Exploring Early Language Acquisition from Different Kinds of Input: The Role of Attention

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ABSTRACT

While most research on infant word segmentation has investigated the extraction of words from fluent speech in standard laboratory settings, the series of experiments in this dissertation examined the role of different kinds of input and exposure on infants' word segmentation and word learning abilities. The first experiment suggests that infants are able to successfully segment words from fluent infant-directed speech (hereafter, IDS), which includes longer pauses, shorter utterances, higher fundamental frequencies, and wider pitch ranges, but also the fast and monotone input of adult-directed speech (hereafter, ADS) provided they were familiarized with these words over an extended-exposure period of six weeks at home. These 9-month-old infants, however, seem to be unable to segment words from fluent IDS during a standard laboratory-familiarization. Therefore, the second experiment examined whether German infants might require a more exaggerated IDS exposure similar to the one American English infants are addressed with. Here, 9-month-old, but not 7.5-month-old, infants successfully segmented the words presented in an exaggerated IDS register. Using neurophysiological measures, the third experiment further explored 7.5-month-old infants' segmentation abilities and revealed that these infants were only able to successfully segment words from fluent exaggerated IDS. The final study of the dissertation extended the investigations to infants' word learning abilities. Critically, infants were trained on word-object associations in fluent IDS or ADS. The results of this study demonstrated that infants were able to learn words regardless of the register they were trained in and suggest that infants are able to learn from a much greater variety of input available to them than previously suggested, extending the findings from word segmentation to word learning.

Importantly, this dissertation presents the earliest evidence of ADS word segmentation and word learning presented in the literature to date. Hence, it provides new insights into infant word segmentation and word learning from different kinds of input and different kinds of exposure. Furthermore, the idea of attention as being a central mechanism in early language acquisition is supported by this dissertation.

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CHAPTER 1: INTRODUCTION

Language is a complex and important means of communication available exclusively to humans. The acquisition of a first language is a remarkably rapid process, beginning even before birth as the fetus perceives maternal speech through the mother’s womb (DeCasper & Spence, 1986). During the first year of life, infants are capable of making incredible achievements in language learning. At birth, babies have the ability to distinguish their native language from a non-native one (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988). Furthermore, infants are able to perceive and discriminate between different speech sounds in both their native language as well as non-native languages (Bertoncini, Bijeljac-Babic, Blumstein, & Mehler, 1987; Eimas, 1974). Initial segmentation abilities are displayed at the age of approximately 5 months through the extraction of the word “mommy” and infants’ own names from fluent speech (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Bouchon, Floccia, Fux, Adda-Decker, & Nazzi, 2015; Mandel, Jusczyk, & Pisoni, 1995). Only one month later, at the age of 6 months, babies have been shown to demonstrate recognition of common names and body parts, thus demonstrating the capability of adding meaning to extracted phonological word forms (Bergelson & Swingley, 2012; Tincoff & Jusczyk, 1999). The ability to discriminate between every sound incorporated into the various languages of the world vanishes at the age of approximately 11 months when speech perception becomes linguistically-bound (Werker & Tees, 1984). The production of first words is observed at approximately 1 year of age (Barrett, 1995; Benedict, 1979; Clark, 1993; Huttenlocher, 1974; Ingram, 1989; Nelson, 1973; Oviatt, 1980). At about 18 months of age, infants start learning new vocabulary explosively and the period of vocabulary spurt commences (Benedict, 1979; Carey, 1978; Ganger & Brent, 2004; Goldfield & Reznick, 1990; Nelson, 1973).

Various factors have been identified as influencing the infant's ability to learn the inventory of words found in their native language. Not only the amount of input and the quality of input influence the performance in the acquisition of a first language, but contextual factors also appear to have an impact (Greenwood, Thiemann-Bourque, Walker, Buzhardt, & Gilkerson, 2011; Hart & Risley, 1995; Houston & Jusczyk, 2000; Shneidman & Goldin-Meadow, 2012; Song, Demuth, & Morgan, 2010; Weisleder & Fernald, 2013). Notably, the kind of speech input that infants are exposed to has been identified as a specific factor that impacts on the infants' performance when learning their native language (Graf-Estes & Hurley, 2013; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011; Singh, Nestor, Parikh, & Yull, 2009; Thiessen, Hill, & Saffran, 2005).

The current thesis aims to further explore this specific factor, namely, the ways in which different kinds of speech input have an impact on an infant's early language acquisition. First, it will investigate the impact of variability within speech input, that is: Infant-directed speech, the slow and exaggerated speech register used to address infants (hereafter referred to as IDS), and adult-directed speech, the fast and monotone speech commonly used in adult conversations (hereafter referred to as ADS). In particular, the thesis examines whether infants are able to learn from these different kinds of speech registers, namely IDS and ADS, and how their learning differs across these registers, as well as across development and across different tasks. As the input that infants are exposed to tends to vary in numerous prosodic characteristics, not only due to different speakers but also the use of different speech registers, it is crucial to examine how this variability influences early language acquisition. The studies presented in this thesis will examine the impact of these different kinds of input in general. In addition, one of these studies will examine the influence of input at the individual level.

Secondly, one must also take into consideration that the kind of input presented to infants changes over time (Englund & Behne, 2006; Zangl & Mills, 2008) and that this is bound to have an impact on the way in which they learn from input. Thirdly, at some point, infants must learn from ADS as well. The thesis therefore takes a developmental approach, investigating infants of different age groups and thus allowing us to determine when the different kinds of input become accessible to infants.

Lastly, learning a language involves many different steps, all of which are essential for the successful acquisition of the mother tongue. Bearing in mind the complex nature of language, these different aspects of language development have been studied separately in the majority of cases. However, some of these processes take place simultaneously and are inherently interlinked, meaning that there is a required combination which makes language acquisition possible. The current thesis therefore attempts to create an integrative picture of how two crucial aspects of language development - word segmentation and word learning – progress. In particular, the thesis focuses on the ability of young infants to segment new words from fluent IDS and ADS and at the same time engage in the process of assigning meaning to these newly segmented words through their exposure to fluent IDS and ADS learning phases.

The current thesis will demonstrate that infants are able to use multiple kinds of speech input when acquiring their first language. Importantly, infants are able to segment and learn words not only from fluent IDS but also from the less engaging overheard speech used between adults, namely ADS. The role of IDS in early language acquisition has been identified as attracting and maintaining infants' attention to the relevant speech stimuli. The current thesis adds to this assumption, concluding that although attention paid to IDS is a generic feature, attention to ADS is vital to learning. In other words, infants learn from IDS as it attracts their attention but at the same time, infants may also learn from the less engaging ADS register *provided that infants are attending to it*. Therefore, the current thesis demonstrates that early on, infants exhibit an enormous flexibility with regards to the different kinds of input they are exposed to in daily life. In addition, it is noteworthy, that the current thesis provides the first evidence of word segmentation and word learning from fluent ADS presented in the literature to date. Hence, this finding suggests that babies are able to learn from a much greater range of input than previously thought possible which substantially impacts on our understanding of language acquisition. Current theories and models appear to have underestimated the role of ADS in early language acquisition and should therefore be adapted. The task of future research should be to further evaluate the role of ADS in infants' word segmentation and word learning.

1.1. LEARNING FROM DIFFERENT KINDS OF INPUT

The quality of input that infants are typically exposed to is one of the factors that has been identified as having an impact on infants' language development. Given the impact of quality of input on language learning and the amount of variability within the input, dramatic differences in learning will be observed as a result of input variability. It is therefore crucial that we understand what kinds of input the child can and cannot learn from. However, existing research focuses on only one particular kind of input, namely IDS – the exaggerated speech that adults and children use when addressing an infant – thus leaving the question of the effects of variability within language input vastly unexplored. The finding that infants are almost equally well capable of learning from IDS and ADS challenges existing theories on word learning that suggest that a specific type of input, namely IDS, is necessary for infants to learn first words. This thesis provides some initial steps in our understanding of how infants overcome this variability which is crucial in mastering language skills.

Modifications of the prosodic properties of IDS have been discovered across different languages (Ferguson, 1964; Fernald et al., 1989; Soderstrom, 2007), and include longer pauses, shorter utterances, higher fundamental frequencies, and wider pitch ranges (Ferguson, 1964; Grieser & Kuhl, 1988; Fernald et al., 1989). In contrast, ADS, the speech register used when adults speak to one another, is characterized by fast, monotone speech (see Soderstrom, 2007, for a review). Whilst previous research has extensively highlighted that infants show a preference to IDS over ADS, this does not seem to be the case from birth. It has, for instance, been shown that newborns do not show a preference for either IDS or ADS (Hepper, Scott, & Shahidullah, 1993; Cooper et al., 1997), which can be attributed to the fact that infants have no prior experience of either register. This highlights that the preference for one specific register is most likely to arise from experience, that is: Since babies are addressed increasingly in IDS, they react more to IDS than ADS. Therefore, after birth, until the age of approximately 5 months, infants' experiences might drive their register preference. They show a robust preference for IDS over ADS (Cooper & Aslin, 1990; Werker & McLeod, 1989), which even extends to IDS of nonnative languages that infants have never previously been exposed to (Werker, Pegg, & McLeod, 1994). At this age, IDS also drives social preferences. For example, it has been found that infants choose their interlocutors according to their register of speech: Infants prefer IDS speakers over novel persons who have not yet addressed them. However, in the case of infants having to decide between a novel person and someone who has addressed them previously in ADS, they prefer the novel person (Schachner & Hannon, 2011). Research on infants' register preferences has revealed mixed results from the age of about 6 months (Hayashi, Tamekawa, & Kiritani, 2001; Inoue, Nakagawa, Kondou, Koga, & Shinohara, 2011; McRoberts, McDonough, & Lakusta, 2009; Newman & Hussain, 2006; Segal, 2011) suggesting that infants might also begin to pay attention to language input other than IDS. This finding again speaks in favor of the idea of an experienced-based account of infants' register preferences.

In addition to the preference for IDS from an early age onwards, IDS has also been shown to facilitate early language acquisition. At 6 months of age, infants are able to parse IDS into prosodic units, but fail to do so in ADS (Kelmer Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989). Performance in word segmentation tasks based on IDS is boosted as infants recognize words from fluent speech, even after 24 hours (e.g., Thiessen, Hill, & Saffran, 2005; Singh, Nestor, Parikh, & Yull, 2009). The same holds true for word learning tasks where infants are able to learn words from IDS better than ADS (Graf Estes, Evans, Alibali, & Saffran, 2007; Graf-Estes & Hurley, 2013; Ma et al., 2011). Furthermore, IDS has been shown to be a predictor of later language outcome measures such as vocabulary size and speed of word recognition (Fernald & Weisleder, 2011). Hence, the different findings based on infants' performances with IDS and ADS leave a picture of a facilitatory IDS that is essential for mastering the acquisition of a first language.

