perception (Baddeley, Eysenck & Anderson, 2009). For white noise, it was, instead, predicted that the early blind would have a greater advantage than late blind and sighted, in accordance with the findings of this study and of previous studies of phonological short-term memory advantages in congenitally and early blind individuals (Hull & Mason, 1995; Röder & Rösler, 2003; Rokem & Ahissar, 2009). The last prediction was that there would be no interaction effect, since the effects of language background and visual status are expected to be independent and additive.
5.5 Results

The statistical method selection procedure was described in chapter 3, General Methodology. The main test results are presented in tables, but for those readers who prefer figures, all test results of the study are presented in figures in appendix 7.

The results are presented in the following order. The first results are from the 2 (language background: L1 speaker or L2 speaker) x 3 (degree of vision: EB, LB, S) ANOVAs, followed by separate ANOVAs for the L1 and the L2 groups. These separate ANOVAs were performed since speech perception in noise presents a very different challenge to L1 and L2 speakers, according to previous research (McAllister, 1997), and because the results reveal additional information not visible in the results from the 2x3 ANOVAs. It should be noted that the more negative a value or score on these tests, the better the result, indicating a greater tolerance of noise.

5.5.1 Speech perception of words in white noise

The results from the speech perception of words in noise test are shown in table 5.1. It was predicted that L2 speakers would be more disadvantaged perceiving speech in noise than L1 speakers. It was also predicted that early blind would have a greater advantage perceiving speech in white noise than late blind and sighted. The final prediction was that there would be no interaction between the variables language background and visual status, since the impact from the variables was expected to be separate and additive.

A 2 (language background: L1 speaker or L2 speaker) x 3 (visual status: EB, LB, S) ANOVA was conducted to evaluate the impact of language background and visual status on perception of words in white noise. The results showed that the main effect of language background was significant $F(1, 74) = 11.14, p = .001$. Effect-size was medium (but nearly large), partial eta squared .13. The mean of the L1 speakers ($M = -9.73, SD = 1.69$) was significantly higher than the mean of the L2 speakers ($M = -7.95, SD = 2.29$). This finding confirmed the prediction. There was, however, no statistically significant main effect for visual status (EB, LB, S), $F(2, 74) =$
Blindness and Second Language Acquisition

0.26, $p = .773$, which does not support the prediction stating that early blind would outperform both late blind and sighted groups, and that late blind and sighted would not differ. The prediction in relation to a possible interaction effect was confirmed, since there was no interaction between language background and visual status, $F(2, 74) = .58, p = .56$.

Since the prerequisites of L1 and L2 speakers are very different when perceiving speech in noise, separate ANOVA analyses were performed on these two groups, but no significant group differences between the different visual status groups were found.

### 5.5.2 Speech perception of words in babble noise

Table 5.2 shows the data from the speech perception of words in babble noise test. It was predicted that L1 speakers would receive a higher mean than the L1 speakers, since L2 speakers have a “hidden” inability to perceive speech in noise. The prediction made in relation to visual status stated that blind individuals would be disadvantaged perceiving speech in babble noise compared to sighted. It was also predicted that there would be no interaction effect between the two variables.

<table>
<thead>
<tr>
<th>Language background</th>
<th>EB</th>
<th>LB</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>-5.34 (2.54)</td>
<td>-4.22 (2.87)</td>
<td>-5.37 (2.73)</td>
<td>-5.10 (2.68)</td>
</tr>
<tr>
<td>L2</td>
<td>-3.52 (1.92)</td>
<td>-3.24 (2.69)</td>
<td>-2.20 (2.77)</td>
<td>-2.80 (2.56)</td>
</tr>
<tr>
<td>Total</td>
<td>-4.43 (2.39)</td>
<td>-3.72 (2.74)</td>
<td>-3.79 (3.15)</td>
<td>-3.95 (2.85)</td>
</tr>
</tbody>
</table>

Note. EB = early blind; LB = late blind; S = sighted

0.26, $p = .773$, which does not support the prediction stating that early blind would outperform both late blind and sighted groups, and that late blind and sighted would not differ. The prediction in relation to a possible interaction effect was confirmed, since there was no interaction between language background and visual status, $F(2, 74) = .58, p = .56$.

Since the prerequisites of L1 and L2 speakers are very different when perceiving speech in noise, separate ANOVA analyses were performed on these two groups, but no significant group differences between the different visual status groups were found.

### 5.5.2 Speech perception of words in babble noise

Table 5.2 shows the data from the speech perception of words in babble noise test. It was predicted that L1 speakers would receive a higher mean than the L1 speakers, since L2 speakers have a “hidden” inability to perceive speech in noise. The prediction made in relation to visual status stated that blind individuals would be disadvantaged perceiving speech in babble noise compared to sighted. It was also predicted that there would be no interaction effect between the two variables.

Evaluating previous predictions, a 2 (language background: L1 speaker or L2 speaker) x 3 (visual status: EB, LB, S) ANOVA explored the impact of visual status and linguistic background on the results on the speech perception of words test in babble noise. It revealed that the main effect of language background was significant (L2 group: $M = -2.80, SD = 2.56$; L1 group: $M = -5.10, SD = 2.68$), $F(1, 74) = 10.24, p = .002$; the effect size was medium (almost large), partial eta squared = .122. This finding supports the prediction. It was also predicted that sighted individuals would have an advantage compared to early and late blind perceiving speech in babble noise, but this prediction was not confirmed, since there was no statistically significant main effect for visual status (EB, LB, S), $F(2, 74) = .51, p = .60$. It was also predicted that there would be no interaction between the factors language background and degree of vision, and this prediction was confirmed, $F(2, 74) = 1.20, p = .31$. 

### Table 5.2. Speech perception of words in the babble noise for early blind, late blind and sighted L1 and L2 speakers, $M (SD)$.

<table>
<thead>
<tr>
<th>Language background</th>
<th>EB</th>
<th>LB</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>-5.34 (2.54)</td>
<td>-4.22 (2.87)</td>
<td>-5.37 (2.73)</td>
<td>-5.10 (2.68)</td>
</tr>
<tr>
<td>L2</td>
<td>-3.52 (1.92)</td>
<td>-3.24 (2.69)</td>
<td>-2.20 (2.77)</td>
<td>-2.80 (2.56)</td>
</tr>
<tr>
<td>Total</td>
<td>-4.43 (2.39)</td>
<td>-3.72 (2.74)</td>
<td>-3.79 (3.15)</td>
<td>-3.95 (2.85)</td>
</tr>
</tbody>
</table>
Since the prerequisites of L1 and L2 speakers are very different when perceiving speech in noise, separate ANOVA analyses were performed on these two groups, but no significant group differences between the different visual status groups were found.

### 5.5.3 Speech perception of sentences in white noise

It was predicted that L2 speakers would be more disadvantaged perceiving speech in noise than L1 speakers. It was also predicted that early blind would have a greater advantage perceiving speech in white noise than late blind and sighted. The last prediction stated that there would be no interaction between the variables language background and visual status, since the impact from the variables were expected to be separate and additive.

The scores of the different groups are displayed in Table 5.3. A 2 (language background: L1 speaker or L2 speaker) x 3 (visual status: EB, LB, S) ANOVA explored the impact of visual status and linguistic background on the results on the speech perception of sentences in white noise. It revealed that the effect of language background was significant (L1 group: \( M = -7.04, SD = 2.49 \); L2 group: \( M = -2.92, SD = 2.13 \)), \( F(1, 74) = 56.36, p = .001 \); the effect size was large, partial eta squared = .432. The mean of the L1 speakers was thus significantly higher than the mean of the L2 speakers, which confirms the prediction. There was no statistically significant main effect for visual status (EB, LB, S), \( F(2, 74) = 1.84, p = .166 \). This finding does not support the prediction. There was no interaction between language background and degree of vision \( F(2, 74) = 2.96, p = .058 \), which supports the prediction.

Separate analyses were performed on the L1 and L2 speaker groups. The analysis revealed that there were no significant differences between the different visual status groups among the L2 speakers. In the L1 group, however, a non-parametric Kruskal-Wallis test revealed a statistically significant difference between the groups of different visual status on speech perception of sentences in white noise (EB, \( n = 11 \): \( M = -9.48, SD = 1.69 \); LB, \( n = 9 \): \( M = -2.88, SD = 1.70 \); S, \( n = 11 \): \( M = -3.28, SD = 2.22 \)), \( \chi^2(2, n = 40) = 8.23, p = .016 \). Group comparisons performed using the non-parametric Mann-

### Table 5.3. Speech perception of sentences in white noise for early blind, late blind and sighted L1 and L2 speakers, \( M (SD) \).

<table>
<thead>
<tr>
<th>Language background</th>
<th>EB</th>
<th>LB</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>-8.48 (1.69)</td>
<td>-5.42 (3.51)</td>
<td>-6.97 (1.89)</td>
<td>-7.04 (2.49)</td>
</tr>
<tr>
<td>L2</td>
<td>-2.88 (1.70)</td>
<td>-3.28 (2.22)</td>
<td>-2.78 (2.38)</td>
<td>-2.92 (2.13)</td>
</tr>
<tr>
<td>Total</td>
<td>-5.68 (3.31)</td>
<td>-4.35 (3.06)</td>
<td>-4.87 (3.00)</td>
<td>-4.98 (3.10)</td>
</tr>
</tbody>
</table>

Note. EB = early blind; LB = late blind; S = sighted
Whitney U test revealed that there was a significant difference between EB and LB, $U = 15.00$, $z = -2.67$, $p = .008$, effect size was large, $r = .60$. A significant difference was also found between EB and S, $U = 58.00$, $z = -2.18$, $p = .029$, effect size was large, $r = .39$. The difference between LB and S was not significant, $U = 66.50$, $z = -1.12$, $p = .262$. This pattern seems to support the prediction made in relation to the visual status variable, which stated that EB would outperform LB and S, and that LB and S would not differ in white noise tasks. This pattern did not appear when both L1 and L2 groups were analyzed together, or in the L2 speaker group. This pattern is thus the same pattern that was found in the phonological short-term memory tests.

### 5.5.4 Speech perception of sentences in babble noise

It was predicted that L1 speakers would receive a higher mean than L2 speakers, since L2 speakers have a “hidden” inability to perceive speech in noise. The prediction made, in relation to visual status, stated that blind individuals would be disadvantaged perceiving speech in babble noise compared to sighted. It was also predicted that there would be no interaction effect between the two variables.

The scores of the different groups are displayed in table 5.4. A 2 (language background: L1 speaker or L2 speaker) x 3 (visual status: EB, LB, S) ANOVA explored the impact of visual status and linguistic background on the results on the speech perception of sentences in babble noise, and it revealed that the effect of language background was significant (L1 group: $M = -1.95$, $SD = 2.26$; L2 group: $M = 0.65$, $SD = 1.78$), $F (1, 74) = 25.42$, $p = .001$; the effect size was large, partial eta squared = .256. The mean of the L1 speakers was thus significantly higher than the mean of the L2 speakers, which confirms the prediction. There was no statistically significant main effect for visual status (EB, LB, S), $F (2, 74) = 3.08$, $p = .052$, but this difference was very close to reaching significance. This finding does not support the prediction. There was no interaction between language background and visual status $F (2, 74) = 1.62$, $p = .205$, which supports the prediction.

### Table 5.4. Speech perception of sentences in babble noise for early blind, late blind and sighted L1 and L2 speakers, $M (SD)$.

<table>
<thead>
<tr>
<th>Language background</th>
<th>EB</th>
<th>LB</th>
<th>S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>-2.12 (2.61)</td>
<td>-0.25 (1.56)</td>
<td>-2.62 (2.00)</td>
<td>-1.95 (2.26)</td>
</tr>
<tr>
<td>L2</td>
<td>0.57 (1.84)</td>
<td>0.93 (1.86)</td>
<td>0.56 (1.80)</td>
<td>0.65 (1.78)</td>
</tr>
<tr>
<td>Total</td>
<td>-0.77 (2.60)</td>
<td>0.34 (1.77)</td>
<td>-1.03 (2.48)</td>
<td>-0.65 (2.41)</td>
</tr>
</tbody>
</table>

**Note:** EB = early blind; LB = late blind; S = sighted
The separate analyses of the L1 and L2 groups revealed that there were no group differences between the different visual status groups in the L2 speaker group. In the L1 speaker group, however, a non-parametric Kruskal-Wallis test analysis showed that there were significant group differences between the different visual status groups (EB, \( n = 11; M = -2.12, SD = 2.61 \), LB, \( n = 9; M = -0.25, SD = 1.56 \), S, \( n = 20; M = -2.62, SD = 2.00 \)), \( \chi^2(2, n = 40) = 7.43, p = .024 \).

Group comparisons in the L1 speaker group using a non-parametric Mann-Whitney U test revealed that the difference between EB and LB was not significant (although very close to significant, \( U = 29.00, z = -1.83, p = .067 \), the EB almost being significantly better than the LB). The difference between EB and S was not significant, \( U = 97.00, z = -0.59, p = .554 \). A significant difference was, however, found between LB and S, \( U = 38.50, z = -2.79, p = .005 \), large effect size, \( r = .52 \), with S performing better than LB. A different pattern thus appears for sentence perception in L1 speakers in babble noise than in the same task with white noise, and this suggests that the character of the noise source, that is, white noise and babble noise, affected the performance of the different visual status groups in different ways. This will be further elaborated in the discussion.

5.6 Discussion

Since the research question of this study was fairly complex, it is presented here in its entirety at the beginning of the discussion:

"Are early blind individuals advantaged compared to late blind and sighted when perceiving speech in noise, or does the perceptual performance depend on (a) if the person is L1 or L2 speaker, or on (b) the noise source (white noise versus babble noise), or on (c) the length of the item to be perceived (single words versus sentences)?"