However, infants are directly addressed in only 15 % of the speech input that they are exposed to (van de Weijer, 1998). Furthermore, the speech input that infants are exposed to does not only consist of utterances directed at them. The majority of the speech that they hear is overheard speech (Soderstrom, 2007; van de Weijer, 2002). In addition to the IDS addressing the particular infant, 30 % of the speech in the infant's environment is overheard IDS addressing other infants, e.g., an older sibling. More than 50 % of the speech infants are exposed to is directed at adults. If infants were indeed only benefiting from exaggerated IDS input directed at them, as suggested by numerous studies, this would put severe limitations on infants' early language acquisition (e.g., Graf Estes & Hurley, 2013; Singh, Nestor, Parikh, & Yull, 2009; Thiessen, Hill, & Saffran, 2005). Not only would it be uneconomical to learn solely from IDS but studies have also demonstrated that children are able to learn from overheard speech (Akhtar, Jipson, & Callanan, 2001; Gampe, Liebal, & Tomasello, 2012). It therefore follows that infants must also be capable of extracting information from the natural language stimuli in ADS in order to learn from the majority of input provided to them. The few studies that have compared infants' learning abilities relating to IDS and ADS have only addressed the learning process from these two inputs within laboratory-based studies (Graf Estes & Hurley, 2013; Ma et al., 2011; Singh, Nestor, Parikh, & Yull, 2009; Thiessen, Hill, & Saffran, 2005). However, language learning occurs predominantly outside of the laboratory and over a period of time. Accordingly, in this thesis, the question of the impact of multiple kinds of input on infants' language acquisition is approached over the course of several projects which expose infants to both the less frequent direct IDS and the more frequent overheard ADS, not only in the laboratory home but also in their own, and explores their influence on infants' lexical segmentation and learning abilities. Note that this thesis incorporates the first attempt to explore ADS word segmentation outside of the laboratory in infants' natural environments. This new design thus leads to an increase in external validity when compared to previous laboratory studies.

The current thesis therefore adds to the ongoing debate of whether infants are only capable of learning from the small portion of IDS input that directly addresses them or whether they may also learn from the simply overheard ADS, which constitutes the majority of input that they are exposed to. Contrary to the general consensus that young infants are unable to learn from fluent ADS (Graf Estes & Hurley, 2013; Singh, Nestor, Parikh, & Yull, 2009; Thiessen, Hill, & Saffran, 2005), studies of the current thesis suggest that infants are, as a matter of fact, able to use this adult-directed register of speech from a relatively early age, underlining infants' flexibility with different kinds of speech stimuli.

1.2. WORD SEGMENTATION: FINDING WORD BOUNDARIES

A central aspect of acquiring a language is learning the words of that language. Word segmentation, that is the extraction of individual word forms from continuous utterances, is the first step in learning the inventory of words of the mother tongue. However, this task is not as simple as it appears at first glance. In addition to the enormous acoustic variability within the speech signal, speech sounds are usually uttered in a fluent, contiguous way without the direct markings of the word boundaries found in written forms (see Figure 1). Nevertheless, children manage to break up the fluent speech stream and recognize individual words.

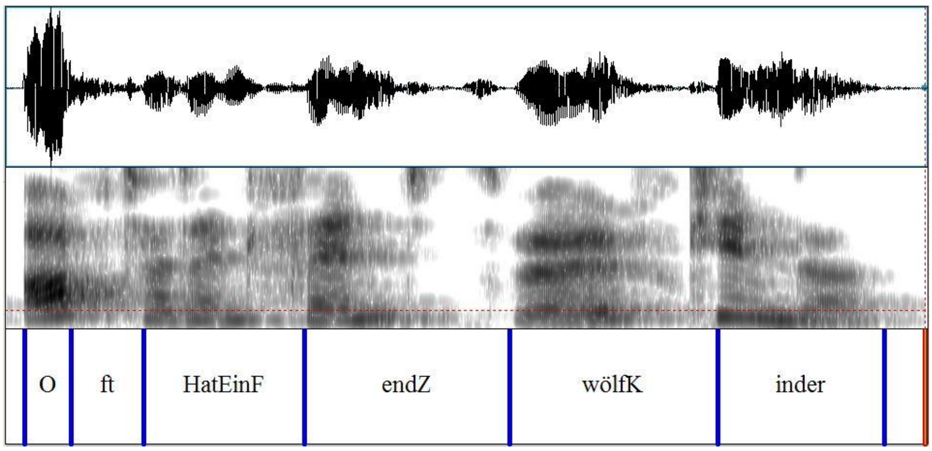


Figure 1 Spectrogram of a continuous speech stream.

The pioneer work on word segmentation was conducted more than two decades ago by Juszcyk and Aslin (1995). Using the head-turn preference procedure, which represents a standard approach in infant language research (see Figure 2)[1], 7.5-month-old American English infants were first familiarized with two lists of isolated tokens of two different words (e.g., cup and dog). In the test phase that followed, infants were then presented with the two familiarized words that they had previously been exposed to as isolated tokens, now embedded in sentences. In addition, they were presented with sentences containing two different novel control words (e.g., feet and bike) which had never been heard before. The results indicated that infants listened significantly longer to passages of sentences containing the two familiarized words than those containing the novel control words. This familiarity preference suggested that infants were able to segment the fluent speech and recognized the familiarized words again in the test phase.

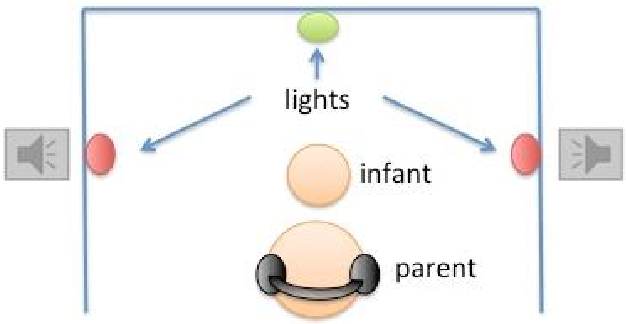


Figure 2 Classical head-turn preference procedure.

In another experiment, Jusczyk and Aslin (1995) reversed the order of the presentation of isolated tokens in the familiarization and test phase, first familiarizing infants with passages of sentences containing the two familiarized words, cup and dog. Subsequently, infants were tested on the recognition of these familiarized words

[1] The head-turn preference procedure will be further explained in more detail later in the introduction as the methods of the dissertation will be described (see 1.5.1).

using lists of isolated tokens of the familiarized words (cup and dog), and two novel control words that were not part of the familiarization passages (bike and feet). Again, infants listened significantly longer to the familiarized than to the novel control words. This might provide even more powerful evidence on 7.5-month-olds segmentation abilities as when infants segment words, they are typically not presented with the isolated word forms but rather with fluent speech.

1.2.1. Factors influencing word segmentation

As Jusczyk and Aslin (1995) were unable to replicate the findings in 6-month-old American English infants using the head-turn preference procedure without any additional cues available, it seems that infants are unable to display successful word segmentation from fluent speech before 7.5-months of age. Since then, numerous studies have investigated infant word segmentation and identified different sources of information that infants might use in segmenting words from fluent speech. These include transitional probabilities between syllables in fluent speech (Saffran, Aslin, & Newport, 1996; Lew-Williams, Pelucchi, & Saffran, 2011; Erickson, Thiesson, & Graf-Estes, 2014), word stress (Jusczyk, Houston, & Newsome, 1999), phonotactic knowledge (Brent & Cartwright, 1996; Jusczyk, Hohne, & Baumann, 1999), the position of a word within a sentence (Seidl & Johnson, 2006), and word-form familiarity (Singh, Nestor, & Bortfeld, 2008; Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Altvater-Mackensen & Mani, 2013). Importantly, in the context of different speech registers, American English infants seem to benefit from speech stimuli presented in the IDS register when segmenting words from speech. Various studies have indicated that infants successfully segment words from fluent IDS but are unable to do so if the familiarized words are presented in an ADS register (Singh, Nestor, Parikh, & Yull, 2009; Thiessen, Hill, & Saffran, 2005).

a) Language input

Studies on word segmentation across different languages however, reveal different findings with respect to the specific age at which infants show successful segmentation of words. It seems to be the case that Dutch and German infants have difficulties in segmenting words from fluent speech at a younger age. Dutch and German infants were not successful in showing a difference between familiarized and novel control words in standard segmentation tasks until 10 and 9 months of age respectively (Kuijpers, Coolen, Houston, & Cutler, 2008; Höhle & Weißenborn, 2003). However, there are also languages, such as Spanish and French, where infants have demonstrated word segmentation abilities at as young as 6-months of age (Bosch, Figueras, Teixidó, & Ramon-Casas, 2013; Nishibayashi & Nazzi, 2016).

One potential factor that may be responsible for the differences in age at which infants segment words across different languages is the properties of the input that infants are exposed to. Cross-linguistic studies of IDS and ADS have indicated that the degree to which IDS is modified differs across languages (Fernald et al., 1989; Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2001). German has been identified as one of the languages that displays less exaggeration in the prosodic features of its IDS compared to the IDS of American English. As most of the research findings on successful word segmentation have been reported with reference to American English infants, the less modified German IDS relative to American English might be a potential reason why findings of studies with American English babies have not been able to be replicated with German babies thus far. Hence, the current thesis investigates whether the failure to replicate these findings in German infants is a result of the differences in the IDS properties of each language. Testing this hypothesis, Floccia and colleagues (2016) were able to show that a more exaggerated American English IDS style positively impacted on the performance in a segmentation task in 10.5-month-old British English infants whereas they failed to segment fluent British English IDS. In order to explore the possibility of a difference in IDS style also being responsible for German infants' delay in segmenting words from fluent speech, the current thesis examined the segmentation abilities of 7.5- and 9-month-old German infants' who were exposed to exaggerated IDS similar to that of American English.

b) Duration and type of exposure

Another factor that has been identified as increasing infants' segmentation abilities is the length and the kind of exposure that infants receive (Juszyk & Hohne, 1995; Nazzi, Mersad, Sundara, Iakimova, & Polka, 2014). Tightly controlled conditions of short-term familiarization periods in laboratory-based situations only allow for limited conclusions about infants' performances outside of the laboratory. Here, infants are tested directly after the familiarization exposure, not allowing us to make generalizations about the storage of the phonological form in the mental lexicon. Contrary to this, long-term exposure in a natural setting, such as the home, may reveal insights into infants' learning and storing of words after being presented with them numerous times and recognizing them later on. This allows us to draw conclusions on infants' retention of newly segmented words in the long-term memory. Therefore, the first study of the current thesis, presented in the paper by Schreiner, Altvater-Mackensen, and Mani (2016), examines infants' word segmentation abilities outside of the laboratory. In order to also address the question of learning from different kinds input, that is the limited availability of IDS language directly addressed at the infant and the ADS language overheard from adult conversations, two groups of infants were familiarized with words in their own home: One group of infants was familiarized with a novel word in fluent IDS while a second group of infants was familiarized with a novel word in fluent ADS. Importantly, this extended research design in infants' natural environments enables generalizations of infants' early language acquisition in everyday life.

Having considered the importance of input variability and differential effects of multiple kinds of input, this thesis attempts to provide a link and an integrative picture of how this information is coordinated. Therefore, the current thesis aims to explore word segmentation from multiple kinds of speech input: IDS, ADS and exaggerated IDS. Furthermore, from a cross-linguistic perspective, it is crucial to explore why it is difficult to replicate word segmentation in German infants: Are they truly unable to segment words and what are the underlying factors contributing to this lack of evidence of German infants' early word segmentation abilities? For this reason, the current thesis employs a developmental approach examining German infants' segmentation and word learning abilities from different kinds of fluent speech across different ages. At the same time, studying infants' experience outside of the standard laboratory setting enables us to go beyond the documentation of short-term effects. It allows for conclusions on which kinds of speech input infants are capable of learning from natural everyday situations, in which infants are exposed to a large variety of input.

1.3. WORD LEARNING: ASSIGNING MEANING TO WORDS

Another important step in learning the inventory of words of the mother tongue following the segmentation of words from fluent speech, is mapping meaning to these newly extracted word forms. The ability to link a word to a particular referent seems to begin relatively early. At the age of 6 months, infants have demonstrated that they know the meaning of the words “mommy” and “daddy” as infants looked significantly longer to the named parent than to the unnamed one (Tincoff & Jusczyk, 1999). Further research supported the claim of this early referent learning: Infants at 6 months also identify the referents of common names and body parts. Notably, Bergelson and Swingley (2012) had infants' own mothers produce the target words of the body part and food category during the eye-tracking task which might have facilitated word recognition (cf., Barker & Newman, 2004).

In addition to the studies on the associations of words and their referents that have already been acquired by infants, a large amount of research has explored infants' abilities to learn new meanings of words (Schafer & Plunkett, 1998; Smith & Yu, 2008; Swingley, 2007). Accordingly, infants are also able to "fast map", meaning that they are able to associate a word and its referent after just a few exposures (Carey & Bartlett, 1978). Furthermore, infants manage to learn novel words and extend the meaning of these words to new exemplars even before the end of their first year of life (Schafer, 2005).

1.3.1. Word learning from fluent IDS and ADS

Isolated tokens are typically used in most research relating to word learning from fluent IDS and ADS, which exempts infants from managing the difficult task of isolating the target word (e.g., Schafer & Plunkett, 1998). The few studies that employ fluent speech rather than isolated tokens all tend to present the stimuli in the same exaggerated way. Although this method might facilitate learning, it may fail to represent the majority of natural language learning situations (e.g., Mani & Plunkett, 2008; Swingley, 2007).

Only a very limited number of word learning studies have addressed learning from speech registers other than IDS (Graf-Estes & Hurley, 2013; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011; Schafer & Plunkett, 1998). Using the switch task, infants at 17.5 months of age were presented with an object and its isolated label either in IDS or ADS during the training phase (Graf Estes & Hurley, 2013). In the test phase, infants watched same trials, where the object and the auditory stimulus were combined as in the training phase, and switch trials, where the object was presented with the auditory stimulus of a different word-object-association to that of the training phase. The difference in looking times between the same trials and switch trials was taken as an index of successful learning and was found only in the IDS group, but not in the ADS group. Similarly, Schafer and Plunkett (1998) investigated word learning from ADS in 15-month-old infants. Here, infants successfully learned word-object associations from this adult-directed register. However, this finding is constrained by the invariability of the input. Infants were only presented with isolated tokens and hence, were not required to demonstrate any word segmentation abilities. In addition, these isolated tokens were used in both the training and test phases, and exempted infants from generalizing across different stimuli.

The only study to date that has addressed infants' word learning from fluent IDS and ADS, suggests that infants develop the capability to learn words from adult-directed input between 21 and 27 months of age (Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011). As already mentioned, an onset of word learning from ADS at this late stage would imply severe limitations on infants' early language acquisition and conflicts with research findings on word learning from overheard speech (Akhtar, Jipson, & Callanan, 2001; Gampe, Liebal, & Tomasello, 2012).

Moreover, the common trait of all the word learning studies presented is that the register at test is always identical to the register during training. If the role of IDS is attracting and maintaining infants' attention, being tested in ADS, a register that infants typically only overhear, might not grasp infants' attention enough to respond to the task. Thus, it remains open whether the failure in learning from ADS reflects the true inability of infants to learn words from this register or whether infants are just unable to demonstrate the successful learning in this particular speech register. Studies on infants' word learning abilities from overheard speech between two adults support the latter possibility (Akhtar, Jipson, & Callanan, 2001; Gampe, Liebal, & Tomasello, 2012). Infants of 24 months have been identified as succeeding in learning from overheard ADS. However, whether infants were also tested in ADS in these studies remains questionable. Adults directly addressed the infant during life interaction which might have increased the likelihood of the use of an IDS register. Therefore, the fourth study of the current thesis, Schreiner and Mani (in revision), systematically addresses the role of speech register during both the training and test phases by exposing infants to both IDS and ADS during tests in order to additionally explore learning from ADS separately from the register in the test.

1.3.2. Pre-exposure and word learning

As words are rarely presented simultaneously and unambiguously with their respective referents (Brent & Siskind, 2001), various studies have explored how pre-exposure to the phonological form of the target word and the object affects infants' word learning abilities, with varying results. After investigating pre-exposure to solely the phonological form of a target word used later, Swingley (2007) reported that 19-month-old infants' word recognition improved if they had been pre-exposed to the target label. In investigating pre-exposure to the object, Fennell (2012) similarly found that only those 14-month-old infants who had been pre-exposed to the object were able to demonstrate successful learning. Through the manipulation of pre-exposure to both label and object, the findings of Kucker and Samuelson (2012) suggest that in order to retain previously learned word-object associations after a five-minute delay, 24-month-old infants require pre-exposure to the object and that pre-exposure to the label is not sufficient. At a younger age, 16-month-old infants require both pre-exposure to label and object in order to demonstrate successful learning of the word-object associations (Altvater-Mackensen & Mani, 2013).

Against this background, the referents of the word-object associations to be learned in the fourth study by Schreiner and Mani (in revision) reported in this thesis are presented individually first, without any label. This allows the infants to have a real-world experience with the objects and increases the infants' engagement in the task whilst simultaneously incorporating the findings on essential pre-exposure to objects for word learning.

As words are commonly not presented to infants as isolated tokens, Graf Estes, Evans, Alibali, and Saffran (2007) explored the effects that pre-exposure to words in fluent artificial ADS have on word learning. The 17-month-old infants of the study successfully differentiated between trials that represented the original word-object association and trials that represented word-object associations that infants had not been familiarized with, which is taken as an indicator of successful learning in switch paradigms. However, the word learning phase of this experiment only contained isolated tokens thus exempting infants from extracting the individual words. Hence, the fourth paper of the current dissertation by Schreiner and Mani (in revision) attempts to explore the interaction of word segmentation and word learning using the natural language stimuli of IDS and ADS in both the segmentation and the word learning tasks. While this approach allows for comparisons of infants' word segmentation and word learning skills in multiple speech registers, it also enables us to investigate the effect of pre-exposure to a label during word learning.

The current thesis therefore provides important insights into three different aspects of word learning. First, it systematically explores the relationship of infants' word segmentation and word learning skills. Second, it investigates the impact of different kinds of speech input on infants' word segmentation and word learning abilities. Third, it explores infants' flexibility in recognizing previously learned words in a register other than the one presented during training.

1.4. EARLY LANGUAGE ACQUISITION: THEORIES AND MODELS

The impact of the rich input provided by IDS has been addressed in numerous studies. However, what is the mechanism by which IDS facilitates early language acquisition? There are two main accounts on how IDS helps infants to learn a language. On the one hand, IDS is seen as a form of hyperarticulated speech that facilitates language acquisition through its exaggerated prosodic features and its simpler sentence structure. On the other hand, various proposals suggest that IDS attracts attention and maintains it, and that this consequently boosts early language acquisition.

Against this background, the current thesis employs empirical investigations in an attempt to explore the validity of these two accounts. According to the hyperarticulation account, IDS is assumed to be strongly associated with an exaggerated articulation of speech that results in clearer speech than provided by speech articulated in the adult-directed register. Evaluating word segmentation and word learning abilities from IDS and ADS will therefore help to provide evidence for or against the hyperarticulation account. In addition, the current thesis uses a measure of infants' attention, which contributes to the validation of the attention-based account of language acquisition. Most importantly, in the context of these two accounts, this thesis attempts to re-evaluate the beneficial impact of IDS in early language learning by also exploring the role of ADS.

1.4.1. IDS as hyperarticulated speech

The first account suggests that IDS as hyperspeech may increase the intelligibility of the language used to address a child (Berstein-Ratner, 1986;

Ferguson, 1977). The simple phrase structure and exaggerated prosody of IDS provide redundant cues to the structure of a language, which aids learning (e.g., Fisher & Tokura, 1996; Morgan, Meier, & Newport, 1987; Steedman, 1996; Venditti, Jun, & Beckman, 1996). Several studies have investigated the structural as well as the prosodic aspects of IDS which appear to facilitate early language learning.

Fernald (2000) argues that IDS facilitates language learning early on through contextual support, but not through the modification of phonetic properties. The use of words in isolation is one such property of IDS suggested to facilitate infants' comprehension (Aslin, Woodward, LaMendola, & Bever, 1996). Furthermore, it is proposed that comprehension benefits from repetitions of utterances (Fernald & Morikawa, 1993). That is, if infants are exposed to exact repetitions, these further exposures allow them to have another attempt in extracting the words from fluent speech. On the structural level, the repetition of simple sentence structures is found to facilitate infants' word recognition (Fernald & Cummings, 2003; Fernald & McRoberts, 1996). Here, the repetitions of sentence structures provide infants with contextual information about characteristic patterns of speech that aid even infants with minimal language experience, for example, in recognizing novel words within carrier phrases (e.g., "Where is the toma?"). In line with this, segmentation and word learning seem to be improved if target words are utterance-final (Aslin, 1999; Fernald & Mazzie, 1991; Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998). An explanation for this could be the longer pauses that are typically used at the boundaries of ID utterances and hence, perhaps aid in the facilitation of the detection of word boundaries.

On the prosodic level, it is assumed that the articulation of consonants and vowels is enhanced in IDS (Burnham, Kitamura, & Vollmer-Conna, 2002; Kuhl et al., 1997). When talking to their infant, mothers seem to exaggerate their articulation of speech which results in clearer and more intelligible utterances (Bradlow, Toretta, & Pisoni, 1996). Kuhl and colleagues (1997) suggested that adults lengthen vowels in IDS in order to enhance phonological contrast. Furthermore, the clarity of the speech mothers use with their infants also impacts on their ability to discriminate speech (Liu, Kuhl, & Tsao, 2003), that is, the larger the vowel space area produced by the mother when talking to her child, the better the infant was able to discriminate between different speech sounds. This view of IDS as clearer speech has however been called into question recently: The enhancement of linguistic contrast may be an unintentional side effect of IDS characteristics (Gendrot & Adda-Decker, 2007) or it may be created by positive emotions (Singh, Morgan, & Best, 2002; Tamis-LeMonda, Kuchirko, & Song, 2014; Schaeffler, Kempe, & Biersack, 2006). For instance, when affect was held constant, 6-month-old infants had no preference of IDS over ADS. However, if ADS was presented to the babies with a more positive affect than the IDS, infants preferred to listen to the ADS passages. This suggests that, on the one hand, one sufficient feature of IDS is that it needs to be happy talk, and that on the other hand, infants may attend to ADS provided it conveys positive emotions. Interestingly, the enhancement of vowels is replicated in all languages (Dodane & Al-Tamimi, 2007; Eglund & Behne, 2006; Green, Nipp, Wilson, Mefferd, & Yunusova, 2010; van de Weijer, 2001). The finding that mothers enhance consonantal contrasts for older but not for younger infants also questions the consistency of the proposed hypothesis (Cristia, 2010) as the preference of IDS vanishes over time and general attention to this exaggerated register might similarly decrease, making IDS less crucial for the acquisition of the mother tongue.

Martin and colleagues (2015) also challenged the hyperarticulation hypothesis as they found that the discriminability of phonetic contrasts was more difficult in spontaneous IDS than in ADS in the large corpus used. This suggests that, surprisingly, the speech of mothers tends to be clearer if they address other adults than if they address their own child. If ADS recordings of mothers are clearer than IDS recordings by the same mother, the function of an enhancement in articulation in IDS cannot be attributed to more intelligible utterances.