According to the findings of this study, there is not a general advantage related to being early blind when speech is perceived in noise. Primarily, it seems to depend on whether the early blind listener is an L1 or an L2 speaker (the language background factor), since speech perception in noise affects the blind L1 and blind L2 speakers quite differently. In fact, all L2 speakers, irrespective of visual status, were clearly affected mainly by the language background factor, since they consistently received much lower results than the L1 speakers, possibly also overriding any influence from the visual status factor. This confirms the “hidden” inability of L2 speakers to perceive speech in noisy environments compared to L1 speakers (McAllister, 1997). A degraded input of signal-dependent information cannot be compensated for with sufficient signal-independent information in L2 speakers. The study by Mayo, Florentine and Buus (1997) showed that an
early age of onset of L2 acquisition is an advantage when perceiving speech in a talkative L2 environment, and Crandell and Smaldino (1996) showed that even children with age of onset of L2 acquisition as low as two years of age performed significantly poorer than their L1 speaking peers in babble noise. This finding was also supported by the finding of Rogers et al. (2006), which compared adult L1 speakers and adult L2 speakers who had learned the L2 before age six, as L2 speakers scored significantly lower than the L1 speakers. It might, therefore, not be too surprising that all L2 participants of the current study performed significantly lower results than the L1 speakers, especially since all L2 participants were adult L2 learners (AO>18).

For this reason, it is not very informative to continue discussing the L1 and L2 speakers as one group (a blind community) in this specific case. The results thus reveal that the L2 speakers were affected mainly by the negative influence of the language background factor, while the L1 speakers were affected by the visual status factor. No differences between the different visual status groups (EB, LB, S) were found among the L2 speakers on any linguistic level or in any type of noise, confirming the discussion above, but it might also indicate that the speech perception in noise tests used in this study might have been too difficult for the L2 speakers to perform. It is not possible to draw any conclusions from the existing L2 speaker results, except for concluding that there is no advantage associated with blindness and stressing the importance of having quiet learning conditions in the L2 classroom or where L2 speakers work. This is even more important to blind L2 learners, since they cannot use facial expressions and lip movements (i.e. signal-independent information) as support when interpreting a degraded verbal signal (i.e. the signal-dependent information). Although congenitally and early blind L1 speakers might have developed the ability to perceive signal-independent information through the verbal signal (Röder, Rösler & Neville, 2000), this is dependent on actually being able to hear the signal and, in blind L2 learners, also on the ability to register these subtle signals in an L2. It is also quite possible, even probable, that the ability to perceive signal-independent information, conveyed redundantly by the speech signal, is an ability only developed in the L1. In noisy environments, sighted L2 learners might actually have an advantage compared to early and late blind individuals, since they can perceive visual information as well.

A surprising finding in the L1 speaker group was that there were no group differences between early blind, late blind and sighted L1 speakers on speech perception of words in noise, irrespective of the source of noise. This indicates that all groups had the same prerequisites for perceiving speech in both white and babble noise, when the speech consisted of single disyllabic words.

Group differences did, however, appear on the sentence level, that is, on the Helen Task, containing longer stretches of speech. This indicates that the
results were dependent on the length of the speech material. The results of speech perception of sentences in white noise showed that the early blind were significantly better than those for the late blind and sighted, and that there were no group differences between late blind and sighted, a pattern that emerged in all phonological short-term memory tests, as well. It should be noted at the beginning of this discussion, that white noise is an unpatterned noise source that only disrupts perception (Baddeley, Eysenck & Anderson, 2009), and the results thus indicate that early blind L1 speakers are less disturbed by this type of unpatterned noise giving them a perceptual advantage under such conditions (the influence from different types of noise is discussed further below).

A possible explanation for an advantage of early blind individuals when processing longer stretches of verbal material in white noise might be that early blind individuals process speech faster than sighted, which has been found repeatedly in many studies (Hertrich, Dietrich & Ackermann, 2013; Hugdahl et al 2004; Niemeyer & Starlinger 1981; Röder, Rösl & Neville, 2000; Röder et al., 2002; Röder et al., 2003; Stevens & Weaver, 2005), suggesting that early blind individuals process speech faster and, thus, process more verbal information within the same timeframe compared to sighted. The results of the current study even suggest that the actual upper limit of the phonological short-term storage capacity might be greater in the early blind (see study I). It is thus suggested not only that congenitally and early blind (a) process more material within the same timeframe compared to sighted, but also that (b) the actual timeframe is greater in these individuals. These advantages in phonological short-term functions or in perception of sentences in white noise found in early blind individuals was not found in the late blind, and the results showed that an early age of onset of blindness is an advantage associated with better verbal processing abilities.

Why then do late blind L1 speakers not display the same advantage as early blind processing sentences in white noise? This may be explained by the different neurological prerequisites that these two groups have. Use-dependent plastic adaptation resulted in a different neurological development early in life in early blind individuals. In the late blind, that is, those who have become blind as adults, many of the relevant neurological systems involved in speech perception (e.g. auditory and visual cortices) have already been established in the same way as in sighted individuals, during a sensitive period early in life, before the age of four (Ward, 2010). Studies of glucose utilization (Veraart et al., 1990; Wanet-Defalque et al., 1988) also suggest that a high level of plasticity, in relevant areas of the brain, is actually retained even in adulthood in the congenitally blind, but not in the late blind and sighted. This finding is in line with Röder and Rösler’s (2003) conclusion that the compensatory neurological development in late blind is only partial. The tendency of the results on speech perception of sentences in
babble noise is the same in comparisons of early and late blind individuals, but the difference does not quite reach statistical significance. These results taken together seem to indicate that late blind individuals are disadvantaged compared to early blind individuals, in general, when perceiving sentences of speech in noisy environments.

The results from speech perception of sentences in noise tests also showed that the results were affected by the type of noise source presented, whether white noise or babble noise, since the familiar pattern, whereby the early blind outperformed the late blind and sighted, was not found when the noise consisted of babble noise. Researchers have suggested that unpatterned noise, like white noise, and babble noise affect all individuals differently. While white noise disturbs perception, babble noise both disrupts perception and impairs recall (Baddeley, Eysenck & Anderson, 2009). Babble noise gains direct access to the phonological short-term store component of the phonological loop and adds noise to the memory trace. The results of speech perception in babble noise show that the late blind had a significantly lower result than sighted, and almost significantly lower than early blind as well, while the difference between the early blind and sighted did not reach significance. The results seem to indicate that the late blind are more negatively affected by babble noise than the other two groups (the possible mechanisms affected will be discussed below). The early blind group does not seem to be as negatively affected by babble noise as the late blind, at first glance, since their results do not differ from the result of the sighted group, but considering that they were significantly better than both the late blind and sighted on perception of sentences in white noise, suggest that the perceptual advantages found in unpatterned white noise actually diminished in babble noise, resulting in equal performances by the early blind and the sighted group, and their recall performance was actually as negatively affected by babble noise as it was for the late blind individuals. The general perceptual advantages of the early blind might have lessened the diminishing effect of babble noise, resulting in a performance equal to, but not worse than, the sighted, which was otherwise demonstrated by the late blind group. Rokem and Ahissar (2009) also found that babble noise diminished the great advantage in speech perception of the congenitally blind compared to the sighted. In their study, congenitally blind individuals still performed better than sighted individuals, although their advantage compared to sighted became much less pronounced by babble noise.

It was suggested by Page and Norris (2003) that babble noise interrupts the chunking-mechanism of verbal material. According to Rokem and Ahissar (2009), it is specifically this mechanism, the ability to chunk to-

---

30 This was confirmed by the results of the current study, since the white noise level tolerance was much greater than the babble noise tolerance level.
gether signal information, which might lead to phonological short-term memory advantages in congenitally blind individuals. Raz et al. (2005), with a similar line of reasoning, suggest that it is the serial memory function and the ability to remember information in a “route-like” sequential manner that explains the better memory performance in the congenitally blind (in this case, the recognition memory advantage). These hypotheses and the findings from this study (study I) are in line with the discussion by Page and Norris (2003) concerning the effect of babble noise, which thus affects blind individuals more negatively than sighted, interrupting the strategy to chunk verbal material, also used by blind children (Perez-Pereira & Conti-Ramsden, 1999).

To conclude, therefore, the answer to the research question is yes, when the early blind individual is an L1 speaker, and if longer stretches of speech are perceived in an environment in which the noise is unpatterned, such as traffic noise from a highway at a distance or a ventilation system. But, the answer is no if the early blind individual is an L2 speaker, if only separate words are perceived, or if the surrounding environment is filled with the sound of talking.

In relation to the methodological aspects of this substudy, it should be mentioned that the test of speech perception of words in babble noise is a standardized and evaluated test. In the current study, only the noise file was changed to white noise in the other version employed in the study. This version has not been evaluated.

On the sentence level, the Helen test procedure was selected as a method because the validity is high. If something is heard it can also be repeated. The sentences, or questions, were also simple for both L1 and L2 speakers to answer, in those cases in which they were perceived properly. The specific computer program used in this study, presenting the sentences in relation to noise, was developed specifically for this study and has not yet been evaluated. The signal-to-noise ratios were equalized to the levels used in the speech perception of words test.

There is a limitation when it comes to test selection, since it would have been wise to also investigate basic speech perception without noise in order to have a baseline measure, as well.
6.1 Introduction

It has been claimed by a teacher of Swedish as a second language that blind adults have the ability to acquire a less-accented L2 speech than their sighted peers. The students, to whom this claim refers, had all arrived as immigrants fairly recently. A possible advantage in relation speech production is presumably related to advantages also in speech perceptual abilities, as these two phenomena are closely linked (Llisterri, 1995), and results from neuropsychological research on blind L1 speakers seem to support this claim, since advantages in perceptual ability in blind individuals have been reported from different research teams. For instance, Niemeyer and Starlinger (1981) and Rokem and Ahissar (2009) found that the congenitally blind demonstrate advantages in speech perception and processing ability, both with and without noise, also leading to a much faster speed of speech processing (e.g. Hugdahl et al., 2004; Stevens & Weaver, 2005; Niemeyer & Starlinger, 1981; Röder, Rösler & Neville, 2000). Hugdahl et al. (2004) also found congenitally blind to have higher phonological sensitivity for speech sounds.

Investigations of the phonological short-term memory function, involved in both speech perception and production (Jacquemot & Scott, 2006), have also been associated with advantages in both congenitally and early blind children (Hull & Mason, 1995) and adults (Röder, Rösler & Neville, 2000; Röder & Neville, 2003). These findings were further supported by the findings of the current study in which the early blind outperformed both late blind and sighted individuals (study I). These advantages might presumably also contribute to a better L2 pronunciation. The results of Lucas (1984) suggest, however, that the relationship between speech perception and production in blind individuals is not straightforward, as the advantages found
in speech perception ability in blind children did not result in advantages in speech production of nonwords.

Late blind individuals have not been included in or reported on in the previous research cited above, and it can be suspected that the advantages in speech perception ability held by the late blind are not as pronounced as in the early blind, as was found in this study. Important parts of the cortex involved in speech perception (for instance, the phonological aspect of language, the auditory and visual cortex) mature early in life, presumably before the ages of one (the phonological language aspect, Werker & Tees, 2005) and four (the auditory and visual cortex, Ward, 2010), respectively, making the neurological system less prone to change. The advantages in late blind in relation to speech perception might, as a consequence, not differ significantly from those of sighted individuals.

L2 pronunciation, and the factors affecting it, has been investigated extensively, both by researchers in the SLA field and in the field of psychology. It has been found that a variety of factors influence L2 speech production, for instance, age of onset of L2 acquisition, length of residence (LOR) in the L2 environment, amount of L1 and L2 use, formal instruction, motivation, musicality, cognitive and personality factors, etc. There is, thus, plenty of research devoted to the L2 pronunciation of sighted L2 learners. There is, however, only a small-scale study performed by Smeds (Kjellberg, 2004, also reported in Kjellberg Smeds, 2008) that has investigated the L2 pronunciation of blind adult L2 learners. The study investigated both speech perception (of sentences in white noise and words in babble noise) and speech production (i.e. degree of accentedness in L2 speech), using tests that have been further developed in the current study. The results of the Foreign Accent Rating experiment showed that there was greater individual variation in the blind L2 group than in the sighted L2 group: some of the blind participants produced L2 speech which was judged as non-accented, sounding like native speakers, while others did not. In the sighted L2 group none of the participants produced a non-accented L2 speech, according to the L1 speaker judges. The difference between the blind and sighted groups did, however, not show significance, and it is still an open question whether the opposing trends (on the one hand, some blind L2 participants being judged as native speakers, and on the other hand no significant differences at a group level between the sighted and blind groups) could be explained by the very limited size of the study (seven blind and seven sighted L2 learners). A still unanswered question is thus whether early blind L2 learners have the ability to produce a less-accented L2 speech than late blind and sighted L2 speakers.
6.2 Theoretical background

In this section, different aspects related to second language speech perception and speech production is presented. Primarily, different factors that have been found to affect second language speech production from SLA research, psycholinguistics and neuropsychology are presented. This is followed by a presentation of research devoted to speech perception and speech production and the relationship between those processes in L1 acquisition, in L2 acquisition in adults, in blind individuals, and in blind individuals acquiring an L2. Finally, the relationship of the two processes to phonological short-term memory is discussed.

6.2.1 Factors affecting L2 pronunciation – findings from SLA

There is plenty of research devoted to the phenomenon of foreign accents and the factors affecting it. Studies investigating degree of accentedness in L2 speech have correlated the findings to a variety of different factors in order to assess what characteristics of speakers that are associated with greater or lesser degrees of perceived foreign accents. The most important of these factors is age of onset (AO) of L2 acquisition. Most of the studies have found that early exposure to the L2 is associated with lesser degrees of foreign accent (Abrahamsson & Hyltenstam, 2009; Flege & Fletcher, 1992; Yeni-Komshian, Flege & Liu, 2000; Moyer, 1999; Flege, Yeni-Komshian & Liu, 1999; Piske, MacCay & Flege, 2001; for more references see Jesney, 2004). This age-related decline in L2 speech production proficiency has been attributed to mainly two factors: (1) a biologically governed critical or sensitive period for acquisition of phonology, or to (2) interference from L1 phonological categories on the acquisition of L2 phonological categories. Studies adhering to the sensitive period explanation and the interference explanation, respectively, will be presented.

Abrahamsson and Hyltenstam (2009) reported that only a small minority of Spanish/Swedish bilinguals (n = 195, AO 1–47 years) who started their acquisition after the age of 12, but a majority of those who started their acquisition before this age, were perceived as native speakers of Swedish. The raters were 30 native university students at Stockholm University with no phonetic training. A second part of this study was also performed in which a subset (n = 41) of those L2 speakers who were judged to be native speakers were scrutinized in greater detail using a battery of highly complex tasks, and the results showed that only a few of the early learners and none of the late learners exhibited actual native-like competence across all of the linguistic abilities tested. The reason that the second part of this study is mentioned here is that the highest performing late learner, who scored within
the native speaker range on seven of ten measures, displayed a deviance from native-speaker norms only on those tasks that were related to phonetic aspects of speech production and perception. The researchers attributed these limitations concerning phonetic aspects of speech perception and production mainly to biological limitations and to a critical or sensitive period for language acquisition.