The argument that it is the positive emotion provided through IDS which leads to the enhancement of speech sounds has also been investigated by Benders (2013). Here, the analysis of mothers' speech directed at their 11- to 15-month-old infants indicated that their realizations of speech sounds reflected positive affect. This line of argumentation is also supported by the fact that higher pitch is reinforced through positive infant feedback (Smith & Trainor, 2008). On the contrary, the IDS of depressed mothers does not influence infants' performance in cognitive tasks which might be due to the lack of positive affect (Kaplan, Bachorowski, Smoski, & Hudenko, 2002). Furthermore, infants' individual performances have been shown to correlate with their caregivers' emotional availabilities (Kaplan, Burgess, Sliter, & Moreno, 2009). Accordingly, the exaggerated speech input used to address infants may just be a by-product of speaking to infants in an emotionally charged manner (Trainor, Austin, & Desjardins, 2000).

In summary, the findings of a clearer ADS than IDS by Martin and colleagues (2015) suggest that the mechanism behind IDS is not one of providing infants with more intelligible speech. In addition, in order for infants to pay attention to IDS, positive emotion appears to be an essential feature. In conclusion, the hyperarticulation account might not be as important and valid as originally proposed. Rather, according to the results on infants' preferences of IDS with positive effect, it might be that the function of hyperarticulating speech sounds is to increase infants' attention to the relevant linguistic stimuli which will be addressed in more detail in the following section.

1.4.2. IDS as promoter of attention

The account of IDS that has promised to be more credible is that of IDS functioning as a promotor of attention. It is suggested that the specific prosodic patterns used by the caregiver function to attract and maintain infants' attention to language (Stern, Spieker, & MacKain, 1982) and may even speed up infants' learning (e.g., Rose, Feldman, & Jankowski, 2003). This is supported by studies measuring a boost in infants' arousal if they were presented with natural IDS stimuli (Kaplan, Jung, Ryther, & Zarlengo-Strouse, 1996) and larger differences in attention between IDS and silent trials than between ADS and silent trials (Kaplan, Goldstein, Huckeby, & Cooper, 1995). Accordingly, these studies suggest that IDS attracts infants' attention to a larger extend than ADS does, which may also explain the large number of research findings on infants' preference of IDS over ADS (Cooper & Aslin, 1990; Werker & McLeod, 1989; Werker, Pegg, & McLeod, 1994).

The *Native Language Magnet-Expanded* model (hereafter, NLM-e), proposed by Kuhl and colleagues (2008), is a model on infants' early speech perception. Specifically, the model tries to address the developmental change in infants from universal listeners to language-specific listeners. That is, at about 11-months of age, infants lose the ability to discriminate the sounds of all the different languages of the world, leaving them able to perceive the sounds of their native language only. In the proposed model of phonetic learning, Kuhl and colleagues (2008) suggest that the distributional frequencies of infants' native language and the exaggerated cues in IDS drive this developmental change. The idea of neural commitment is another important part of the model: Through early language exposure, the neural tissue of the infant brain changes according to the patterns of the native language input provided to them, whereas the sensitivity to alternative non-native phonetic patterns disappears. Furthermore, the model incorporates social interaction as facilitating phonetic learning by increasing infants' attention and arousal. A last feature of the model relates to the link of perception and production which it proposes is shaped by infants' development. Based on their perceptual experience with their native language, infants are first able to learn the phonetic patterns of their mother tongue, which also drive the development of their motor skills. Infants compare their own vocalizations to the movements of their articulatory apparatus, mapping the produced sounds onto sounds stored in their memory.

The social-gating model, originally coined by Kuhl (2007), is an advancement of the hypothesis that social interaction is necessary in order for infants to acquire language-specific knowledge. The first mechanism behind social interaction is motivation. Infants' attention and arousal to speech is identified as a factor impacting learning, and suggests that the preference of IDS over ADS (Fernald, 1985; Fernald & Kuhl, 1987) ensures that infants are attracted to IDS in order to learn. Moreover, it supports the idea of hyperarticulation of speech contrasts as facilitating greater learning, thus supporting the idea of IDS as a major contributor to early language acquisition. A second mechanism behind social interaction is information: Natural settings may provide the infant with information that facilitates language learning. Social agents provide referential information and communicative intent. Referential information in the form of an eye gaze and pointing may help infants in segmenting words from fluent speech whereas the perception of the communicative intentions of others may help in understanding reference.

Csibra's (2010) theoretical account of infants' development of comprehension of communicational intent is based on three related proposals. One, communicative intentions may be recognized even before they have been accessed. Two, the recognition of such commutative intentions may be steered by ostensive signals, that is: A specific signal designed for the interpreter, that the communicator wants to convey a communicative intention to them. And three, even infants expect infant-directed ostensive signals that help them in recognizing communicative intentions. By definition, ostensive signals to infants must unambiguously refer to the infant as the addressee, must be detectable by newborns, and must attract an orientation towards its source. According to this definition, Csibra (2010) proposes eye contact, IDS, and contingent responsiveness as ostensive signals indicating the communicative intentions of the communicator. Csibra's claim that the immediate function of IDS is to inform the infant that they are being addressed is of special interest to the current thesis. The use of IDS as an ostensive cue by infants has been supported by empirical findings in six-month-olds who follow the gaze of an adult conversational partner to an object if a preceding attention-getting phase included IDS but not ADS (Senju & Csibra, 2008). Hence, infants' gaze-following behavior is facilitated by IDS but not ADS, which supports the idea of IDS attracting infants' attention and hence enhancing the communication of referential acts. The facilitation of early language acquisition may just be a side effect of infants' preferential attention to the IDS source.

Models of curiosity-driven learning suggest that infants have an intrinsic desire to reduce uncertainty. In order to satisfy this intrinsic desire, curiosity might drive infants' attention in early language learning. In these models, IDS is proposed to modulate infants' attention and is therefore also called attention-driven learning (Dominey & Dodane, 2004; Gottlieb, Oudeyer, Lopes, & Baranes, 2013; Oudeyer & Smith, 2016). Importantly, these models in no way want to propose that a native language is only acquired via IDS (note that there are languages that do not contain a special speech register that is used to address infants, e.g., Samoan and Quichee Mayan, Pye, 1986). On the contrary, all language, even ADS, may be exploited by the child. In using IDS, the significant aspects of the speech signal that are already present in ADS are exaggerated and the accessibility to these important aspects is increased. Hence, learning may be driven by extrinsic factors, such as IDS, which increase infants' attention to the relevant aspects of speech. But in order to satisfy the intrinsic desire to reduce uncertainty, curiosity might also drive infants' attention to ADS and stimulate learning from ADS. Thus, infants are active participants in language learning and seek the experiences that provide useful information (Oudeyer & Smith, 2016). Additionally, the vocalizations of 9-month-old infants become more mature if mothers provide continuous feedback on their infants' babbling but not if it is provided with a delay (Goldstein & Schwade, 2008). Hence, caregiver responsiveness – a behavior associated with IDS – may act as a method of reinforcement, serving as an extrinsic factor in language learning (Gottlieb, Oudeyer, Lopes, & Baranes, 2013), and might therefore also play a role in fostering infants' language development (Bornstein, Tamis-LeMonda, & Haynes, 1999; Weisleder & Fernald, 2013). It appears that both infants' active participation (intrinsic motivation) as well as parents' responsiveness to their infants' participation (extrinsic motivation) play an important role in the process of language acquisition.

Another model that might consider different kinds of input for language learning is the emergentist coalition model by Hollich, Hirsh-Pasek, and Golinkoff (2000). It takes on a developmental account of early language acquisition, specifically word learning, and is based on three different hypotheses. First, it is suggested that infants use multiple sources of information, attention, social, and linguistic cues when learning new words (see Figure 3). However, the second hypothesis assumes that these cues are weighted differently and that the weighting of the cues changes over the course of time. Thirdly, the model proposes that learning is emergent, with infants moving from an immature to a mature state. That is, younger infants in an immature state may rely heavily on attentional cues which include the temporal synchrony of objects and language, i.e., temporal contiguity, as well as the novelty of objects, i.e. perceptual salience, both of which are suggested to attract infants' attention (phase I, Figure 3). It is noteworthy that during this phase, infants can be exposed to both IDS and ADS and, provided attentional cues are available, they may exploit either register for language learning. As they move towards a mature state, social and linguistic cues become accessible to the infant for the process of word learning (phase II, Figure 3). Importantly, the model includes prosody as a linguistic cue, suggesting that the exaggerated intonation of IDS attracts infants' attention. Hence, IDS prosody might be weighted more heavily at some point in language development. However, as other cues become accessible, children may use eye gaze, pointing and social intentions of the speaker thus making learning from the more monotone register of ADS possible. A similar prognosis can be made for grammatical information which might have a higher density in ADS due to its complex nature and, hence, provide important cues for language learning.

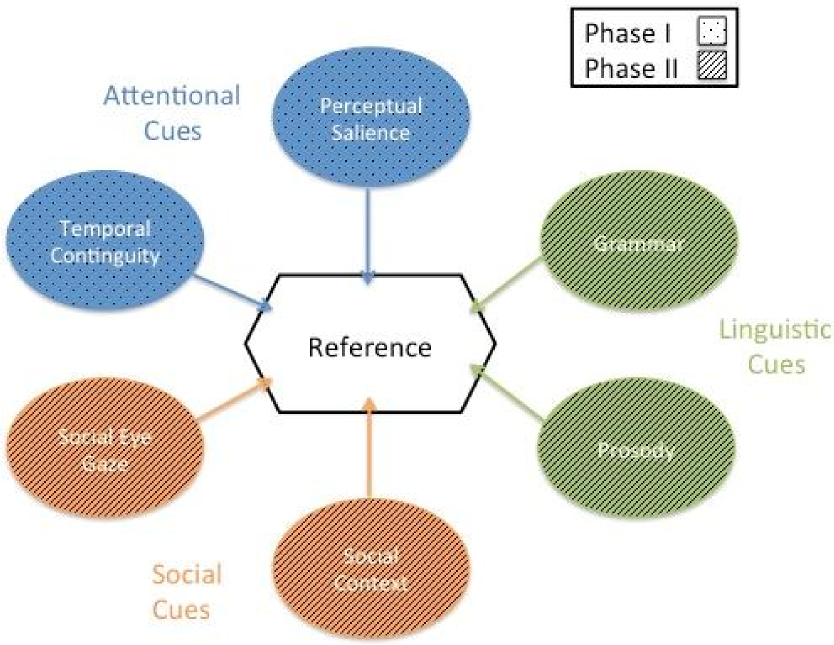


Figure 3 The coalition model (adapted from Hirsh-Pasek, Golinkoff, & Hollich, 2000).

1.4.3. Limitations of the models of early language acquisition

Whereas the NLM-e might underestimate the role of different kinds of input and fails to provide room for overheard speech that does not necessarily involve social interaction between the speaker and the language learner, the emergentist coalition model grants the use of multiple kinds of input which may change over time. Importantly, it also allows for the combination of different cues when learning words. Hence, at first the immature language learner might rely heavily on attentional and linguistic cues that include the wide, exaggerated prosody of IDS. However, as language learners become more mature, they might also master learning from the monotone overheard register of ADS which makes more cues available. Having reviewed the different models on early language acquisition and word learning, it seems that they all favor the exaggerated IDS register which suggests that it significantly impacts on early language acquisition. However, if infants were ultimately able to learn from IDS only, this may have a long-lasting effect on infants' abilities to become masters of their native language. Nonetheless, as already outlined above, the majority of the input infants receive is provided by the monotone and less engaging register of ADS. In order to become a proficient speaker of a language, infants must start to learn from the variety of input provided to them at some point. The possibility of successful learning from ADS is not directly addressed in any of the models reviewed but may be accounted for by the emergentist coalition model and by curiosity-driven learning. The emergentist coalition model suggests an early reliance on IDS through attentional cues but the more mature the infant becomes, the more cues become available and thus may allow for the use of multiple kinds of available input. Similarly, curiosity-driven learning may encompass an early IDS benefit as infants are extrinsically motivated by the exaggerated cues that attract their attention. However, with increasing intrinsic motivation, infants may also explore ADS to actively participate in learning.