While many studies of foreign accent consistently distinguish nonnative speakers and native speakers, some studies have found that there are some, even adult, L2 learners whose pronunciation scores fall within the native-speaker norm (e.g. Bongaerts, 1999). These exceptionally talented L2 learners are, however, extremely rare.31

Other studies from the SLA field attribute these age effects to interference from already established L1 categories rather than to biological constraints. For instance, Flege (1995) concluded that it is the firmly established phonological categories of the L1 that interfere with the perception of the L2 phonological categories, especially in cases of similar L1 and L2 sounds (Flege, Yeni-Komshian & Liu, 1999; Flege, Munro & MacKay, 1995; Flege, 1999). Inaccuracies in L2 speech production is explained in terms of an age-related decline in the ability of L2 learners to recognize that certain auditorily detectable differences between the L1 and L2 phonetic categories are \textit{phonetically relevant}. Based on previous research presented in the discussion above, it can be concluded that there is a general agreement that accentedness in L2 speech production is the linguistic aspect most clearly affected by the age of onset of acquisition (e.g. Oyama, 1976; Flege, Yeni-Komshian & Liu, 1999; Piske, MacKay & Flege, 2001; Newport, Bavelier & Neville, 2001).

Other factors have also been found to contribute to overall pronunciation proficiency in these studies adhering to the interference explanation. AO is typically correlated with length of residence (LOR) in the L2 environment and with the amount of L1 use, although all three factors have been found to exert independent influence on perceived foreign accent. LOR has, for example, resulted in improved global foreign accent according to some studies (e.g. Flege & Fletcher, 1992), while other studies have not found this effect (e.g. Oyama, 1976). In a number of studies, the amount of L1 use has been found to be significantly correlated to global foreign accent. In Guion, Flege and Loftin (2000), Quechua-Spanish bilinguals were found to have more accented speech in their L2 Spanish when their L1 use was high, whereas when their L1 use was low, the accent was less pronounced. AO was controlled for in this study.

31 According to an estimation by Selinker (1972), 5% of all adult L2 learners attain "absolute success," an amount that is challenged by Abrahamsson and Hyltenstam (2009), who suggest that ultimate L2 attainment is, in principle, never reached by adult L2 learners.
Another factor that has been found to exert an independent influence on L2 pronunciation and comprehensibility is *speech rate*, and somewhat faster speech was considered more comprehensible than very slow or fast rate, which impeded comprehensibility (Munro & Derwing, 2001).

*Formal instruction* is also a factor that, on its own, has sometimes been reported to improve global foreign accent in L2 learners (Derwing & Rossiter, 2003). In a couple of studies, it has been mentioned, however, that individual variation is great with respect to performance as a result of instruction (Golestani & Zatorre, 2009; Hanulikova et al., 2012).

Other factors that also have been investigated are, for instance, the attitudes towards foreign accents that are held by native speakers, accent as a marker and preserver of identity (Piske, 2012), professional motivation (Moyer, 1999), gender (Flege, Munro & MacKay, 1995), motivation to sound like a native speaker and continued access to massive and authentic L2 input (Bongaerts, 1999). Some of these studies have investigated the combined effect of more than one of these factors (e.g. Piske, MacKay & Flege, 2001; Flege, Munro & MacKay, 1995; Bongaerts, 1999).

Piske (2012) discussed different factors affecting perception and production of L2 speech and concluded that age of onset is the variable that plays the most important role in perception and production of L2 speech. He also pointed out that the relative importance of other variables is uncertain, as existing research has been difficult to interpret because of a variety of reasons, for instance, because of the great variability in terms of design and methodology between different studies of foreign accents. According to Piske (2012), studies of individual learners have found that each of these variables may be of different importance to different individuals, suggesting a wide range of individual variation with respect to the relative importance of different variables.

### 6.2.2 Factors affecting L2 pronunciation – findings from psycholinguistics and neurolinguistics

There are a few interesting case studies on exceptionally talented adult L2 learners who have been found to produce non-accented L2 speech. In these studies, the general language talent ability has been investigated, and the participants have been selected because of their accent-free L2 production.

In a case study performed by Novoa, Fein and Obler (1988), a very talented and motivated L2 speaker called C.J. was investigated using a large battery of psychological tests measuring general cognitive functioning and intelligence, language aptitude (MLAT; Carrol, 1959), visuospatial functions, musical ability, memory and personality. C.J. was selected for having learned several languages postpubertally, very easily and quickly, and because native speakers of all his acquired languages confirmed his native-
like abilities, which included a lack of foreign accent. The results showed that C.J. did not display a general cognitive ability and IQ above normal, and that he also had average musical and visuospatial abilities. He was, on the other hand, exceptionally talented at tests related to vocabulary learning and vocabulary definition, acquisition of new code, and the ability to perceive and complete formal patterns. His verbal memory skills were exceptional (although not on digit span, which presumably measures phonological short-term memory). In relation to personality traits, he had a willingness to adapt to a new culture and the language spoken, and to be assumed to be a native speaker. He was also somewhat of a risktaker, being rather impulsive, which can be seen as facilitating the acquisition of accent-free speech. He also had some of the traits associated with language talent according to the Geschwind cluster: mixed handedness, homosexuality, allergies, twinning and some history of schizophrenia in the family.

Another case study was performed by Ioup et al. (1994). In this study, Julie and Laura, two women with English as L1, were investigated because of their exceptional and nativelike competence in Arabic. Julie had acquired her Egyptian Arabic without formal instruction, while Laura had acquired standard Arabic in formal settings. Laura was actually a control group participant, but she is discussed in great detail because of her impressive achievements. Five other female speakers were also included as control subjects: three other educated L1 speakers of the Cairene Arabic dialect and two fluent L2 speakers living in Cairo who still retained nonnative features in their speech. They performed a large battery of language tests, but only the ones related to language perception and production will be mentioned here. The ability to discriminate between different accents has been a skill that is associated with nativelike competence in perceptual ability, and both Julie and Laura were able to discriminate between the Egyptian dialect and five other non-Egyptian Arabic dialects with 100% accuracy (two native speaker controls attained only 85%). In order to investigate speech production ability, a Foreign Accent Rating experiment was performed, and it was based on freeform speech. The judges were 13 teachers of Arabic as a foreign language. The results showed that all judges correctly categorized the distractor participants as either native or nonnative. Julie and Laura were rated as native speakers by 8 of 13 judges (62%). Only native speakers especially sensitive to phonetic discrimination were able to hear any deviations from native speech in their speech. Both Julie and Laura had obviously developed excellent abilities related to both speech perception and speech production.

---

32 Traits associated with language talent, according to the Geschwind cluster: cerebral lateralization (mixed- or left-handedness, indicating a different neural organization), twinning, allergies and asthma, migraines, schizophrenia and fair skin complexion (Abu-Rabia & Kehat, 2004).
and the researchers found Julie, despite not having acquired the language in formal settings, to be very consciously aware of her language use. The researchers suggested language talent to be an important factor explaining her success, and that she was more cognitively flexible in processing the L2 than the average L2 learner, just as other studies of general language learning talent have found in other high language achievers (Novoa, Fein & Obler, 1988; Schneiderman & Desmarais, 1988). She also had traits belonging to the Geschwind cluster found to be associated with language talent in other studies (for example, in Novoa, Fein & Obler, 1988; Schneiderman & Desmarais, 1988). The researchers concluded that if there are individuals who seem like exceptions to the critical period, their development is not of the ordinary kind and that it remains to be answered whether these individuals use already existing L1 systems during L2 acquisition or whether an alternative subsystem, that is, another part/s of the brain, subsumes the role of language acquisition.

It should thus be pointed out that even if one accepts the critical period hypothesis, it does not mean that incredible achievements in language learning are not possible. There are always some individuals whose achievements are far above average and who are able to use their high-cognitive abilities and/or other neurological systems or parts of the brain to acquire a second language than the ones they used in L1 acquisition (Newport, Bavelier & Neville, 2001).

A large-scale study of pronunciation talent was performed by Dogil, Ackermann, Grodd and Reiterer (reported in Dogil & Reiterer, 2009; Hu et al., 2012; Reiterer et al., 2011). The major aim of the project was to provide a comprehensive investigation of language talent, and especially of L2 pronunciation talent. To do so, 138 L1 speakers of German between 20 and 40 years old (mean age 25.94 years old) were selected (Reiterer et al., 2011), and they applied a wide range of different measures for the investigation: multiple phonetic/linguistic measurements, psychological and behavioral measures, fMRI and sMRI. Perception and production was, for example, assessed by allowing participants to perceive words and short phrases in German (L1), English (foreign language) and Hindi (unknown language), and reproduce them immediately or in delayed repetitions (Jilka, 2009a, 2009b). The results revealed that the ability to pronounce and imitate English correlated with phonological coding ability, music aptitude and empathy, and that the difference between the high and the low achieving participants was significant in relation to English pronunciation, the ability to imitate sentences and on empathy (Hu et al., 2012). A selection of participants, one high (n = 9) and one low (n = 9) ability group, was investigated further while performing word and sentence imitation tasks, using both sMRI and fMRI (Reiterer et al., 2011). The participants repeated 50 sentences: 25 German and 25 English (13 sentences with American accent and 12
with British accent), and 48 four-syllable words (24 Tamil words and 24 English words, the latter of which comprised 12 in an American accent and 12 in a British accent).

The most striking differences between high- and low-ability accent imitators were found on the task in which participants imitated the untrained language Hindi (Reiterer et al., 2011). The results showed that the low-ability imitators activated a left-lateralized neural network to a significantly greater extent than the high-ability imitators. The increase of activation in this area was also accompanied by a decrease on the functional level in motor speech areas, reflecting a decreased ability to produce the items. The high-ability imitators displayed increased gray matter volumes (i.e. a higher degree of non-myelinized matter, associated with a higher degree of plasticity) in these areas, in addition to a lower degree of activation, reflecting more efficient processing.

6.2.3 Speech perception and speech production

Since one primary assumption of this study is that speech perception and speech production are related phenomena, a further review of this relationship is presented here. Research on the topic has attempted to answer the following fundamental questions: Does perception precede production, or vice versa? In other words, is it possible to produce new L2 sounds if they are not correctly perceived, or is it a prerequisite to be able to perceive the sounds correctly in order to produce them? Regardless of what the answers are to these questions, there exists a close link between speech perception and production, according to Llisterri (1995). A presentation of findings in relation to speech perception and production will follow.

6.2.3.1 The development of speech production in the first language and the relationship to early speech perception

This section will primarily discuss infant speech perception, since perception affects production in the earliest stages of language acquisition (Kuhl, 1995). At birth, infants are able to distinguish between all phonetic units of the world’s languages, an ability that has become severely restricted in adulthood. During the first year of life, this language-general ability to perceive phonetic contrasts becomes language-specific, and this indicates that perception of human speech is influenced by innate factors, to a very large degree, according to Kuhl et al. (1992). Polka and Werker (1994) found, for instance, that four-month-old infants had the ability to discriminate non-

---

33 Comprising left premotor cortex (BA 6), Broca’s area, the opercular part (BA 44) and left inferior parietal area (the “phonology” part or the phonological loop, according to the researchers; BA 40, supramarginal gyrus) (Reiterer et al., 2011).
native vowel sounds, but by six months of age, the same infants could no longer discriminate the same nonnative vowels. Kuhl et al. (1992) studied the perception of vowels in six-month-old infants from the United States and Sweden and demonstrated that the exposure to a specific language, that is, a language-specific experience, starts to alter the language-general phonetic perceptual ability of vowels by this age. Native-language specific “prototypes” assimilate similar sounds of foreign languages, according to the researchers, which are then perceived incorrectly and are thus not discriminated from the native language prototype.

Studies of consonant discrimination suggest that language-specific contrasts are discriminated by 10–12 months of age, that is, at a later age than for vowels (Polka & Werker, 1994), and that the change from language-general to language-specific ability to perceive consonants takes place between 6–8 and 10–12 months of age.

This attunement to familiar input can also be seen in relation to other aspects of the sound system, such as suprasegmental aspects. Mehler et al. (1988) found, for instance, that infants shortly after birth (two-month-olds), can distinguish utterances in the native language from utterances in an unfamiliar language, based on prosodic cues, and that infants as young as four days old show preference for native language prosody. This finding was supported by the findings of Moon, Cooper and Fifer (1993) of native language prosodic preference in two-day-olds. Infants show preference for native language prosodic pattern of word-units by six months of age (Jusczyk et al., 1993) and, for phrasal units, by 9 months of age (Jusczyk et al., 1992).

Looking at research that has been conducted since the mid 1980s on the development of the sound system in infants, it can thus be concluded that results show that by 12 months of age infants no longer discriminate between the foreign categories that they once had the ability to discriminate (Kuhl, 1995), suggesting that there is a neural reorganization from language-general to language-specific phonetic contrasts during the first year of life (Kuhl et al., 2008; Werker & Tees, 2005). According to Kuhl (1995), the perceptual and perceptual-motor systems are already tuned to the specific sounds of the language/s of the surrounding input by the time infants begin to master the higher levels of language, such as sound-meaning correspondence, grammatical rules and contrastive phonology. After this initial attun-

---

34 A phonetic “prototype” is a phonetic speech sound identified by adult speakers of a specific language to represent the ideal from a given phonetic category. These prototypical variants of a specific phonetic category function like “perceptual magnets” during speech perception, automatically assimilating similar nonprototypical sounds, which are then perceived to be more similar to the prototype. This explains the difficulty of older children and adults to discriminate foreign language speech sounds that resemble a native phonetic category (for instance, Japanese speakers have difficulty discriminating between /r/ and /l/, which are assimilated to a similar sounding native-language prototype) (Kuhl et al., 1992; Kuhl, 1995).
Blindness and Second Language Acquisition

ement to the language-specific phonetic contrast during the first year of life, the speech perception mechanisms continue developing during childhood and adolescence, becoming more well defined and organized over time (Archila-Suerte et al., 2013). By 12 years of age, children still display less consistent categorization of phonemic contrast than adults, but they have become relatively stable by early adulthood (Hazan & Barrett, 2000). This gradual adjustment can also be seen in relation to speech production (Walsh, Smith & Weber-Fox, 2006; presented below).

Werker and Tees (2005) discussed the acquisition of the language sound system, that is, the phonological aspect of language, in relation to the notion of critical periods. They suggested that the speech perception system, as a representative of one of the interrelated and hierarchically organized sub-systems of language, can be used to understand more about the plasticity of all language systems in the brain. The researchers proposed a nested, cascading model to explain the development of the sound system and suggested that a better term for the critical period might be “optimal period” because (a) the onset (opening) and offset (closing) of these periods is open to experiential influences that are variable rather than absolute, and because (b) the phonological acquisition includes the development of a range of phonological capabilities, each with its own optimal/sensitive periods and each developed in a sequential manner through a set of sequences, or “nested capabilities”35 and in a specific order in relation to other phonological capabilities. Every developing sequence in the phonological development constrain and direct the development of the next series of nested capabilities to be developed according to the order of acquisition and is therefore cascaded.

Werker and Tees (2005) exemplified their line of reasoning in the following way. It has been found that the experience of listening to speech in utero makes infants develop preferences for listening to speech with the same rhythmical properties and the same stress pattern as the native language. The stress pattern of the native language is then later used to segment words from continuous speech. During the first year of life, the infant also attunes to and shows preference for the specific phonotactic properties of the native language. By the second year of life, the phonetic categories of the L1 are used to represent words and to direct word learning. In school, the phonetic categories guide rhyming and the mapping of sounds onto the orthography, affecting reading, writing and spelling, and ultimately the

---

35 It has been found that the acquisition of grammar develops in a similar fashion according to a specific order of acquisition, and each step in that order proceeds in a sequential manner. This theory is called processability theory and was developed by Manfred Pienemann (e.g. Pienemann, 1998).
acquisition of all aspects of language (for references to research devoted to
the different developmental steps, see Werker & Tees, 2005).

It is not difficult to imagine that the impact of experience of blindness in
infants affects the developing sound system in a different cascading manner
than in sighted infants, because of the greater dependence on the auditory
signal and, as a consequence, greater focus on the phonological properties of
the sound signal. The greater dependence on the auditory signal shapes not
only the development of the phonological language aspect, but presumably
also the neurological development of the sensory cortical areas (for instance,
the visual and auditory cortical areas), as well as other cortical areas (for
instance, aspects of memory and language). The sensory development also
develop in a cascading sequential manner (the visual sense develops in this
manner, for instance, see Werker & Tees, 2005), in parallel to the cascading
phonological language development, thus together creating the composite
and complex experience and development of each individual. In other words,
its very likely that the simultaneous development of different cortical areas
and different aspects of language affect each other in this sequential casca-
ding manner resulting in a very complex, interrelated and interdependent
neurological development of different neurological systems.

The developmental speech production follows a similar pattern as the de-
veloping perceptual ability, from language-universal to language-specific.
Speech production is a highly skilled motor behavior, since it requires co-
ordination of the respiratory, the laryngeal and the orofacial systems (Walsh,
Smith & Weber-Fox, 2006), and all infants, irrespective of cultural or lingu-
stic background, develop through the same universal stages36 during the first
year of life (Kuhl & Meltzoff, 1995; Stoel-Gammon, 1992). In order to imi-
tate, the infant has to recognize the relationship between the articulatory
movements and the sounds that they produce and, by the end of the first
year, the developing speech starts to reflect the specific phonological pro-
erties of the surrounding linguistic environment (Kuhl & Meltzoff, 1995).

Kuhl and Meltzoff (1995) investigated whether there is evidence of vocal
learning, that is, of vocal imitation, in 12-, 16- and 20-week-old infants. The
infants watched and listened to a female producing the vowels /a/, /i/ and /u/,
and recordings and transcriptions were made of the infants’ spontaneous
responses. The researchers offer a model explaining the connection between
audition and articulation in infancy, which explains the results of the study.
This model emphasizes two notions: representation and ambient language
influences. The results showed that there was a developmental change from
week 12 to week 20 as the infants’ vocalizations became more clearly sepa-

---

36 Universal stages of infant speech production, according to Kuhl & Meltzoff (1995): (1)
phonation (0–2 months); (2) cooing (1–4 months); (3) expansion (3–8 months); (4) canonical
babbling (5–10 months) and (5) meaningful speech (10–18 months).
rated from each other. This means that each vowel category became more tightly clustered towards a stored “target” or prototypical representation of each vowel. These “targets” stored in memory thus represent and influence both perception, displaying a perceptual magnet effect for stimuli in the same category of sounds, and subsequent production of speech. The results also showed that the particular vowel that was presented immediately influenced the vowel produced by the infants, suggesting that the influence from the ambient language was both short-term (during a test procedure that required only 15 minutes of laboratory exposure), as well as long-term (the longitudinal section of the study lasting from week 12 to 20 in the infants’ lives). Formations of representations deriving from perception of the ambient language subsequently act as targets for articulatory motor output, showing that speech perception precedes speech production.

Walsh, Smith and Weber-Fox (2006) discussed children’s speech production, that is, the speech motor system, in terms of plasticity. They compared 20 children (between 9 and 10 years of age) with 20 young adults (between 18 and 31 years) on the production of nonwords. The results showed that both groups ended up producing the nonwords correctly. The children, however, displayed a practice effect, producing more consistent nonwords in the final trials than in the initial trials. Adults, on the other hand, did not display this variability or practice effect between trials. Thus, they had greater control of their articulators and did not change the coordinated motor patterns between trials. The results suggest that children show short-term changes in their speech coordinative patterns with practice, thanks to a high degree of neural flexibility. This neural flexibility, that is, plasticity, is also thought to be an advantage in L2 acquisition, according to the researchers, resulting in a greater capacity to acquire a nativelike L2 accent in children than in adults.

6.2.3.2 The relationship between second language speech perception and speech production in adults

According to the general view on first language phonological acquisition, adult-like perception in children precedes the ability to produce L1 phonemes as an adult would produce them. This view on the relationship between perception and production is also dominant in second language teaching and learning, and perceptual mastery should preferably precede production mastery of new phonemes (Sheldon & Strange, 1982).

That perception precedes production has thus been the “default” explanation in important theories of L2 phonetics, for instance, according to Flege (1995, 2003), who claimed that “L2 production accuracy is limited by perceptual accuracy” (Flege, 2003: 4). Flege’s model, the Speech Learning Model, predicts that, at earlier stages of L2 acquisition, learners perceptually assimilate most of the L2 phonemes to existing L1 categories, but if the L2
phonemes are sufficiently dissimilar from the L1 categories that they can be recognized and differentiated, a new L2 perceptual category becomes established over time. For L2 categories that are more similar to L1 categories, the development over time towards forming new/separate L2 categories may be blocked, because of equivalence in the classification of L1 and L2 categories to form a single perceptual category. This leads to an accented production of that specific category, which in time might even change the production of the L1 category away from the monolingual norm (Strange, 1995). This suggests that L2 speech perception and production is dependent on the perceived distance between L1 and L2 segments and crosslinguistic similarity can either support or hinder L2 speech perception and production (Trofimovich, Gatbonton & Segalowitz, 2007).

Another model that attempts to predict and explain the relationship between L2 perception and production is Best’s Perceptual Assimilation Model (PAM). According to this model, L2 categories are perceived and assimilated to existing L1 categories according to the articulatory (gestural) similarity to L1 gestural constellations. The L2 sounds that are produced by similar articulatory gestures as L1 speech sounds become assimilated and perceived as L1 speech sounds (Best, 1995).

There are great similarities between Flege’s Speech Learning Model, Best’s PAM model and a third model called the perceptual magnet model, which was proposed by Kuhl and colleagues (Kuhl et al., 1992; Kuhl, 1995; Kuhl & Meltzoff, 1995, see previous section). All three models suggest that L2 sounds that are similar to L1 sounds become assimilated to the L1 categories, due to either perceptual similarity (the Speech Learning Model and the perceptual magnet model) or similar articulatory gestures (the PAM model). Increasing difficulty in perceiving nonnative sounds are ascribed to either biological limitations (auditory perceptual limitations in plasticity in Kuhl’s model and articulatory motor limitations in Best’s model) or to interference from the native language sound system (Flege’s model). Perception precedes production in all three models. In a recent study, a more dynamic model has been used that emphasizes the variability and the gradual development and mastery of L2 speech sounds over time – a Gradual Diffusion Model (Trofimovich, Gatbonton & Segalowitz, 2007).

Rochet (1995) emphasized a question, which according to the researcher, has not been answered satisfactorily, which is whether an accented L2 pronunciation can be attributed to faulty perception and/or faulty production. In an attempt to answer this question, an experiment was conducted using an imitation task (to establish how the target vowel [y] was pronounced) and a perceptual task (to establish how the high vowel continuum was produced (/i/, /y/, /u/). The participants were ten native speakers of Standard French, ten speakers of Canadian French (who had the tendency to replace French [y] with [u]), and ten speakers of Brazilian Portuguese (who replaced French
[y] with an [i]-like vowel). In the imitation task, participants repeated monosyllables produced by a speaker of Standard French containing the vowels [i], [y], [u] and [a] in different consonant contexts. In the perceptual task, the individuals had to identify vowels on the continuum from /i/ to /u/. The results showed that both Portuguese and English speakers were able to produce a high front rounded vowel correctly (approximately 50% of the words were produced correctly), and Rochet concluded that the faulty production of French [y] could not solely be explained by a deficiency in articulation. The results of the production task also confirmed that Portuguese speakers tended to replace French [y] with an [i]-like vowel and English speakers with an [u]-like vowel. The perceptual task results showed that L2 learners, in earlier stages of acquisition, perceive L2 sounds based on the L1 phonological system, which is in line with Flege’s Speech Learning Model. The researcher concluded that accented pronunciation may be perceptually motivated.

According to other researchers, production can also precede perception (Sheldon & Strange, 1982). For instance, Sheldon and Strange (1982) investigated the perception and production of English /r/ and /l/ in advanced Japanese learners of L2 English. The researchers found that some of the six Japanese participants had a more accurate production than perception of English /r/ and /l/, and that perceptual difficulty varied with the position of these sounds in the words. Sheldon (1985) discussed the relationship between perception and production, and concluded that this relationship changes over time in relation to amount of L2 experience. In earlier stages of L2 acquisition, perception precedes production, but as experience in the L2 is gained, the difference between perception and production scores decrease. In advanced stages of L2 attainment, the relationship between perception and production seems to show the opposite trend, whereby production precedes perception, as was also found in Sheldon and Strange (1982). Time, therefore, seems to be a predictor of the relationship between L2 speech perception and production. That production precedes perception might seem counter intuitive, but Sheldon (1985) explained this phenomenon by suggesting that L2 learners at advanced levels of L2 acquisition already master a functional perceptual level in their L2, and are able to understand L2 speech from familiarity with the topic, with the interlocutor, with the words that contain the difficult sounds and with other redundant information. The oral message is understood, although some L2 phonemes might not be perceived accurately. The motivation to improve perception is not that strong. The pressure to acquire a non-accented speech, however, might be highly motivated socially, since a heavy accent might be stigmatizing. It is still somewhat puzzling how a more fine-tuned production is not perceptually registered by the person able to make such adjustments towards the native speaker norm.
It can be concluded from the above discussion that there is a close link between L2 speech perception and production, but that this link is complex and far from well understood (Llisterri, 1995; Strange, 1995; Rochet, 1995).

6.2.3.3 The relationship between speech perception and speech production in blind individuals

In this section, only a short summary of findings from studies of speech perception and speech production in blind children and adults will be made, as in-depth discussions have been presented in chapters 2 and 5. There are only two studies that have investigated both speech perception and speech production in the same group of blind individuals: Lucas (1984) studied this relationship in blind monolingual children, and Kjellberg Smeds (2008) in blind adult L2 learners. Lucas (1984) will be presented below and Kjellberg Smeds in the next section.

Summing up the research conducted on blind children’s speech perception and production, Pérez-Pereira and Conti-Ramsden (1999) concluded that neither pattern nor rate of L1 speech perception and production differ greatly between sighted and blind children. The only difference observed in their study was that blind children were sometimes delayed in learning to produce the phonological sounds that are produced with visible articulation, for instance, labials, where sighted children hold an advantage in being able to visually perceive how the sounds are produced by the lips. This is, however, only temporary, and blind children learn to make use of acoustic information and attain adult pronunciation norms.

Many studies on different aspects of speech perception in blind adults have, on the contrary, shown that congenitally and early blind individuals have great advantages compared to sighted individuals. They have, for example, been found to have a higher phonological sensitivity for speech sounds (Hugdahl et al., 2004), an increased speed of processing of speech (Hugdahl et al. 2004; Röder, Rösler & Neville, 2001; Stevens & Weaver, 2005), and a greater ability to perceive L1 speech in noise (Niemeyer & Starlinger, 1981; Rokem & Ahissar, 2009). Speech perception abilities have not been investigated in late blind individuals, except in this study, and it might be hypothesized that the advantages in speech perception ability in the late blind are not as great as in the early blind based on the findings presented in chapter 5, since important parts of the cortex involved in speech perception (for instance, the phonological aspect of language, the auditory and visual cortex), develop early in life, presumably before the age of one (the phonological language aspect, Werker & Tees, 2005) and four (the auditory and visual cortex, Ward, 2010), respectively, that is, before the onset of blindness in these individuals.

Speech production has not received much attention in research in either blind adult L1 or L2 speakers and, according to Ainkin Araluce (2002), this
is because it is taken for granted that blind and sighted individuals do not differ in this respect. Lucas (1984) investigated both speech perception and production in a group of ten blind monolingual children and ten sighted controls between the ages of five and seven. They performed a speech perception task and a speech production task. In the speech perception task, the children had to detect mispronounced consonants in words, for instance, “vusi” instead of “fussy.” In the speech production task, the children repeated nonwords. The results showed that the blind children spotted significantly more articulatory errors than the sighted children, which indicates that the advantages found in blind adults can also be found among blind children as early as between the ages of five and seven. The speech imitation task, on the other hand, revealed that the blind and sighted children were equally good at imitating and articulating the nonwords. The conclusion drawn by the researcher was that blind children have developed superior auditory discrimination skills and that they are as good as sighted children at imitating unfamiliar articulatory sequences, which suggests that perception, but not production, is above average in blind children. Lucas (1984) also pointed out that the blind children behaved quite differently from the sighted children after performing a task. The blind children wanted to talk about the nonwords, and some of them found the mispronounced words very amusing. They also started to spontaneously invent new nonwords. The researcher concluded that the blind children “showed a heightened auditory awareness and inventiveness that was strikingly absent in the normal primary school children” (Lucas, 1984:76).