Against this background, the current thesis examines the developmental trajectory of infants' learning from IDS and ADS and the factors which drive learning in both registers. Thereby, the thesis will be able to evaluate the accuracy of the current models of early language acquisition and make suggestions for improvement.

1.5. METHODS OF THE DISSERTATION

In order to investigate infants' abilities to segment and learn words from IDS and ADS input, this dissertation utilizes three different methods: Preferential-listening, EEG, and eye-tracking. In the following section, each of these methods will be described in detail.

1.5.1. Preferential-listening

A modified version of the head-turn preference procedure has been employed in several studies in this thesis (Kemler Nelson, Jusczyk, Mandel, Myers, Turk, & Gerken, 1995). The traditional procedure uses a three-sided testing booth and is used to investigate both infants' phoneme discrimination and word segmentation abilities, as well as their speech preferences. A trial is started by the experimenter initiating a green flashing light in front of the infant. When the infant orientates herself towards this light, the experimenter initiates one of the two red lights located at each side of the booth. If again the infant orientates herself towards this flashing light with a minimum of a 30-degree head turn, the experimenter starts the presentation of the auditory stimulus. The experimenter continues to play the auditory stimulus until the infant looks away for more than 2 s.

Instead of using three sides, the modified preferential-listening paradigm employed in our laboratory uses one panel of the testing booth - a central panel with a screen. This screen was used to present the visual stimulus of a blinking checkerboard. The experimenter initiated a trial whenever the infant orientated herself towards the screen presenting the blinking checkerboard accompanied by the auditory stimulus. As long as the infant fixated this checkerboard, the experimenter coded the infants' fixation with a corresponding button on the keyboard. If the infant looked away from the screen for more than 2 s, the presentation of the auditory stimulus was ended. There are commonly two different types of phases used in preferential listening tasks: A familiarization and a test phase. The word segmentation studies in this current thesis had a familiarization phase with two different passages of sentences containing one of two pseudowords. There were two triggers that terminated the familiarization phase. The familiarization phase ended either when the child had listened to a 100 s of familiarization passages or when all 12 trials of the two different passages had been played. The familiarization phase was followed by the test phase where infants listened to isolated tokens of the two pseudowords which had been embedded in the sentences of the familiarization phase, hereafter referred to as familiarized words, and to isolated tokens of two novel pseudowords which had not been previously presented to the infants in the familiarization phase, hereafter referred to as control words. The test phase consisted of three blocks of four different trials with the four different pseudowords - two familiarized and two control words. To quantify infants' behavior in the test phase, we computed mean listening times in the test phase for the familiarized and the control words. A difference in average listening time between the familiarized and the control words indicated successful segmentation of the familiarized words. According to segmentation literature, the difference in listening time may either be a preference for the familiarized word, commonly termed the familiarity effect, or a preference for the novel word, commonly termed the novelty effect. A familiarity effect tends to be observed in younger infants (e.g., Jusczyk & Aslin, 1995), whereas a novelty effect tends to be more dominant in older infants as well as in segmentation tasks that involve a familiarity with words (e.g., Seidl & Johnson, 2008).

One advantage of the modified preferential-listening paradigm is that infants are not required to initiate a head movement. This might be beneficial, especially in younger infants who may still have difficulties moving their heads. While we cannot completely rule out the possibility of these methodological differences influencing the obtained results, our paradigm has provided successful evidence of speech segmentation in infants across a range of age-groups (e.g., 7-month-olds: Altvater-Mackensen & Mani, 2013; 16-month-olds: Mani & Pätzold, 2016). However, it is important to note that the presentation of stimuli is always dependent on the behavior of the infant in this paradigm. Hence, the absence of a difference in listening times within a preferential listening paradigm might not infer an inability to segment words from fluent speech but instead may indicate that infants are not engaged in the task.

1.5.2. EEG and ERPs

Electroencephalography (EEG) and event-related potentials (ERPs) have become well-established methods to investigate the relationship between brain maturation and the development of infants' cognitive abilities. The noninvasive technology of the EEG and ERP methods provides a valuable tool to examine the relationship between the brain and infants' behavior from birth onwards. EEG and ERPs both measure the electrical activity of the brain. Whereas the EEG measures the ongoing electrical activity of the brain, ERPs reveal the potential changes in this electrical activity in response to different kinds of stimuli or events.

There are different systems available for the use of EEG/ERP data collection. The system used in our laboratory (BIOSEMI) uses an electrode cap of stretchable material with sewn-in plastic rings that hold the electrodes. After the cap is placed on the infants' head and secured by a chin strap (see Figure 4), an electrode gel is inserted into each ring on the cap with a syringe. This gel conducts the electrical signal from the skull of the infant to the electrode. In addition, two reference-electrodes are located at the mastoids bone to record the background signal, which is assumed to reflect noise and not neural activity. This background signal is later subtracted offline from all other electrodes. Another additional electrode is placed underneath the left eye of the infant to record blinks and eye movements. The whole preparation procedure of capping takes about 20 min.

After data-collection over multiple trials, intensive offline processing of the data is required. First, the data is filtered using a band-pass filter (usually 0.01-30 Hz) and resampled from the original 2048 Hz to 250 Hz. The continuous signal is then split into individual epochs from 200 ms before stimulus onset to 800 ms after stimulus onset. A correction of the waveforms is performed relative to the 200 ms baseline period before the stimulus onset. Afterwards, trials with artifacts, for instance blinks and eye movements recorded with the left eye electrode, are rejected. Following this, trials of the same condition are averaged. In infancy research, it has become common practice to only include subjects into the final analysis that contribute a minimum of 10 artifact-free trials for each condition. The average waveforms of each subject are then averaged for each condition into the grand average. The ERPs of the different conditions are then compared for differences in their waveform. The positive and negative peaks, also referred to as components, are labeled according to their polarity (e.g., N for negative, P for positive) and latency (e.g., N400 for a negative peak around 400 ms after the stimulus onset).

Typically, infants' word segmentation abilities have been observed as starting at about 200 ms after the word onset with a more negative ERP response for the familiarized than for the novel control word (Junge, Kooijman, Hagoort, & Cutler

(Goyet, de Schonen, & Nazzi, 2010; Männel & Friederici, 2010). The distribution of ERP effects in word segmentation studies have predominantly been over the frontal electrodes but less-pronounced effects have also been identified in the posterior electrodes.

Figure 4 Infant capped for an ERP-study.

The collection of infant EEG data however is not simple as it tends to be prone to artifacts, especially, if infants become tired or move during recordings. Hence, it requires patience and cooperation on the part of the participant, failing which the data becomes unusable because of fussiness or movement artifacts.

On the other hand, the advantages of the ERPs are that they do not require an overt response. Furthermore, infants do not need to have a preference of one stimulus over another. In addition, the high temporal resolution of ERPs provides an extremely precise online-measure of speech processing.

1.5.3. Eye-tracking

Finally, the current dissertation investigates word learning by tracking corneal reflections using an automated eye-tracker. Through an infrared light directed at the infant's eye, the corneal reflections, that is the reflections of the light on the cornea of the eye relative to the pupil center, give an estimate of where the gaze of an infant is fixating. This enables us to track whether the infant looks at an area of interest that is a named object in every 8 ms frame. On this basis, proportional target looking (PTL) is computed by dividing the time that infants looked at the named object, hereafter called target, by the overall time infants looked at the target and another unnamed object, hereafter called distractor. PTLs of the time window in the pre-naming phase before an object is labeled are compared to the PTLs of the time window in the post-naming phase after an object has been labeled. An increased PTL for the post-naming phase is an indicator of the successful recognition of the target object.

1.6. OUTLINE OF THE DISSERTATION

The following four chapters include the four papers which the current dissertation is based on. The first paper (Schreiner, Altvater-Mackensen, & Mani, 2016) explores the effects of extended word-familiarization periods at home on infants' word segmentation abilities from IDS and ADS (Chapter 2). The second paper by Schreiner and Mani (2017) explores German-learning infants' segmentation of exaggerated IDS in 7.5- and 9-month-olds using behavioral measures (Chapter 3). Following the failure to find successful segmentation abilities in 7.5-month-old infants, the third paper by Schreiner, Hildenbrand, and Mani (in prep) explores 7.5-month-olds' word segmentation abilities of exaggerated and typical German IDS through neurophysiological measures (Chapter 4). Finally, the fourth paper by Schreiner and Mani (in revision) investigates infants' word learning abilities from IDS and ADS (Chapter 5). Chapter 6 of this dissertation will summarize the conducted studies of this thesis and describe the results obtained. Chapter 7 will provide a general discussion of the main findings and the implications of these findings on the understanding of early language acquisition, taking multiple kinds of input into consideration. Furthermore, it identifies further possible directions for future research.

Chapter 8, the last chapter of this dissertation, will offer some concluding remarks.

CHAPTER 2: EXTENDED-EXPOSURE AT HOME – LIMITED EFFECTS OF SPEECH REGISTER

2.1. ABSTRACT

We examined 7.5-month-old infants' ability to segment words from infant- and adult-directed speech (IDS and ADS). In particular, we extended the standard design of most segmentation studies by including a phase where infants were repeatedly exposed to target word recordings at their own home (extended-exposure) in addition to a laboratory-based familiarization. This enabled us to examine infants' segmentation of words from speech input in their naturalistic environment, extending current findings to learning outside the laboratory. Results of a modified preferential-listening task show that infants listened longer to isolated tokens of familiarized words from home relative to novel control words regardless of register. However, infants showed no recognition of words exposed to during purely laboratory-based familiarization. This indicates that infants succeed in retaining words in long-term memory following extended-exposure and recognizing them later on with considerable flexibility. In addition, infants segmented words from both IDS and ADS, suggesting limited effects of speech register on learning from extended-exposure in naturalistic environments. Moreover, there was a significant correlation between segmentation success and infants' attention to ADS, but not to IDS, during the extended-exposure phase. This finding speaks to current language acquisition models assuming that infants' individual attention to language stimuli drives successful learning.

2.2. INTRODUCTION

One of the many challenges facing the young language learner is the task of acquiring an inventory of words in their native language. However, this task is not as simple and straightforward as it might seem since infants are rarely presented with words in isolation (Woodward & Aslin, 1990; Johnson, Lahey, Ernestus, & Cutler, 2013). Instead, infants are presented with a stream of acoustic input without knowing what the individual words in their language are and without explicit information about where the boundaries between words occur in this continuous stream (Cole & Jakimik, 1980). Understanding the factors that influence infants' development of the ability to segment words from fluent speech has, therefore, been a central focus of the literature on infant language acquisition.

The aim of the current study was to further examine these factors. In particular, we compare the extent to which infants are able to extract and store words in long-term memory through repeated exposure to words in a naturalistic setting at home versus a brief laboratory-based familiarization. Furthermore, we compare infants' ability to segment words from speech presented in two different registers, the infant- and the adult-directed speech register, in both naturalistic and laboratory settings, given that previous research reports differences in infants' ability to segment words from infant- and adult-directed speech (Thiessen, Hill, & Saffran, 2005; Singh, Nestor, Parikh, & Yull, 2009).