6.2.3.4 Second language speech perception and speech production in blind individuals

The prerequisites to perceive and produce L2 speech are a slightly different matter than perception and production of L1 speech, and it can be speculated that some of the advantages associated with speech perception in the L1, found in blind adults, might not be as prevalent in L2 speech perception. This speculation is based on the following hypothesis. Röder, Rösler and Neville (2000) suggested that non-linguistic information, like facial expressions (“signal-independent information” according to Lindblom’s model of speech perception, see chapter 5), is actually conveyed in parallel through very subtle variations in the speech signal. According to Röder, Rösler and Neville (2000), blind individuals have, unlike sighted individuals, developed the ability to perceive these signals. The hypothesis put forward here is that the ability to register such subtle signals is mainly connected to the L1 and to linguistic and culture-specific knowledge developed in childhood. This advantage might, therefore, not be as prevalent in adult L2 perception. On the other hand, the general advantages found in relation to speech perception mentioned previously, as well as findings of advantages in phonological
short-term memory functions in blind individuals (Röder & Neville, 2003; found also in study I), might still give early blind adult L2 learners an advantage compared to late blind and sighted L2 learners in L2 speech perception and production.

According to Aikin Araluce (2002), L2 speech production in blind adults has not received any attention in L2 research since it is simply taken for granted that blind and sighted adults do not differ in their production of second and foreign languages, since there are no differences in first language speech production. In order to investigate this further, Smeds (reported in Kjellberg, 2003; Kjellberg Smeds, 2008) performed two small-scale studies of both speech perception in noise (reported in study II) and L2 speech production in seven blind and seven sighted adult L2 learners. The participants mastered Swedish at secondary school-grade level. The groups were compared in a small Foreign Accent Rating experiment. The participants read Swedish words known to be difficult for second language learners to pronounce (taken from Bannert, 1994), and they were judged by a panel of 15 L1 speakers. They rated the items on a 10-point scale, from “No accent, sounding like a native speaker” to “Very severe accent, impeding comprehensibility.” No group differences were found, but the range was greater in the blind group, since three of the blind participants were judged as “native speakers” on at least one item, which none of the sighted participants were. The conclusion drawn was that a larger experiment had to be performed in order to investigate whether the findings were only coincidental or, in fact, displayed a possible difference in L2 pronunciation between blind and sighted adults.

6.2.3.5 The relationship between speech perception and speech production and the phonological short-term memory

It has been demonstrated in studies of phonological short-term memory functions that congenitally and early blind individuals are advantaged compared to sighted (Hull & Mason, 1995; Röder & Neville, 2003) and late blind (study I) individuals. According to Jacquemot and Scott (2006), models of speech perception and production do not generally include or discuss concepts like phonological short-term memory, and they argued that it should be integrated into such models. In the model they proposed, they suggested that the phonological short-term memory is an emergent property of the cycling of information between the phonological input store and the phonological output store involved in speech perception and production. They also argued for the existence of two separate input (perception) and

---

37 The stores are called “buffers” in Jacquemot and Scott (2006), but to make it easier to relate the discussion to that of the WM model by Baddeley and Hitch (1974), presented in study I, the term store is used.
output (production) stores (unlike the working memory model proposed by Baddeley & Hitch, 1974, which has only one phonological store component, the phonological short-term store subcomponent) in reference to research on both normal and brain-damaged persons (for instance, aphasics), which shows that the two stores might be differently affected or impaired in the same individual. Thus, they suggested that the recruitment of the phonological perceptual and production stores, as well as the conversion between them, constitutes the phonological short-term memory. Herman et al. (2013) also found support for two separate short-term stores, one for perception and one for production.

In a neurolinguistic study by Reiterer et al. (2011), it was found that the phonological short-term memory and the activation of its neurological network predicted L2 speech production talent at earlier stages of L2 acquisition. This finding, in relation to pronunciation talent, is in line with findings from other studies that have also shown that behavioral measures of phonological short-term memory (measured by using digit span and nonword repetition tests) and language-learning ability could be documented for early stages of L2 learning, an association that declined in advanced learners (for more on this subject, see Hu et al., 2012).

It thus seems clear that the phonological short-term memory is of importance to both speech perception and speech production, and advantages in phonological short-term memory functions have been found in congenitally (Röder & Neville, 2003; Hull & Mason, 1995) and early blind (study I) individuals. This suggests that they might hold an advantage over sighted individuals in relation to L2 speech production, at least at earlier stages of L2 acquisition (Reiterer et al., 2011).

### 6.3 Research question

Based on the research background presented, the following research question was formulated:

> Are early blind L2 learners better at producing a less accented L2 speech than late blind and sighted L2 speakers?

### 6.4 Method

#### 6.4.1 A Foreign Accent Rating experiment

In order to study the phenomenon of foreign accents, a commonly used method within the SLA field has been global foreign accent rating experiments (FAR experiments), in which native speakers judge perceived degree of foreign accent in L2 speech production (Hopp & Schmid, 2011). Here, a FAR experiment was conducted to assess the perceived foreign accent in the
L2 learners’ spoken Swedish. Although frequently used, this is still a method that remains unstandardized, which has led to large differences between studies in relation to a variety of methodological issues, including rating scales, types and length of stimuli, range of accents, proportion of native control samples included, number of judges etc. (a summary of studies using FAR experiments in studies of L2 acquisition was provided by Jesney, 2004). On the positive side, FAR experiments are inexpensive and less time-consuming than detailed phonetic analyses, and are characterized by high reliability scores (Schmid & Hopp, 2014). The terminology used in this section is often employed within the FAR paradigm.

6.4.1.1 Speakers
In the FAR experiment, speech samples from all 40 L2 speakers of the current study, presented in chapter 3, were included: early blind (n = 11), late blind (n = 9) and sighted (n = 20). Here, they are referred to as speakers, since it is their speech samples that are being judged and rated in the experiment.

6.4.1.2 Speech material

Recording procedure
Recordings of the speech material were made in two stages. First, recordings were made of the sentences that were going to be repeated by the speakers. The sentences were spoken by a voice professional native speaker, and the recordings were made in an anechoic chamber in the phonetics laboratory at the Department of Linguistics at Stockholm University. These recordings were then used as native speaker models to be repeated by the speakers of the FAR experiment.

Secondly, sample recordings were collected of the speakers repeating the sentences, using a Dell laptop Latitude E4300 and Sennheiser PC-350 headphones with adjustable volume. An external USB soundcard, Creative Sound Blaster X-fi Go, was used to ensure high-quality sound recordings and maximum audio quality. The recordings of the speaker samples were made in a test room at the Centre for Research on Bilingualism or at the home of some of the blind speakers. The speech samples were then used in the FAR experiment. The computer program used for the recording procedure was Audacity, version 1.2.6.

Speech samples
In the current study, 4 different speech samples from each speaker were recorded and rated: 3 samples of elicited speech (repetition of spoken sentences) and 1 of free speech, resulting in a total of 160 samples. The samples of repeated sentences or elicited speech were based on a native speaker
model. The sentences were: “Borås är en stad som ligger öster om Göteborg” (Borås is a town situated east of Göteborg), “Är det katten som dricker mjölken?” (Is it the cat that is drinking the milk?) and “En stol har fyra ben” (A chair has four legs). These sentences were exercise sentences in a book on Swedish prosody (Kjellin, 1998). The elicited speech samples were approximately four seconds long.

The free-speech sample was an excerpt from the speakers’ retellings of an auditorily presented story (Alomba, see study I). Long pauses and pause fillers like “eeehhh”/“uhmm” were cut from the samples so that it would be easier for the raters to focus on pronunciation and accentedness, rather than on, for example, temporary lack of fluency, and in order to enhance intelligibility and comprehensibility. The free-speech samples of the current study were approximately 20 seconds long. The inclusion of both repeated and natural speech was thought to result in a balanced measurement of the speakers’ accents.

No speech samples from L1 speakers were included in the current experiment, since the speakers, as a group, could not be classified as nativelike or near-native and since it was not an aim of the study to establish a native-speaker norm. The listeners were also informed of this.

All samples were normalized to 3 dB, and background noise was reduced to eliminate perceived differences between the samples. The computer program used for cutting and normalization of the speech samples was Adobe Audition, 1992-2004, version 1.5. Adobe Systems Incorporated.

6.4.1.3 Listeners

The L1 speakers who rated the speakers’ speech samples, that is, the instrument of the FAR experiment, are called listeners. All 25 listeners (age 18–32, average age: 23, 19 female, 5 male) of the current study were undergraduate students at the Centre for Research on Bilingualism or at the Department of Linguistics at Stockholm University. They had received no training in phonetics.

The primary selection criteria for the members of the listener group were that they were L1 speakers of Swedish, having grown up with Swedish-speaking parents/caregivers. As undergraduate university students they were all accustomed to test situations and test participation.

The listeners of FAR experiments have generally been native speakers with no phonetic training (Hopp & Schmid, 2011), just as in the current study, and it has been shown that L1 speakers are “[…] acutely sensitive to divergences from the phonetic norms of their native language […],” making L1 listeners able to make reliable judgments of perceived foreign accents even when the samples are reduced down to 30ms of a syllable (Flege, 1984). Schmid and Hopp (2014) compared the interrater reliability between phonetically untrained listener ratings and ratings conducted by students of
phonetics (from a separate study presented in Mennen, 2010) and concluded that phonetic training does not change FAR ratings. Consistently strong correlations found across L1 raters (phonetically trained or untrained) and across studies points to a high reliability in FAR experiments, according to the researchers. Untrained native judges have even been found to be able to distinguish nonnative speakers, with the very low AO between one and five years from native speakers (Yeni-Komshian, Flege & Liu, 2000).

Being an L1 speaker would thus be considered the most important, and also sufficient, factor characterizing a good foreign accent rater. This was also found in the current study, as the average interrater correlation of the entire experiment was \( r = .78 \), and the average intrarater correlation \( r = .70 \) (\( r \)-values between .50 and 1.0 are considered strong correlations; Pallant, 2013:139).

It was found that individual listeners made more or less strict but consistent judgments (some always made strict judgments, while others made consistently less strict judgments). The average judgment of the entire experiment was 4.97, using a Likert scale from 1 to 10 (see details below), and the judgment score distribution, according to Kolmogorov-Smirnov, indicated normality (sig. value .099).

The listeners were divided into three groups (group 1: \( n = 9 \), group 2: \( n = 7 \), group 3: \( n = 8 \)), and the order of presentation varied between the three groups. None of the listeners of the experiment suffered from dyslexia or hearing impairments.

6.4.1.4 Scale
The most commonly used scale measuring nativelikeness in L2 speech are Likert scales (Jesney, 2004), and a Likert scale of 10 gradients was used in this study. The ends of the scale were given the following labels: “No foreign accent” and “Very heavy foreign accent, impeding comprehensibility.” The same Likert scale was also used in the small-scale study performed by Smeds (reported in Kjellberg, 2004; Kjellberg Smeds 2008).

6.4.1.5 Reliability
As was mentioned above, the average interrater correlation was strong, \( r = .78 \), and the average intrarater correlation was also strong, \( r = .70 \). The internal consistency of the items was very high, with an average Cronbach’s alpha coefficient of .97 (sentence 1: Cronbach’s alpha coefficient .96, sen-

38 It might, however, be advisable to not include listeners with dyslexia, since some of these individuals might suffer from a cognitive deficiency in phonological processing, according to the phonological deficit hypothesis (Hedman, 2009). None of the listeners in the current FAR experiment suffered from dyslexia.
6.4.1.6 Procedure

The FAR experiment was conducted at the Centre for Research on Bilingualism at Stockholm University. In order to avoid random measurement errors caused, for example, by the researcher, the entire experiment was computerized using a Microsoft Office PowerPoint automatic slideshow, so that all listeners received the same information concerning the experimental procedure, and had the same time to listen to the samples and for making judgments, as well as spent the same total amount of time on the experiment, namely 45 minutes. The first 5 minutes of the slideshow were devoted to explaining the instructions for the experiment and the remaining 40 minutes to the actual experiment. Schmid and Hopp (2014) investigated the development of ratings during a 35- to 40-minute timeframe. They found no training effects (raters getting better at discriminating samples, resulting in decreased variability) or fatigue effects (raters getting worse at discriminating samples, resulting in increased variability) during the time that the experiment lasted, suggesting the suitability of the length of the current FAR experiment.

Before the computerized versions of the experiment were finalized, a pilot experiment was conducted, resulting in further improvements of the experimental setup and procedure. Before each of the four different speech samples were presented in the slideshow, example sentences were provided so that the listeners would get a sense of the variation in degree of accent present in the experiment. This was done to strengthen the validity of the experiment, to “tune the instrument,” that is, the judges. There was a silent pause of four seconds between the samples that were presented, during which time the listeners made their assessments. Four seconds were judged as a suitable amount of time by the participants of the pilot experiment. The order of the presentations of the speech samples varied between the three groups of listeners, and the orders were randomized, fixed orders. This was done in order to avoid random errors caused by the order of presentation, for example, if a specific order of presentation favored some participants more than others. The researcher ascertained that the three different orders of presentation did not present the same speakers in the first five or the last five samples. The first five samples of every order of presentation were also randomly presented later in the same presentation, which means that the first five samples were presented twice. This was done so that intrarater reliability (test-retest reliability) could be measured.
The listeners all signed a written informed consent form after receiving a description of the study and its purpose, a description about the information that they were asked to provide and how they would be asked to provide it, how long the experiment would take, a reassurance that data would be treated confidentially and the name and email of the researcher in case they were interested in receiving a summary of the results. The listeners were also given time for questions both before and after the experiment. Each participant received a payment of SEK 100 for attending the experiment.

6.4.2 Predictions

It was predicted that early blind individuals would receive higher FAR scores than late blind and sighted and that late blind and sighted would show similar results. This prediction was motivated by the advantages in phonological short-term memory functions found in congenitally (Röder & Neville, 2003; Hull & Mason, 1995) and early blind (study I) individuals, since this specific memory function has been found to be of importance to speech production (Jaquemot & Scott, 2006).

6.5 Results

The main test results are presented in table 6.1, but for those readers who prefer figures, all test results of the study are presented in figures in appendix 7. There was no significant difference between the ratings from elicited speech and free speech, when the mean result of the three samples of elicited speech \( (M = 4.94, SD = 1.10) \) was compared to the mean score of free speech \( (M = 5.07, SD = 1.40) \) using paired-samples t-test, \( t (39) = -0.94, p = .36 \). For this reason, only the total mean score from all four speech samples was analyzed statistically. It should be noted that a lower score indicates a lesser degree of accent.

According to the prediction, it was likely that early blind individuals would receive higher FAR ratings than late blind and sighted individuals, but this prediction was not confirmed as the one-way between-groups ANOVA analysis of variance conducted to explore the impact of visual status (EB, LB, S) on perceived level of accent in L2 Swedish speech production showed that the differences between the groups (early blind, \( M = 4.80, SD = \))
0.95, late blind, $M = 4.85, SD = 1.55$ and sighted, $M = 5.22, M = 0.95$) were not significant: $F(2, 37) = 0.65, p = .54$.

Possible confounding factors will be commented on, since it was found that they had no significant correlations with FAR scores. AOB and LOB might potentially affect speech production scores, but there was no significant correlation between AOB and FAR scores. LOB also differed between the different visual status groups, but there was no significant correlation between the FAR experiment scores and LOB either (covariates like age, gender, educational background, AO and LOR was controlled for as previously mentioned).

### 6.6 Discussion

Existing research on phonological short-term memory functions in congenitally and early blind individuals show that both blind children and adults display advantages compared to the sighted (study I of the current project; Hull & Mason, 1995; Röder & Neville, 2003), and that phonological short-term memory functions are involved in both speech perception and production (Jacquemot & Scott, 2006). These findings suggest that blind individuals might be better at or have an advantage with respect to speech production and accentedness in an L2. According to the results of study III, however, this is not the case in this specific population, as early blind individuals as a group do not produce less-accented L2 speech than late blind and sighted individuals.

The findings of the current study seem to parallel the findings of Lucas (1984), who found that ten blind children (ages five to seven) had a perceptual advantage (detection of mispronounced words) compared to ten sighted children, but that the speech production (production of nonwords, not used as a memory/serial recall test, as it is in the current study) did not differ between the groups. This suggests that a perceptual advantage does not necessarily lead to an advantage in speech production. The perceptual advantage of the early blind participants of this study (measured by the phonological short-term memory tests in study I), which presumably includes greater plasticity of the different parts of the perceptual system (e.g. the auditory and visual cortex), has not led to an advantage in L2 speech production and to greater plasticity of the articulatory motor component, which is usually less plastic in adulthood (Walsh, Smith & Weber-Fox, 2006).

Both Listerri (1995) and Strange (1995) pointed out that the relationship between perception and production is far from well understood, and it seems even less so in relation to blind individuals. The current study does not investigate basic auditory perceptual abilities. It only investigates speech perception in noise, and as shown in study II, this specific situation involving noise was extremely difficult for all L2 speaker groups to perform. For this
reason, no conclusion concerning possible group differences between sighted and blind individuals in the relationship between L2 speech perception and speech production could be drawn.39

There is research that suggests that the phonological short-term memory functions are of greatest importance during earlier stages of learning a new language (in later stages, there is instead a greater contribution from familiar phonological long-term representations, according to Masoura and Gathercole [Masoura & Gathercole, 2005; Gathercole & Masoura, 2005]), and also that phonological short-term memory specifically predicts pronunciation aptitude in early-stage L2 learners (Reiterer et al., 2011; Hu et al., 2012) and not in late-stage L2 learners. This suggests that the phonological short-term memory advantages of early blind individuals are mainly associated with an advantage in speech production at early stages of L2 acquisition, and thus not as evident in L2 speakers of the current study who have reached a more advanced L2 level. Thus, the findings of the current study do not provide evidence countering the claim made by an experienced teacher of Swedish as a second language that blind individuals produce a less-accented L2 speech, with reference to L2 learners at early stages of L2 acquisition. The blind L2 learners may simply be better at producing less-accented speech at earlier stages of L2 acquisition, and the sighted L2 learners eventually catch up.

Foreign Accent Rating experiments are widely used in studies of ultimate attainment of second language phonology and, although unstandardized, the experiments are characterized by high reliability scores (Schmid & Hopp, 2014), just as in this study. It is very likely that the validity is also high and that the judges rate the degree of accent in the L2 speakers. It has been found that being an L1 speaker is a sufficient factor characterizing a good foreign accent rater, since phonetic training does not result in more reliable judgments (Schmid & Hopp, 2014). Both inter- and intrarater reliability measures were high in the current study, as well as the internal consistency of the items, which indicates, that the experiment produced reliable data. A possible weakness of the experiment was that native speaker samples were not included.

39 The results could, however, confirm that there was a medium strong correlation between the results on the speech perception in noise tests (transferred to z-scores and summarized) and mean scoring on the FAR experiment, Pearson product-moment correlation; \( r = .42, n = 40, p < .007. \)
7.1 Memory, blindness and second language acquisition

The overall aim of this study was to investigate whether blind individuals have better prerequisites for second language acquisition than sighted individuals, and the answer to this question, based on the results of this study seems to be yes. Support for these findings can be found in neuropsychological research studying neural plasticity and perceptual compensation in blind L1 speakers, using a variety of language and memory paradigms (e.g. Röder, Rösler & Neville, 2000; 2001; Amedi et al., 2003; Raz et al., 2005; Hugdahl et al., 2004). Although it was not the case that all the test results of the current study displayed an advantage for blind individuals (discussed further below), the results of the phonological short-term (early blind) and recognition memory tests (both early and late blind) clearly did, and these cognitive functions have been found to be very important to both second and foreign language acquisition (Baddeley, Gathercole & Papagno, 1998; O’Brien et al., 2007; Bolibaugh & Foster, 2013; Speciale, Ellis & Bywater, 2004).

The specific function of the phonological short-term memory is, according to Baddeley, Gathercole and Papagno (1998), the acquisition of novel word forms, but it has also been found to influence many other important aspects of L2 acquisition: acquisition of syntax (Papagno & Vallar, 1995), early oral fluency gains (O’Brien et al., 2007) and the ability to produce less-accented speech at early stages of L2 acquisition (Hu et al., 2012), as well as improved rate and ultimate L2 attainment (Bolibaugh & Foster, 2013). Baddeley, Gathercole and Papagno (1998) also suggested that a good phonological short-term memory capacity provides the prerequisites for the development of a natural talent for learning languages. The phonological short-term memory functions have also been found to be related to both perception and production of speech (Jacquemot & Scott, 2006) investigated in the present study.
The general finding of the study in relation to phonological short-term memory is that early blind individuals hold advantages in relation to this memory function compared to both late blind and sighted individuals. It was, for example, found that the phonological short-term store capacity of early blind individuals was significantly greater than in sighted individuals when the demand on the phonological short-term store was 1.8 seconds until it was 3.012 seconds, that is, when the demand was increased by approximately 50% compared to the average store capacity of 2 seconds (Baddeley, 2012). With respect to Lat A, a ranking of the participants showed that the individuals who positioned themselves from first place to eleventh place were all early blind individuals (six L1 speakers and five L2 speakers) and their scores were all better than one standard deviation above mean. This means that half of all early blind participants of the study positioned themselves above the remaining participants.

The advantages of late blind compared to sighted individuals were seen on lower levels (for example, one to four syllable levels on Lat A), and not on overall scores, which supports the conclusion that the ability to compensate in late blind is only partial (Röder & Rösler, 2003).

A research team of neuroscientists has investigated what it is that leads to this compensatory behavior in congenitally and early blind individuals, and it was suggested by Rokem and Ahissar (2009) that it is a compensatory mechanism at the level of perceptual encoding that leads to advantages in phonological short-term memory performance in congenitally blind individuals, and that it specifically is the ability to chunk verbal material that has become enhanced in these individuals. This hypothesis seems highly plausible, as the strategy to learn, imitate and use chunks of verbal material in the form of imitated ready-made adult speech is a common strategy used by blind children acquiring their L1 (Pérez-Pereira & Conti-Ramsden, 1999). This is also further supported by the finding of study II, where the perceptual advantages of early blind L1 speakers, found in perception of sentences in white noise (which only disturb perception), was diminished by babble noise, which disrupts the chunking mechanism (Page & Norris, 2003).

The other memory function for which blind individuals displayed advantages compared to sighted individuals was recognition memory. This is also a very important memory function in L2 acquisition, since it enhances the speed of acquisition of novel word forms (Meara, 2005; Speciale, Ellis & Bywater, 2004), as well as other grammatical functions, including morphological endings (Meara, 2005). It is also a function that, together with phonological short-term memory, makes additive contributions to receptive and productive foreign language lexical competence (Speciale, Ellis & Bywater, 2004), and both functions have been associated with language learning talent (Speidel, 1993; Papagno & Vallar, 1995; Granena, 2013) and high-attainment outcomes in a recent study related to the development of a new apti-
tude test battery (Hi-LAB; Linck et al., 2013). According to the recent advances of Linck et al. (2013), a set of cognitive and perceptual abilities can be associated with highly successful language learners, and they are related to working memory; phonological short-term memory (measured by DS, CNRep, Lat A), implicit learning (measured by Llama D; Granena 2013) and associative memory.

Both the phonological short-term memory tests and the recognition memory test in the current study focus on remembering or recognizing aspects of the sound system of language, both abilities thus being related to the auditory perceptual ability, which has been found to be better in blind compared to sighted L1 speakers (e.g. Amedi et al., 2003; Röder, Rösler & Neville, 2000; 2001; Röder & Rösler, 2003; Gougoux et al., 2004; Hugdahl et al., 2004; Niemeyer & Starlinger, 1981; Stevens & Weaver, 2005). Not surprisingly, there is a fairly strong and highly significant correlation between the summarized phonological short-term memory test scores and the recognition memory test scores in the current study, suggesting that these two memory functions are inextricably entwined processes of second language acquisition and competence (Speciale, Ellis & Bywater, 2004).

Besides these two memory functions, this study also had one episodic memory test, as well as measures of speech perception in noise and L2 speech production, which did not show that blind individuals held an advantage over sighted individuals. The episodic memory test Alomba thus showed that the blind participants of the current study were not better at remembering events in which they heard many facts being presented, either in the L1 (for the L1 speakers) or in the L2 (for the L2 speakers), to a greater degree than the sighted participants. The results of the current study suggest that blind individuals do not develop this specific memory function to a greater degree than sighted individuals; however, this would need to be investigated more thoroughly using further tests to draw any firm conclusions on the matter. It is very interesting to note, though, that this memory test is the only memory test of this study that does not require the participants to focus on the actual characteristics of the speech signal, otherwise found to be better done by the blind individuals of this study.

7.2 Speech perception in noise and blindness

The current study found that the tests measuring speech perception in noise were very difficult for L2 speakers to perform, confirming that L2 speakers have a “hidden” inability to perceive speech in noisy environments (McAllister, 1997). All L2 participants, irrespective of visual status, produced low results on these tests, and no group differences emerged. In relation to speech perception in noise, the language background factor was thus of major importance to the task performance in the L2 speaker group. In
order to investigate speech perception in L2 speakers, it might be a better option not to add noise to the speech signal, but instead to manipulate the loudness of presentation (decibels) of the actual speech signal and investigate basic speech perception (as Rokem & Ahissar, 2009, did on congenitally blind L1 speakers).

Group differences did, however, emerge in the L1 speaker group, when longer stretches of speech (sentences) had to be perceived. The results suggested that early blind individuals outperformed late blind and sighted when perception was hampered by white noise (displaying the same pattern as in the phonological short-term memory test results). But when the noise that was added not only disturbed perception (as in the case of white noise) but also interfered with recall (the effect of babble noise according to Baddeley, Eysenck & Anderson, 2009) by interrupting the verbal chunking mechanism (Page & Norris, 2003), both blind groups displayed a diminished performance compared to the performance with white noise. The strategy to chunk verbal material is commonly and more frequently used in L1 acquisition by blind children, and it is a strategy that might have resulted in the memory advantages found in congenitally blind adults (Rokem & Ahissar, 2009). The late blind produced significantly lower scores than the other two groups on speech perception of sentences in babble noise, and the perceptual advantage of the early blind (found for the white-noise condition) was thus eliminated.

The implication of this finding is that environments in which there is a great deal of talk present great challenges to blind individuals, in general, but especially for the late blind. It is also suggested from the findings in relation to all L2 speakers that it is very important to have quiet learning conditions in the L2 classroom, especially for blind L2 learners, since they are not able to support auditory perception with visual input, in terms of lip movement, facial expressions, etc., from the interlocutor. The signal-dependent information is degraded in chatty environments, resulting in no signal-independent information being available to support perception for blind individuals. It is also suggested that the diminishing effect produced by an environment in which there is a great deal of chatter might be even more pronounced in relation to late blind L2 speakers, based on the findings from the L1 speaker group.

### 7.3 Blindness and accentedness in a second language

Second language speech production was also investigated in the current project. It was mentioned above that phonological short-term memory advantages are of greatest importance to pronunciation ability at an early stage (Hu et al., 2012). This might explain the results of the current study, which showed that blind L2 speakers who are not at a beginner level of L2 acqui-
sition do not have a more nativelike L2 accent than sighted L2 speakers. Further investigations will be required to clarify this by comparing earlier and later stages of L2 acquisition in blind individuals compared to sighted individuals with respect to L2 pronunciation.

7.4 Conclusion

Summarizing the results of the three studies, the conclusion is that advantages in different aspects of the memory system, important to second and foreign language acquisition, are found in blind individuals – phonological short-term memory (for early blind) and recognition memory (for both early and late blind). These two memory functions seem to be inextricably entwined processes of second language acquisition, and they are both associated with language learning talent. It is thus suggested that loss of vision and the unique experience of living as a blind individual result in a different neurological development leading to cognitive advantages related to second language acquisition.