2.2.1. Infants' segmentation of words from fluent speech

Two decades ago, Jusczyk and Aslin (1995) investigated American infants' ability to detect words in a continuous fluent speech stream. Familiarizing 7.5-month-old infants with isolated tokens of words and testing them on their recognition of these words in passages, they found that infants listened significantly longer to passages containing the previously familiarized words compared to passages containing novel control words. This pattern was also observed when infants were familiarized with passages containing target words and tested on isolated tokens of either the familiarized target words or novel control words, thereby providing stronger evidence for the finding that infants can detect words and word boundaries in fluent speech.

The fact that younger infants at 6 months of age did not show such a preference was initially taken to suggest that the ability to detect words in fluent speech develops around 7.5-months of age. However, more recent studies report segmentation success in different contexts at younger ages as well (Johnson, Seidl & Tyler, 2014; Altvater-Mackensen & Mani, 2013; Shukla, White & Aslin, 2011; Thiessen & Erickson, 2013), suggesting that the context in which segmentation abilities are tested is critical to segmentation success.

One factor, in particular, that has been shown to impact infants' segmentation skills and retention of words is the kind of exposure to words that infants receive. Most segmentation studies to-date have focused on exposing infants to isolated tokens or short streams of continuous speech in a laboratory-based situation and then immediately examining their recognition of the previously presented words. While such studies are critical to examining the kinds of cues that infants use to segment words from fluent speech, it is difficult to evaluate the extent to which these findings allow conclusions regarding infant learning from more naturalistic environments and their retention of words heard over extended periods of time in such environments.

Studies examining infants' learning in more naturalistic environments and/or their later retention of learned words provide more information on this issue: Jusczyk and Hohne (1997) familiarized 8-month-old infants with words embedded in stories across an extended two-week period and tested their retention and recognition of these words after a further two weeks had passed. They found that infants listened significantly longer to the isolated tokens of the previously familiarized words relative to novel control words, suggesting that extended-exposure to words at home aids in the retention of lexical tokens in long-term memory. Furthermore, Mandel, Jusczyk, and Pisoni (1995) report that even 4.5-month-olds are able to detect their own names in fluent speech, while Bortfeld and colleagues (2005) find that 6-month-olds can use their knowledge of a limited set of words, e.g., their own names, to segment adjacent words from the speech stream. These findings suggest that even very young infants are learning from speech presented in their naturalistic environment and are able to retain words acquired through such exposure and use these early words to help them segment other words from the speech stream (see also Altvater-Mackensen & Mani, 2013 for similar findings) .

However, as suggested in the Jusczyk and Hohne (1997) study, such findings might be restricted to circumstances where infants are sat down in a chair and made to listen to pre-recorded stories while a research assistant engaged the infants by flipping through a picture book related to the stories. While story-telling sessions have repeatedly been shown to improve infants' learning of words (e.g., Horst, Parsons, & Bryan, 2011), they constitute only a small portion of the caregiver-child interactions. The findings by Jusczyk and Hohne (1997) do not, therefore, inform us with regard to infants' learning from overheard speech without additional contextual support (i.e., a storybook).

Against this background, the current study examined the extent to which infants are able to detect words in fluent speech through repeated-exposure to stories containing these words in their everyday environment at home. In particular, we compare infants' segmentation of words from fluent speech across different learning contexts, i.e., repeated exposure to the stories at home versus a brief laboratory familiarization phase (to examine the additional benefit of extended exposure in a naturalistic setting on infant segmentation.

We further extended the findings of Jusczyk and Hohne (1997) in one important respect, namely, by manipulating the kind of speech presented to infants in the different learning contexts. Infants are exposed to different kinds of speech in their naturalistic environment. On the one hand, infants in many cultures are addressed in an exaggerated register, typically referred to as infant-directed speech or motherese (see Soderstrom, 2007 for a complete review). On the other hand, infants are also exposed to communication between other members of their household, e.g., either to speech between two experienced users of their native language, typically referred to as adult-directed speech, or speech between their caregivers and other siblings. While Jusczyk and Hohne (1997) examine infant segmentation of infant-directed speech stimuli, the current study explores infant segmentation of words from speech in naturalistic and laboratory settings in two different speech registers, namely, infant- and adult-directed speech. This allows us to examine the extent to which infants are able to learn from the variety of input available to them in their naturalistic home environments.

2.2.2. Infants' processing of infant- and adult-directed speech

The acoustic characteristics of infant-directed speech (henceforth referred to as IDS) differ from the kind of speech that adults typically use when speaking to one another, i.e., adult-directed speech (henceforth, ADS; Ferguson, 1964; Grieser & Kuhl, 1988). Some of the main differences between IDS and ADS lie in their prosodic characteristics : speech addressed to infants is slower, higher in pitch, with longer pauses between words, and with greater variation in pitch within utterances and enhancement in the articulation of the vowels and consonants (e.g., Kuhl et al., 1997;

Bernstein Ratner & Luberoff, 1984; McRoberts & Best, 1997; Papousek, Papousek, & Symmes, 1991; van de Weijer, 2002; Fernald et al., 1989; see Soderstrom, 2007 for a comprehensive review; but see Martin et al., 2015; Benders, 2013 who call the hyperarticulation hypothesis, i.e., the enrichment of input through hyperarticulation of phonemes, into question).

Studies show that, from a very early age, infants attend preferentially to IDS relative to ADS, with important implications for language learning success from speech presented in the infant- as opposed to the adult-directed register. For instance, even two-day-old infants prefer to listen to IDS relative to ADS (Cooper & Aslin, 1990) while electrophysiological studies find differences in the brain activity to IDS and ADS in 6- and 13-month-old infants (Zangl & Mills, 2007). Furthermore, it has been shown that IDS facilitates infants' detection of words from fluent speech (Thiessen, Hill, & Saffran, 2005) and that even after 24 hours, infants are able to recognize previously familiarized words if they were familiarized with these words in IDS (Singh, Nestor, Parikh, & Yull, 2009), but not if they were familiarized with these words in ADS. Infants also show improved learning of word-object associations when the words are presented in IDS relative to ADS (Song, Demuth, & Morgan, 2010; Graf-Estes & Hurley, 2013; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011).

On the one hand, the linguistic and acoustic properties of IDS may foster learning given that repetitive structures like those found in IDS facilitate infant word recognition (Fernald & Cummings, 2003) and given that the simplified phrasal structure, exaggerated prosodic markings and consistencies found in IDS may facilitate vocabulary growth (Fisher & Tokura, 1996; Weisleder & Fernald, 2013; Vosoughi, Roy, Frank, & Roy, 2010) and are a predictor for later vocabulary size (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2013). Alternatively, it is also possible that the facilitatory effect of IDS may lie in its focusing infants' attention on language (e.g., Rose, Feldman, & Jankowski, 2003), thus speeding learning from speech presented in this register. While we cannot, at this point, draw strong conclusions as to the reasons why IDS may preferentially foster learning, it remains to be seen whether there is a similar facilitatory effect of IDS in learning from speech input presented in naturalistic environments, as has been suggested in laboratory-based studies.

So the current study compares German infants' detection of words from fluent speech presented in both the infant and adult-directed register. In particular, infants were exposed to words embedded in stories in a naturalistic setting at home, presented in either IDS or ADS. Parents were asked to play the stories to their infants but not otherwise draw their attention to the stories or give additional contextual support for the stories, e.g.,such as a picture-book as in Jusczyk and Hohne (1997). Following six weeks of familiarization, infants were invited to the lab, where we tested their recognition of words they had heard before in the stories at home (hereafter, extended-exposure at home condition), words they heard for the first time in sentences in a laboratory familiarization phase (hereafter, lab-familiarization condition) – similar to standard segmentation studies – and control words they had never heard before. This enables us to study infant word segmentation outside of the standard laboratory setting in their everyday environment allowing for generalizations on early language acquisition in real life. Based on the findings reviewed above, we predict that infants ought to show improved recognition of words embedded in stories in IDS relative to ADS, regardless of whether they were familiarized with the words at home or in the laboratory alone. Furthermore, we suggest that infants may show improved learning and retention of words they were also exposed to in a naturalistic home environment relative to words they heard only in the laboratory-based setting, thereby examining how experiences outside the laboratory may shape the path of language learning.

2.3. METHOD

The study consisted of three different phases: an extended-exposure phase at home, a lab-familiarization phase and a test phase (see Table 1).

Table 1 Overview of study phases and characteristics of words presented in each phase.

Phase	***Words***	***Speech Register***	***Speaker***
Extended-exposure at home	1 word embedded in 6 stories	ADS or IDS (between-subject)	Speaker A
Lab-familiarization	Word from extended exposure phase and 1 additional novel word embedded in passages	moderate IDS	Speaker B
Test	Word from extended exposure phase, laboratory familiarization phase and 2 novel control words presented in isolation	moderate IDS	Speaker B

2.3.1. Participants

48 monolingual German infants at the age of 7.5 months were recruited for the study. Half of the infants were familiarized with the stimuli in infant-directed speech (IDS condition) while the other half of the infants were familiarized with the same stimuli in adult-directed speech (ADS condition). At the start of the extended home familiarization period, infants ranged in age from 7 months 3 days to 7 months 26 days (mean age 231 days) for the IDS condition and 7 months 3 days to 7 months 25 days (mean age 232 days) for the ADS condition. Infants were then invited to the lab for testing when they were aged between 8 months 20 days to 9 months 15 days (mean age 275 days) in the IDS condition and from 8 months 22 days to 9 months 16 days (mean age 276 days) in the ADS condition. For each condition, exactly half of

the children were boys and half were girls. An additional three children had to be excluded from the study (not completing the test phase, n=1; no data saved, n=1; fussiness, n=1).

2.3.2. Material

Six different short narratives from the Brothers Grimm were used for the study (see APPENDIX A). The protagonist of each of the narratives was replaced by a monosyllabic pseudo-word, i.e., Fend (fɛnt), Mieck (mi:k), Nohl (no:l), and Kulb (kʊlp). We created eight versions of each story such that two versions of each story contained the same protagonist. Thus, the story "Der Fend und das Pferd" was recorded twice with Fend as the main protagonist (once in typical German IDS, and once in ADS), and similarly for each of the other three protagonists.

Acoustic analysis ensured the validity of the stimuli for German infants. Independent samples t-test revealed that there were significant differences between ADS and IDS with respect to mean pitch (ADS, M=180.84 Hz; IDS, M=230.65 Hz, $t(484)=-32.80$, $p<0.001$), maximum pitch (ADS, M=227.71 Hz; IDS, M=348.15 Hz, $t(484)=-37.41$, $p<0.001$), pitch range (ADS, M=13.24 Hz; IDS, M=19.73 Hz, $t(484)=-13.94$, $p<0.001$), and duration (ADS, M=4.70 s; IDS, M=8.30 s, $t(484)=-11.96$, $p<0.001$). There was a near-significant difference for minimum pitch (ADS, M=111.97 Hz; IDS, M=116.98 Hz, $t(484)=-1.83$, $p=0.068$). The acoustic characteristics of the stimuli were similar to typical infant- and adult-directed German speech (Fernald et al., 1989).

In addition, we created four different passages with six different grammatically and syntactically correct sentences for the lab-familiarization. As in Jusczyk and Aslin (1995), we ensured that the target word occurred systematically in different positions in the sentence: each novel monosyllabic word occurred twice in the beginning, twice in the middle and twice towards the end of the sentences of its passage. The number of words in each sentence was identical across the four different passages. The passages presented to infants in the lab- familiarization were recorded by a different speaker to the one who recorded the stories presented to infants at home. This ensured a) that lab-familiarization was not influenced by infants' prior familiarity with the speakers' voice for comparability with previous segmentation studies and b) that performance for the extended-exposure at home words was not influenced by children having heard the same speaker say the words before. Furthermore, we ensured that the stimuli presented in the lab-familiarization were recorded in moderate German IDS, a speech style in between ADS and IDS, with a mean pitch of 222 Hz in order to exclude results being driven exclusively by potential facilitatory effects of IDS. Thus, the task also examines how infants generalize learning from stimuli presented in ADS to recognition of the same stimuli in moderate IDS in the laboratory.

Furthermore, the same female speaker who recorded the stimuli for the lab-familiarization was asked to record a number of isolated tokens of all four novel monosyllabic words. Three different isolated tokens were selected for each novel monosyllabic target word to be presented to infants in the test phase.

2.3.3. Procedure

Extended-Exposure at Home Phase. Parents of 7.5-month-old infants (n = 48) were sent CDs with six different stories containing one and the same novel pseudoword in either German infant- or adult-directed speech and were asked to ideally play one story to their child every day over a six-week period (extended-exposure at home). Thus, each child heard only one novel word in all of the stories at home. Across children it was counterbalanced which of the four novel words occurred in the stories so that an equal number of children (n = 12) heard each of the four novel words in the stories. Parents were instructed to have their child lie or sit in a room near the loudspeakers and play a story every day for one week and then move to the next story on the CD. Thus, when children were invited to come to the laboratory after six weeks, at the age of 9 months, they had listened to all six different stories. Each child heard all six stories in either IDS or ADS, with children randomly assigned to each condition. Thus, half the children heard the stories in only IDS and the other half of the children heard the stories in ADS.

In addition, parents were given a diary to track the frequency with which they played the stories to their babies at home, as well as their infants' attention to the stories for each day the story was played. Parents were told not to attract the child's attention to the stories but rather to rate the individual infant's attention on a scale of 1 to 5 (with 1 being inattentive and 5 being very attentive). So the total number of stories listened to and the degree of attention paid to the stories was collected for each child. Parents did not report their infants to be familiar with any of the stories presented to them.

Lab-Familiarization Phase. Following the extended-exposure at home phase, children were invited to the laboratory. Each child was tested individually in a separate, quiet room. The child either sat by herself strapped into a car seat or on the parents' lap about 60 cm away from a large monitor, which presented infants with a blinking checkerboard. The auditory stimuli were presented via loudspeakers that were situated above the television screen. Two cameras mounted directly above the TV screen recorded children's eye-movements during the experiment. Synchronized signals from the cameras were routed via a digital splitter to provide two separate time-locked images of the child, which were used for both online and offline scoring.

Stimuli were presented using the Look software (Meints & Woodford, 2008). Each trial presented infants with the blinking checkerboard on the screen paired with an auditory stimulus. A trained experimenter controlled the experiment from an adjacent room. Based on the video image of the child, she started a trial when the infant was looking to the screen and continued to indicate throughout the trial whether the infant was looking to the screen or away by pressing the corresponding button on a keyboard.. In between trials the screen remained blank. However, if infants lost interest and did not look back at the screen, the experimenter initiated a flashing light paired with the sound of a ringing bell to reorient infants towards the screen (see Altvater-Mackensen & Mani, 2013, for a similar procedure).

Infants listened to alternating blocks of two passages containing six sentences spoken in an infant-directed manner. We only presented infants with IDS in this phase, since we know from previous work that infants have difficulties segmenting words from ADS based on brief-laboratory based exposure (Thiessen, Hill, & Saffran, 2005; Singh, Nestor, Parikh, & Yull, 2009; Mani & Pätzold, 2016). One passage contained sentences including the word that children had been exposed to in the stories at home, while the second passage contained sentences including another pseudo-word that the children had not heard before. Each passage was repeated either for a total of six times or until the child had listened to both passages for a total of 100 seconds. Each trial contained one passage, consisting of six sentences with 1 second of silence between sentences, adding up to a trial length of approximately 23 seconds. Each trial lasted until completion or until the infant looked away for more than 2 consecutive seconds. Trial order was randomized.

Test Phase. The test phase started directly after the laboratory-familiarization phase. Infants were presented with isolated tokens of the word they had heard in stories at home during the extended-exposure phase, the word they heard only in the laboratory during the lab-familiarization phase and two novel control words. Each child received three trials each containing isolated tokens of the extended-exposure, the lab-familiarized and the two control words, i.e., 12 trials in total. As in the lab-familiarization phase, the experimenter waited until the child fixated the center of the monitor where the blinking checkerboard was located to initiate the playing of the isolated words. Each trial presented 15 repetitions of the word alternating between three different tokens, with each token being repeated five times, separated by 500 milliseconds of silence, leading to a trial length of approximately 18 seconds. Each trial lasted until completion or until the infant looked away for more than 2 consecutive seconds. Trial order was randomized.

Across infants, we counterbalanced which words were presented during the extended-exposure, the lab-familiarization and as novel control words in the test phase. Thus, any differences in listening times to isolated tokens of the words could not be a result of a preference for the sounds of one word relative to the other, but rather due to infants' previous exposure to the words alone.

2.3.4. Coding and reliability

The looking behavior of the infants was assessed online using the digital stimulus presentation and scoring system (Present; Meints & Woodford, 2008). A trained coder indicated whether the child was looking at the screen or away at any point during the experiment. The experimenter was blind to the experimental condition: there were no information on the condition provided by the computers and the experimenter could not hear the stimuli as she sat in the adjacent room to the booth where the stimuli were presented and wore Philipps SHN9500 noise cancelling headphones that cover the entire ear during the whole experiment.

A second independent coder assessed a random sample of 15% of each condition offline to confirm the reliability of the online-coded data with a high degree of inter-rater reliability ($r = .99$). The coding output was later aligned with information about the phase of the experiment and the auditory stimulus presented. For each infant we calculated the summed listening times during the lab-familiarization and test phase separately for sentences containing extended-exposure and lab-familiarization words as well as for the isolated tokens of extended-exposure, lab-familiarization and novel control words.

2.4. RESULTS

2.4.1. Familiarization phase

First, we analyzed infants' listening times to passages containing the words in the laboratory familiarization phase. Note that infants had heard the extended-exposure words before in the stories at home but had not heard the lab-familiarized words before. A repeated-measures ANOVA on mean listening time with the within-subject factor familiarity (extended-exposure, lab-familiarization) and the between-subject factor condition (IDS; ADS) revealed a significant main effect of familiarity ($F(1, 47) = 11.15$, $p = .002$), but no main effects of condition or interactions between condition and familiarity. Thus, infants listened longer to passages containing the extended-exposure word ($M = 14.79$, $SD = 4.71$) relative to the novel lab-familiarized word ($M = 12.69$, $SD = 5.09$), already in the lab-familiarization phase, regardless of whether they had heard the stories in IDS or ADS at home (see Figure 5).

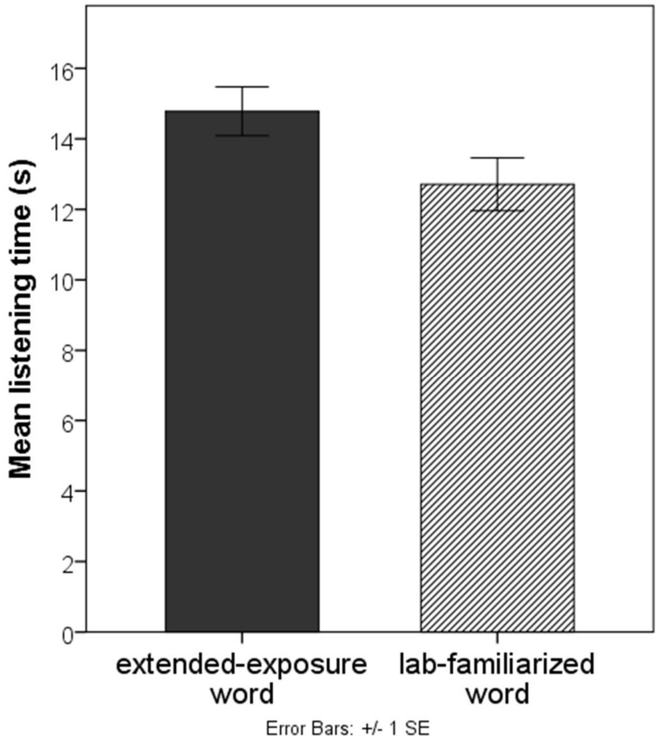


Figure 5 Mean listening times during the laboratory familiarization phase to sentences containing the words presented during extended-exposure at home and novel lab-familiarized words.

2.4.2. Test phase

We then analyzed infants' listening times to the different types of isolated words in the test phase (see Figure 6). A repeated-measures ANOVA on mean listening time with the within-subject factor familiarity (extended-exposure, lab-familiarized, control word) and the between-subjects factor condition (IDS versus ADS) found no significant main effect of condition ($F(2, 92) = 1.25$, $p = .270$) but again a significant main effect of familiarity ($F(2, 92) = 6.69$, $p = .002$). There was no significant interaction between familiarity and condition ($F(2; 92) = 0.15$, $p = .860$). Three further repeated-measures ANOVA examined the differences between the three different familiarity levels. A repeated-measures ANOVA with the within-subject factor familiarity (extended-exposure at home and control word) revealed that there was a significant main effect of familiarity ($F(1, 46) = 11.93$, $p = .001$), with increased listening times to extended-exposure words ($M = 10.57$, $SD = 3.82$) relative to novel control words ($M = 8.88$, $SD = 3.35$). This pattern was shown by 15 of 24 infants in the ADS condition and by 18 of 24 infants in the IDS condition. Similarly, a repeated-measures ANOVA with the factor familiarity (extended-exposure at home and lab-familiarization) also showed a significant main effect of familiarity ($F(1, 46) = 5.17$, $p = .028$) with increased listening times to extended-exposure words relative to lab-familiarized words ($M = 9.46$, $SD = 3.98$). This pattern was shown by 16 of 24 in the ADS condition and 16 of 24 in the IDS condition. There was no significant main effect of familiarity with the two levels lab-familiarized and control word ($F(1, 46) = 1.84$, $p=.182$). Neither were there any significant main effects of condition or significant interactions between familiarity and condition for the three different two-leveled repeated-measures ANOVAs conducted ($ps > .248$), suggesting similar performance in IDS and ADS. Importantly, there was also no significant main effect of the between-subjects factor word (Fend, Kulb, Nohl, Mieck), suggesting that successful segmentation was not driven by infants' preference for one word over the others ($F(3, 40) = 0.77$, $p = .518$). Table 2 provides a summary of the results.

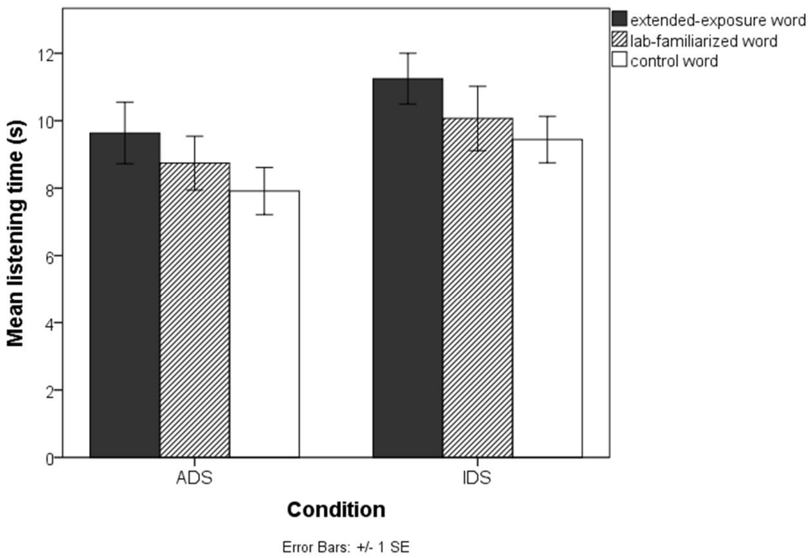


Figure 6 Mean listening times for the extended-exposure, the lab-familiarized and the control word in the ADS and IDS condition.