7.5 Theoretical and practical implications of the results

What is the theoretical and practical significance of the results, and what is the basis for these interpretations? This discussion will first focus on the theoretical implications of the results of the study. The results indicate that blindness, especially early blindness, leads to better prerequisites for second and foreign language acquisition, and these advantages specifically seem to be related to the processing of the sound system of language. The very unique interaction with the environment, caused by blindness, thus presumably results in use-dependent plastic changes and the development of talents in certain cognitive functions such as the phonological short-term and auditory recognition memory functions. Although talent is not explicitly investigated in this study, many of the prior studies that were referred to (e.g. Papagno & Vallar, 1995; Bolibaugh & Foster, 2013; Forsberg Lundell & Sandgren, 2013) stress the importance of these cognitive functions investigated in relation to language talent. Two of the tests measuring these cognitive abilities, Lat A and Llama D, are both subtests of language learning aptitude test batteries. Some theories of talent stress the fact that talent is something innate, predisposed by genetic factors, and also a kind of fixed trait not susceptible to change. Based on the findings from this study, however, a different view of talent is supported, a view that is more in line with the current trend in plasticity research showing that the brain is far more flexible and affected by training and use than what has previously been suggested. This is in line with the general theoretical framework of talent devel-
oped by, for example, Gagné (2000). Recent advances in research devoted specifically to language learning aptitude from the field of SLA also seem to adopt a view in which language aptitude is seen as something that can be affected by training and use over time, as future research suggested by, for example, Linck et al. (2013) should have a longitudinal design rather than cross-sectional, which has previously been standard practice.

What is then the practical significance of the outcome of the results? It is very clear that quiet learning conditions are essential based on the findings from the speech perception in noise tests, and on earlier research conducted by McAllister (1997) on second language learners’ “hidden” inability to perceive L2 speech in talkative environments, which must be even more pronounced in blind individuals who are extremely dependent on their ability to perceive via the auditory channel due to not having access to a visual impression of the interlocutor. This would need to be a priority both in educational and work settings.

7.6 Future research

Based on the general conclusion that the blind, especially the early blind, have better prerequisites for L2 acquisition, it is suggested that a possible continuation of the current study would be to compare blind and sighted L2 speakers on their actual L2 use by investigating, for example, the development, breadth and width of their vocabulary, following the development of different grammatical aspects of the L2, for instance, the syntax, and also examining how L2 speech production develops over time, starting at the early stages of L2 acquisition. It would, thus, be preferable to complement cross-sectional measures with longitudinal measures.

Another possible continuation of this research would be to investigate language learning talent, not only by employing behavioral measures but neuroimaging techniques as well. One possibility could, for example, be to compare polyglots (or hyperpolyglots), that is, individuals who speak more than six languages fluently (Hyltenstam, forthcoming), and blind individuals, or even blind polyglots with individuals with an average or low language talent, to obtain further insights into neurological activation in relation to different aspects of language talent (e.g. phonological vs. grammar).

Although the study does not have an educational perspective of second language acquisition in blind individuals or investigate pedagogical aspects of second language acquisition in blind individuals, the results nevertheless suggest that such research is needed and that a sighted control group should be included according to the common practice of SLA research. In chapter 2, there was mention of a method of second language teaching for blind individuals that was developed in New York in the 1960s, namely the aural-oral method (Snyder & Kesselman, 1972). In adhering to this method, great
emphasis is primarily placed on developing the ability to master the sound system before reading or writing is introduced. At early stages of L2 acquisition, grammar was, thus, acquired aural-orally. Based on the findings of the current study, which suggest that blind individuals (especially early blind) have better prerequisites for L2 acquisition because of phonological short-term and recognition memory advantages, as well as on earlier research demonstrating the importance of the phonological short-term memory functions, especially at earlier stages of L2 acquisition in relation to acquisition of novel word forms (Masoura & Gathercole, 1999; 2005), oral fluency gains (O’Brien et al., 2007), and L2 pronunciation (Hu et al., 2012), this way of teaching a second language, that is, focusing on the sound system of language at beginner stages, might prove to be a beneficial L2 development for blind individuals, and should be evaluated and compared to other methods.

Syftet med denna studie var att undersöka om blinda individer hade bättre förutsättningar att lära sig ett andraspråk, eller om detta bara är en allmän upplevelse. I studien undersökttes tre olika aspekter av kognition som är centrala i samband med andraspråksinlärning: (i) minnesfunktioner (fonologiskt korttidsminne, igenkänningsminne för nya ord, och episodiskt minne), (ii) talperception (talperception i vitt brus samt babbelbrus, både enstaka ord och meningar) och (iii) talproduktion, dvs. grad av brytning i andraspråk- uttalen.

Totalt engagerades 80 deltagare, 40 L1-talare och 40 L2-talare. Inom varje grupp fanns 11 tidigt blinda (barndomsblinda, dvs. individer som blivit blinda som barn innan puberteten), 9 sent blinda (individer som blivit blinda som vuxna, dvs. efter 18-års ålder) och 20 seende. Alla grupper var väl matchade när det gäller samtliga bakgrundsvärder (ålder, könsfördelning, utbildningsbakgrund, yrkessituation, startålder för blindhet (age of onset of blindness, AOB), antal år av blindhet (length of blindness, LOB), startålder för L2 inlärning (age of onset, AO), vistelsetid i Sverige (length of residence, LOR) och modersmålsbakgrund). Inga deltagare hade hörselnedsättning eller dyslexi.

Deltagarna fick genomgå en rad olika test för att undersöka de ovan nämnda kognitiva aspekterna:
Fonologiskt korttidsminne:

Igenkänningsminne, igenkännning av främmande ord:
Llama D, deltest i ett språkbegåvningstestbatteri, Llama Language Aptitude Tests (Meara, 2005).

Episodiskt minne:
Alomba, en fiktiv historia om ett land presenterades auditivt (173 ord) och deltagarna ombads återberätta så många detaljer som möjligt från berättelsen omedelbart efter presentationen.

Talperception i brus:
(1) Enstaka ord presenterade i babbelbrus, ett test utvecklat av McAllister och Brodda (McAllister, 2002).
(2) Enstaka ord presenterade i vitt brus, samma test som ovan men med vitt brus.
(3) & (4) Meningar presenterades i både babbelbrus och vitt brus. Både signal och brusnivåer anpassades så att de motsvarade nivåerna i McAllister och Broddas ursprungliga test med enstaka ord och babbelbrus. Testet utvecklades av Anders Branderud.

Uttalsexperiment:
Resultatet visade att tidigt blunda var signifikant bättre än både sent blinda och seende på samtliga fonologiska korttidsminnestest. På Lat A, som var det mest krävande av de tre testen, rankades 11 tidigt blunda högst (6 L1-talare och 5 L2-talare), vilket innebär att hälften av alla tidigt blinda del-
Sammanfattning på svenska
191


På ordigenkänningstestet Llama D var både tidigt och sent blinda bättre än seende. Även förmågan att känna igen nya ord har associerats med språkbegåvning (Meara, 2005; Granena, 2013), och specifikt associerats med förmågan att lära sig nya ord, att känna igen grammatiska drag, och med förmågan att lära sig kollokationer på ett andraspråk (Speciale, Ellis & Bywater, 2001; Service, 1992; Service & Kohonen, 1995; Granena, 2013; Meara, 2005; Forsberg Lundell & Sandgren, 2013). Enligt Speciale, Ellis & Bywater (2004) bidrar igenkänningsminnet, dvs. förmågan att känna igen nya ord m.m., och det fonologiska korttidsminnet tillsammans till receptiv (igenkänningsminnet) och produktiv (fonologiska korttidsminnet) lexikal kompetens i ett andraspråk, och de menar att dessa förmågor tillsammans bidrar mer till denna kompetens än vad dessa minnesförmågor gör var för sig.

Resultatet från det episodiska minnestestet visade att det inte fanns några fördelar av att vara blind när det gäller förmågan att minnas episoden då en
stor mängd information presenterades, varken hos blinda L1- eller L2-talare. Mönstret vi anar här är således att de minnesfördelar vi ser hos blinda verkar vara tätt förknippade med förmågan att registrera detaljer hos och karaktären på själva talsignalen, dvs. det finns en tydlig koppling till en förhöjd auditiv perceptuell förmåga.

Resultaten från talperceptionstesten i brus visade exempelvis att talperception i brusiga miljöer är extremt krävande för andraspråkstalare. Detta bekräftar McAllisters (1997) slutsats att talperception i brus är en “dold” oförmåga (a “hidden” inability) även hos mycket avancerade andraspråkstalare. Inga fördelar associerade med blindhet fanns heller hos gruppen L2-talare. I L1-talargruppen däremot framkom samma mönster som i de fonologiska korttidsminnestestresultaten, nämligen att tidigt blinda var bättre på att uppfatta meningar i vitt brus än sent blinda och seende, och att inga skillnader förekom mellan sent blinda och seende. Men när bruset, å andra sidan, bestod av babbelbrus, försvann den perceptuella fördel som de tidigt blinda hade upprivasat i vitt brus, och de sent blinda blev signifikant sämre än de seende, och närapå signifikant sämre än de tidigt blinda. För att kunna tolka dessa skillnader måste man ha en förståelse för effekten av olika brus. Vitt brus, stör enbart själva perceptionen, medan babbelbrus inte bara stör själva perceptionen utan även själva minnesprocessen, dvs. förmågan att plocka fram ur minnet det man just har perceripat (Baddeley, Eysenck & Anderson, 2009). Det verkar således som om blinda generellt, i högre grad än seende, påverkas negativt av ett brus som även stör minnesfunktionen. Slutsatsen man kan dra av resultaten är att (1) andraspråkstalare behöver vistas i miljöer utan brus för att ha samma förutsättningar att uppfatta tal som förstaspråksstalare, och att (2) det är mycket viktigt att både tidigt och sent blinda vistas i miljöer som inte är pratiga, då de i högre grad än seende störs av detta, allrahelst som de inte har fördelen av att kunna se sin samtalspartner.

Uttalsexperimentet visade att det inte fanns några fördelar av att vara blind när det gäller förmågan att producera ett mer målspråkslikt uttal. Förklaringen till detta resultat kan vara att perceptuella fördelar inte nödvändigtvis leder till fördelar i talproduktionen, något som exempelvis Lucas (1984) resultat visade då de perceptuella fördelar som hon fann hos tidigt blinda barn inte ledde till fördelar vid talproduktion av påhittade nonsensord. Detta tyder på att relationen mellan talperception och talproduktion inte är så enkel som man skulle kunna tro, men det antyder också att talperception och talproduction är neurologiskt separerade aspekter av det fonologiska korttidsminnet (Jaquemot & Scott, 2006). En alternativ förklaring hittar man hos Hu et al. (2012). I denna studie fann man att en högre processningsskapacitet hos det fonologiska korttidsminnet framföralt ledde till ett bättre andraspråkssuttal i tidiga faser av inlärningen. Detta gör således att de tidigt blinda deltagarna i denna studie inte kan dra nytta av sina fonologiska korttidsminnesfördelar i detta sammanhang, eftersom de alla är avancerade andra-
språkstalare och har passerat den initiala fasen av inlärningen. Denna senare förklaring motsäger inte heller uppfattningen att blinda SFI-elever har ett bättre uttal än seende elever, eftersom SFI-elever är i tidiga faser av sin andraspråksinlärning.

Sammanfattningsvis visade denna studiess resultat att framförallt de tidigt blinda, men även sent blinda i lägre grad, har kognitiva fördelar vid andraspråksinlärning jämfört med seende andraspråksinlärare, och att dessa fördelar verkar kunna associeras med en förhöjd förmåga att uppfatta och minnas karaktären hos själva talsignalen.


Acquisition and the Critical Period Hypothesis, 133–159. NJ: Lawrence Erlbaum Associates.


Conti-Ramsden, G. & Pérez-Pereira, M. (1999). Conversational interaction between mothers and their infants who are congenitally blind, have low
vision, or are sighted. *Journal of visual impairment and blindness*, 93(11), 691–703.


References


Appendices

Appendix 1

Digit span test

Developed by Kirk, McCarthy & Kirk (1990), subtest of Illinois Test of Psycholinguistic Abilities.
Appendix 2

**CNRep nonword repetition test**

The original test developed by Baddeley et al. (1994), the Swedish test developed by Hedman (2009).

<table>
<thead>
<tr>
<th>Exercise nr</th>
<th>Syllable number</th>
<th>Original test</th>
<th>Swedish test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 test</td>
<td>3</td>
<td>dopelate</td>
<td>dopelat</td>
</tr>
<tr>
<td>2 test</td>
<td>3</td>
<td>glistering</td>
<td>glistering</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>pennel</td>
<td>pennel</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>defermication</td>
<td>defermikation</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>contramonist</td>
<td>kontramponist</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>hampent</td>
<td>rampent</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>reutterpation</td>
<td>reutterpation</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>perplisteronk</td>
<td>perplisterank</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>blunterstaping</td>
<td>blunterstapping</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>sepretenniäl</td>
<td>sepretenniäl</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>detratapillic</td>
<td>detratapillack</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>glistow</td>
<td>gister</td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>frescovent</td>
<td>freskovent</td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>bannifer</td>
<td>bannifar</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>stopogratific</td>
<td>stipogratik</td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>woogalamic</td>
<td>vogalamik</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>ballop</td>
<td>balopp</td>
</tr>
<tr>
<td>18</td>
<td>5</td>
<td>contrantually</td>
<td>kontranteriska</td>
</tr>
<tr>
<td>19</td>
<td>4</td>
<td>fenneriser</td>
<td>fenneriser</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>altupatory</td>
<td>altupatorisk</td>
</tr>
<tr>
<td>21</td>
<td>5</td>
<td>pristoractional</td>
<td>pristoraktionell</td>
</tr>
<tr>
<td>22</td>
<td>5</td>
<td>underbrantuand</td>
<td>underbrantuand</td>
</tr>
<tr>
<td>23</td>
<td>3</td>
<td>trumpetine</td>
<td>trumpetin</td>
</tr>
<tr>
<td>24</td>
<td>2</td>
<td>sladding</td>
<td>sladding</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
<td>commeecitate</td>
<td>komesitat</td>
</tr>
<tr>
<td>26</td>
<td>2</td>
<td>tafflest</td>
<td>tafflest</td>
</tr>
<tr>
<td>27</td>
<td>4</td>
<td>loddermapish</td>
<td>loddermapisk</td>
</tr>
<tr>
<td>28</td>
<td>3</td>
<td>barrazon</td>
<td>barrasán</td>
</tr>
<tr>
<td>29</td>
<td>3</td>
<td>commerine</td>
<td>kommerin</td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>empliforvent</td>
<td>empliförvesk</td>
</tr>
<tr>
<td>31</td>
<td>3</td>
<td>thickery</td>
<td>tickerisk</td>
</tr>
<tr>
<td>32</td>
<td>5</td>
<td>vultularity</td>
<td>vultularitet</td>
</tr>
<tr>
<td>33</td>
<td>5</td>
<td>versatrationist</td>
<td>versatrationist</td>
</tr>
<tr>
<td>Exercise nr</td>
<td>Syllable number</td>
<td>Original test English (not tested)</td>
<td>Swedish test</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------</td>
<td>-----------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>34</td>
<td>2</td>
<td>rubid</td>
<td>rubid</td>
</tr>
<tr>
<td>35</td>
<td>3</td>
<td>brasterer</td>
<td>brasterá</td>
</tr>
<tr>
<td>36</td>
<td>2</td>
<td>diller</td>
<td>diller</td>
</tr>
<tr>
<td>37</td>
<td>4</td>
<td>penneriful</td>
<td>pennerifal</td>
</tr>
<tr>
<td>38</td>
<td>2</td>
<td>bannow</td>
<td>bannar</td>
</tr>
<tr>
<td>39</td>
<td>2</td>
<td>prindle</td>
<td>prindla</td>
</tr>
<tr>
<td>40</td>
<td>3</td>
<td>skiticult</td>
<td>kritikult</td>
</tr>
</tbody>
</table>
Appendix 3

*Lat A nonword repetition test*

Subtest of the Swansea Language Aptitude Tests, Swansea LAT (v.2.0), developed by Meara, Milton & Lorezo-Dus (2003).

<table>
<thead>
<tr>
<th>Syllable boundaries indicated with dot</th>
<th>Number of syllables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ta.si</td>
<td>2</td>
</tr>
<tr>
<td>2. lu.a</td>
<td>2</td>
</tr>
<tr>
<td>3. to.lu</td>
<td>2</td>
</tr>
<tr>
<td>4. fa</td>
<td>1</td>
</tr>
<tr>
<td>5. li.ma</td>
<td>2</td>
</tr>
<tr>
<td>6. i.le.vai</td>
<td>3</td>
</tr>
<tr>
<td>7. hi.nu.vai.o.i.a</td>
<td>5</td>
</tr>
<tr>
<td>8. i.tu.a.o.le.nu.u</td>
<td>7</td>
</tr>
<tr>
<td>9. ta.te.o.i.lei.ta.va.le</td>
<td>7</td>
</tr>
<tr>
<td>10. ma.nu.ia.le.ga.ue.ga.i.le.a.so</td>
<td>11</td>
</tr>
<tr>
<td>11. o.toi.nei</td>
<td>3</td>
</tr>
<tr>
<td>12. ma.ta.u.ti.a.lei</td>
<td>6</td>
</tr>
<tr>
<td>13. o.le.ti.mu.i.ile.po</td>
<td>7</td>
</tr>
<tr>
<td>14. sui.no.fo.i.se.n.no.fo.a</td>
<td>8</td>
</tr>
<tr>
<td>15. e.te.mu.su.ai.e.sa.ui.le.si.va.ma</td>
<td>12</td>
</tr>
<tr>
<td>16. le.toi.nei.e.si.va</td>
<td>6</td>
</tr>
<tr>
<td>17. i.to.to.nu</td>
<td>4</td>
</tr>
<tr>
<td>18. i.lu.ma.o.le.fa.le.o.ma.li.a</td>
<td>11</td>
</tr>
<tr>
<td>19. e.a.lu.o.ia.ma.o.ie.i.le.a.la</td>
<td>12</td>
</tr>
<tr>
<td>20. su.fe.mi.sa.i.i.la.to</td>
<td>8</td>
</tr>
<tr>
<td>21. u.a.mu.su.le.ta.ma</td>
<td>7</td>
</tr>
<tr>
<td>22. ta.lu.o.na.a.lu.ta.bi.ta.le.a.gua.ga</td>
<td>13</td>
</tr>
<tr>
<td>23. o.le.va.a.o.io.an.ne</td>
<td>8</td>
</tr>
<tr>
<td>24. se.fa.ia.e.le.fa.io.ga.le.ia</td>
<td>11</td>
</tr>
<tr>
<td>25. te.le.mai.lei</td>
<td>4</td>
</tr>
</tbody>
</table>
Appendix 4
*Episodic memory test Alomba*

Participants heard an auditory presentation of a fictitious story about a country called Alomba. Participants were asked to immediately recall as many details as possible from the story.

Minnestest
Deltagarna får lyssna på berättelsen om Alomba. Därefter ska de berätta vad de kommer ihåg om landet. Återberättelserna spelas in.

Appendix 5

Speech perception of sentences in noise

Test items: Helen questions asked in white noise and babble noise

Talperception av meningar i vitt brus

1. Vilken är första bokstaven i ordet vatten?
2. Hur många hjul har en trehjuling?
3. Vilken dag kommer efter onsdag?
4. Vilken dag kommer efter lördag?
5. Vad är motsatsen till lång?
6. Vilket nummer kommer efter 98?
7. Vad är motsatsen till stor?
8. Hur många ben har en hund?
9. Hur många hörn har en tavla?
10. Vilken är första bokstaven i ordet bok?
11. Vilken månad kommer efter juli?
12. Vad är 2+2?
13. Vilket nummer kommer före 20?
14. Vilken är första bokstaven i ordet sol?
15. Vad är motsatsen till varm?
16. Vad är 5+5?
17. Vad är 1+1?
18. Vilket nummer kommer före 3?

Talperception av meningar i babbelbrus

1. Vilken är första bokstaven i ordet hus?
2. Vilken är första bokstaven i ordet penna?
3. Vad är 20+5?
4. Vilket nummer kommer efter 50?
5. Hur många händer har en människa?
6. Vilket nummer kommer före 40?
7. Vad är 3+3?
8. Vilken årstid kommer efter våren?
9. Vilken är första bokstaven i ordet rosa?
10. Hur många fingrar har en hand?
11. Hur många ben har en stol?
12. Vilket nummer kommer efter 60?
13. Vilken månad kommer före december?
14. Vad är 8+2?
15. Vad är motsatsen till glad?
16. Vad är motsatsen till mjuk?
17. Vilket år kommer efter 2009?
18. Vad är motsatsen till gammal?

Frågetyper: (a) Nummerfrågor; vilket nummer kommer…. (b) Bokstavsfrågor; vilken bokstav….. (c) Motsatsfrågor; vad är motsatsen till…? (d) Före/efterfrågor; vad kommer före/eft er…? (e) Enkel addition, (f) Frågor av olika slag
Appendix 6
Grammaticality judgement test

The test items were presented auditorily as a screening test. Participants were asked to judge if the items were grammatically correct or not.

1. √ Båten visade sig vara helt rostigt. kon
2. Om det ska gå bra måste alla vara ordentliga. inv
3. √ Bilen på gatan var brunt. kon
4. √ Benny Andersson och sin orkester uppträdde igår. ref
5. Eftersom vi vill komma i tid till festen måste vi gå nu. inv
6. √ På grund av signalfel i tunnelbanan alla kom för sent till mötet. inv
7. Mekanikern hade lagat hissen som sällan brukade fungera. sadv
8. Hästen i hagen verkade orolig. kon
9. √ Kvinnan väntade på mannen som kom inte i tid. sadv
10. Problemen hade blivit mer vanliga. kon
11. √ Mannen hade på sig en tröja som sin fru hade köpt. ref
12. Man började gå ombord på flygplanet som säkert skulle gå i tid. sadv
13. Hunden med sin tjocka päls svettades i solen. ref
14. Kylan förvärrade kaoset som inte kunde undvikas. sadv
15. Mannen ville att hans bagage skulle hämtas på tågstationen. ref
16. √ Eftersom vi ska ha gäster måste vi städa först. inv
17. √ Snötäcket dolde isfläckar som man hade inte saltat på ordentligt. sadv
18. √ Instruktionerna var inte tydligt. kon
19. Kungen och hans familj var med på Nobelfesten. ref
20. Huset med stora fönster var gult. kon
21. √ Älgarna med deras stora horn skrämdes turisterna. ref
22. Solen lyste på himlen som inte hade ett enda moln. sadv
23. √ Kvinnan med hennes långa kjol snubblade i trappen. ref
24. När mannen hade målat halva väggen tog färgen slut. inv
25. Explosionerna var mycket kraftfulla. kong
26. √ När läraren är sjuk barnen måste gå hem. inv
27. Hon körd in i parkeringsgaraget som inte hade några lediga platser. sadv
28. Flyttfåglarna med sina vackra färger satt på taket. ref
29. √ När kvinnan kom fram till T-centralen täget hade gått. inv
30. Flickan hade med sig mat som hennes mamma hade lagat. ref
31. √ Hjärtat kan i vissa fall bli förstorat. kon
32. Röken var väldigt giftig. kon
33. På grund av väderet ställdes alla turer in under natten. inv
34. När pojkarna är färdiga med läxan blir deras mamma glad. \textit{inv}
35. √ Fartyget körde in i en båt som kaptenen hann aldrig uppmärksamma i tid. \textit{sadv}
36. √ Kvinnan väntade på sin vän som hade inte gått hemifrån ännu. \textit{sadv}
37. √ Syskonen var väldigt lik varandra. \textit{kon}
38. √ Snön föll i backen som skulle säkert bli full av skidåkare. \textit{sadv}
39. √ Pojken överlämnade blommor som sin syster hade plockat. \textit{ref}
40. √ Om de ska gå på bio de måste boka biljetter i förväg. \textit{inv}

Strukturer som undersöks: inversion, reflexiva possessiva pronom, sats-adverbial i bisats (relativsatser) och kongruens.
Appendix 7

Figures for all test results of the study

Study I: figures 1–5, study II: figures 6–9, study III: figure 10.

Figures presenting test results from study I

Figure 1. Mean overall score on digit span for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers.

Figure 2. Mean overall score on CNRep for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers.
Figure 3. Mean overall score on Lat A for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers, correctly repeated syllables in the correct serial order.

Figure 4. Mean overall score on Llama D for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers.
**Figures presenting test results from study II**

The results obtained by the tests are expressed in negative signal-to-noise values, but they are presented as positive values in the figures for clarity.

---

*Figure 5.* Mean overall score on Alomba for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers.

*Figure 6.* Speech perception of words in white noise for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers.
Figure 7. Speech perception of words in babble noise for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers.

Figure 8. Speech perception of sentences in white noise for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers.
Figure 9. Speech perception of sentences in babble noise for early blind (EB), late blind (LB) and sighted (S) L1 and L2 speakers.

Figure presenting test results from study III

Figure 10. Mean foreign accent rating scores for early blind (EB), late blind (LB) and sighted (S) groups. Rating scale: 1 = “no foreign accent”; 10 = “very heavy foreign accent, impeding comprehensibility”.
Dissertations in Bilingualism

No. 1 (1994)
Axelsson, Monica

No. 2 (1995)
Lindberg, Inger
Second Language Discourse in and out of Classrooms. Studies of Learner Discourse in the Acquisition of Swedish as a Second Language in Educational Contexts.

No. 3 (1996)
Obondo, Margaret

No. 4 (1997)
Yukawa, Emiko
L1 Japanese Attrition and Regaining. Three Case Studies of Two Bilingual Children.

No. 5 (1998)
Wingstedt, Maria

No. 6 (2001)
Abrahamsson, Niclas
Acquiring L2 Syllable Margins. Studies on the Simplification of Onsets and Codas in Interlanguage Phonology.

No. 7 (2001)
Tuomela, Veli
Tvåspråkig utveckling i skolåldern. En jämförelse av sverigefinska elever i tre undervisningsmodeller.

No. 8 (2002)
Namei, Shidrokh

No. 9 (2002)
Wiklund, Ingrid
Social Networks and Proficiency in Swedish. A Study of Bilingual Adolescents in both Mono- and Multilingual Contexts in Sweden.

No. 10 (2003)
Heugh, Kathleen
No. 11 (2004)
Wedin, Åsa
Literacy Practices in and out of School in Karagwe. The Case of Primary School Literacy Education in Rural Tanzania.

No. 12 (2005)
Haglund, Charlotte

No. 13 (2007)
Philipsson, Anders
Interrogative Clauses and Verb Morphology in L2 Swedish. Theoretical Interpretations of Grammatical Development and Effects of Different Elicitation Techniques.

No. 14 (2007)
Milani, Tommaso M.

No. 15 (2008)
Ganuza, Natalia
Syntactic Variation in the Swedish of Adolescents in Multilingual Urban Settings. Subject-verb Order in Declaratives, Questions and Subordinate Clauses.

No. 16 (2008)
Allardt Ljunggren, Barbro
Åland som språksamhälle. Språk och språkliga attityder på Åland ur ett ungdomsperspektiv.

No. 17 (2008)
Bylund Spångberg, Emanuel
Age Differences in First Language Attrition. A Maturational Constraints Perspective.

No. 18 (2009)
Kerfoot, Caroline
Changing Conceptions of Literacies, Language and Development. Implications for the Provision of Adult Basic Education in South Africa.

No. 19 (2009)
Hedman, Christina
Dyslexi på två språk. En multipel fallstudie av spansk-svensktalande ungdomar med läs- och skrivsvårigheter.

No. 20 (2010)
György-Ullholm Kamilla

No. 21 (2011)
Lubińska, Dorota
Förstaspråksattrition hos vuxna. Exemplet polsktalande i Sverige.
No. 22 (2013)
Plüddemann, Peter R.
Language Policy from Below. Bilingual Education and Heterogeneity in Post-Apartheid South Africa.

No. 23 (2013)
Stölten, Katrin

No. 24 (2015)
Aktürk-Drake, Memet
Phonological Adoption through Bilingual Borrowing. Comparing Elite Bilinguals and Heritage Bilinguals.

No. 25 (2015)
Smeds, Helena

Distribution:

Centre for Research on Bilingualism
Department of Swedish Language and Multilingualism
Stockholm University
SE-106 91 Stockholm

distribution@biling.su.se
www.biling.su.se