Table 2 Summary of results.

Phase	***Condition***	***Results (listening times)***
Lab-familiarization	IDS and ADS	extended-exposure > lab-familiarized
Test	IDS and ADS	extended-exposure > lab-familiarized extended-exposure > novel control lab-familiarized = novel control

Bivariate correlations were conducted to assess whether (a) the total amount of listening to the stories during the extended-exposure phase and (b) infants' mean attention to the extended-exposure stories correlated with infants' recognition of isolated tokens of the extended-exposure words (indexed by the difference in listening times to extended-exposure and control words). On average, parents reported that their children attended to the stimuli with a score of 2.4 (ranging from 1.0 to 3.9) and that they played the stories to the children an average of 37 times (ranging from 22 to 42). There was no significant difference in mean attention between the two speech register conditions (ADS: M = 2.33, SD = 0.68, IDS: M = 2.47, SD = 0.72; $t(45) = -0.68$, $p = .5$). Similarly, there was no significant difference in the total number of times the stories were listened to between the IDS and ADS group ($t(45) = -0.56$, $p = .577$).

However, children's attention to the stories during extended-exposure correlated significantly with their segmentation of the extended-exposure words for those children who had listened to the stories in ADS ($r(24) = 0.45$, $p = .028$). Thus, those children who were presented with the stories in ADS were better able to segment the words from the stories if they were reported to have attended more to the stories. This was not the case for children who were presented with the stories in IDS (see Figure 7).

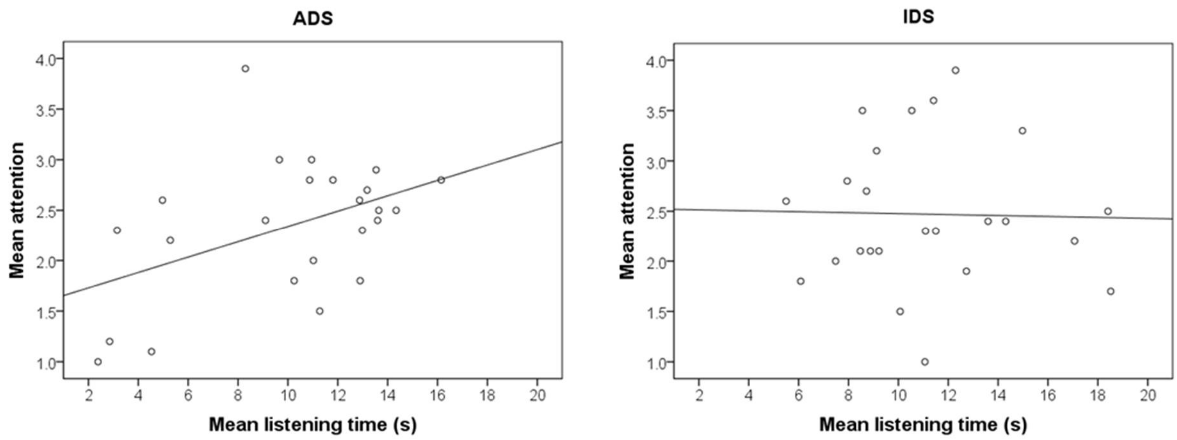


Figure 7 Mean listening times for the extended-exposure at home words and children's mean attention while listening to the stories at home for the ADS and IDS condition.

2.5. DISCUSSION

The aim of the current study was to investigate infants' segmentation abilities from fluent speech outside of the laboratory in infants' everyday environment. In particular, we examined whether German infants' ability to segment words from fluent speech is influenced by (a) the type of exposure to the words they receive (lab-familiarization versus extended-exposure at home), and (b) the register of speech the words are presented in (IDS versus ADS).

Half of our infants were exposed to target words embedded in stories in IDS while the other half were exposed to the same stories in ADS over an extended six-week period. We found that German 9-month-olds successfully recognized the words they had been exposed to previously at home – regardless of whether this exposure was in the infant- or adult-directed register. In contrast, infants did not recognize isolated tokens of words they were familiarized with in a brief laboratory-based exposure phase (for similar findings in German 7-month-olds see Altvater-Mackensen & Mani, 2013). In the following sections, we will examine the findings in more detail, outline future implications and address limitations of the present study.

2.5.1. Infants' learning from extended exposure to IDS and ADS at home

The main finding of the study was that infants listened longer to words they had previously been familiarized with through the extended-exposure phase relative to novel control words. These results suggest that infants were able to recognize these words based on either their previous extended exposure to these words at home and/or through their recent familiarization with these words in the brief laboratory-based familiarization phase. We suggest that the results are based on infants' prior extended exposure to the words for the following reasons. First, we note that the preference for the extended-exposure words was already present in the lab-familiarization phase, i.e., infants listened longer to the passages containing the extended-exposure word relative to the passages containing the lab-familiarized word which was presented to them for the first time in the laboratory. This suggests that even before the test phase infants displayed recognition of the words from the extended-exposure phase. Second, we note that infants showed no evidence of learning from the lab-familiarization phase (discussed in further detail below), i.e., in the test phase, infants did not listen longer to words they had been exposed to only in the lab-familiarization phase relative to novel control words. Hence, infants' discrimination of extended-exposure words from lab-familiarized and novel control words (in the lab-familiarization phase and the test phase) suggests that infants had segmented these words from the stories during the period of extended exposure at home and were able to retain these words in long-term memory, e.g. in their proto-lexicon (Swingley, 2005), in order to successfully segment and recognize them later on in the lab-familiarization phase as well as during the test phase. This finding is in line with our predictions.

Our study further indicates that German 7.5- to 9-month-old infants are already able to extract and retain words in long-term memory regardless of whether their exposure to these words was in IDS or ADS. That is, both groups of infants showed discrimination of the extended-exposure at home words from the lab-familiarized words in the lab-familiarization phase as well as discrimination of the extended-exposure at home words from novel control words in the test phase. Based on previous findings demonstrating differences in infants' segmentation of words from infant- and adult-directed speech (Thiessen, Hill, & Saffran, 2005), we predicted that infants would benefit from hearing the stories in IDS in the extended exposure phase. Nevertheless, our current findings suggest that infants do attend to and learn from exposure to language in the adult-directed register, even when their attention is not extrinsically drawn to the stimulus. Thus, not only are young infants capable of learning from speech presented in the background, i.e., overheard speech, but they are also able to learn from overheard speech in different speech registers. This has enormous implications for our understanding of the language input presented to infants. Typically, studies have focused on infants' learning from speech presented directly to infants in the infant-directed register and the benefits of such interactions with children. Whilst not underplaying the benefits of infant-directed interactions, our findings suggest that infants are, from an early age, also capable of learning from overheard speech in the adult-directed register. This dramatically expands the repertoire of language input that the child is able to learn from and, as we discuss below, has important implications for our understanding of the learnability from infant language interactions.

Note that despite being given at least 100s of exposure to sentences containing the lab-familiarized words, this exposure was not adequate for German infants to extract these words from the speech stream and recognize them when presented in isolation later. This is similar to the findings reported by Altvater-Mackensen and Mani (2013), who found that German infants were only able to segment a word from a speech stream (based on laboratory-familiarization) when this word sounded similar to a previously heard word. Thus, at least for German-learning infants, speech register alone, in this case IDS, does not provide sufficient cues to attract infants' attention and drive learning in a lab-familiarization context (see also Höhle & Weissenborn, 2003 for similar results with 9-month-old German infants; albeit with commonly occurring function words which infants were likely to have heard earlier).

German-learning infants appear, therefore, to require additional support to extract words from the speech stream, either through extended-exposure to stories containing the words to be learnt (current study), prior exposure to similar-sounding words (Altvater-Mackensen & Mani, 2013) or experience hearing words in isolation before recognizing these words in fluent speech (Höhle & Weissenborn, 2003). This is consistent with the findings of a number of recent studies showing considerable language-specific differences in infants' speech segmentation abilities (Nishibayashi, Goyet, & Nazzi, 2015; Nazzi, Mersad, Sundara, Iakimova, & Polka, 2014; Altvater-Mackensen & Mani, 2013; Junge, Cutler, & Hagoort, 2014).

Ongoing studies in our group are currently examining the reasons for this difficulty, with one potential reason being the quality of IDS presented to German infants (Fernald et al., 1989). German caregivers typically do not exaggerate their speech as much as American caregivers: the prosodic characteristics of German IDS and ADS are less distinct, in that mean pitch, maximum pitch, minimum pitch and pitch range are more similar across the two registers in German relative to American English or French (Fernald et al., 1989). We suggest, therefore, that one reason German-learning infants may face difficulties with segmenting words from fluent speech is because of the less exaggerated nature of infant-directed speech presented to them. We note that this may also be one reason why we find successful learning from ADS in the current study. In other words, given that German IDS is more similar to ADS, German-learning infants may show a reduced preference for IDS over ADS relative to American English infants (see Dunst, Forman, & Hamby, 2012 for a meta-analysis of the IDS preference) and may therefore be more tuned to learning from both speech registers.

2.5.2. Implications for theories of early language acquisition

As noted earlier, studies suggest that infants show a preference for IDS over ADS from an early age (Cooper & Aslin, 1990; Zangl & Mills, 2007). This finding has been taken to support social gating models of learning, which suggest that infants must be attracted to speech in order to learn from the input (e.g., Kuhl, 2007). Similarly, curiosity-based theories of learning suggest that infants seek the sources from which they wish to learn (O'Regan, 2011) and that infants prioritize contexts which are easier to learn from (Gottlieb, Oudeyer, Lopes, & Baranes, 2013). Our finding that infants were able to learn from speech presented in the infant- and adult-directed register might, then, be viewed as contrary to such approaches, given that infants appear to be able to learn from a register that they typically attend less to (at least as suggested by studies showing a preference for listening to IDS versus ADS).

On the contrary, however, we suggest that our findings may be taken to support precisely such socially gated models of learning. In particular, we note that infants' recognition of previously familiarized words (and their discrimination of these words from novel control words) correlated significantly with the amount of attention they were reported to have paid to the stories at home (as indexed by parental reports). This, however, was only true for those infants who heard the stories in ADS. Thus, when the stories were presented in IDS, the amount of overt attention that children paid to the stories did not impact their learning success but in ADS, individual children's attention to the stories impacted their success in learning the words from the stories. We interpret these results in the following manner. IDS, as noted in the Introduction, may drive infants' attention to the relevant aspects of a speech stream without any modulation of overt attention to the stories. ADS is, in contrast, child-exploitable: given reduced cues, overt attention helps infants to find the relevant aspects of the speech signal (Dominey & Dodane, 2004). We suggest these findings support socially gated models assuming that infants must be attracted to IDS in order to learn (Kuhl, 2007, p.116), while extending such models from the processing of IDS to speech in general. Thus, while not being able to adjudicate between the role of the linguistic features of IDS and increased attention to IDS as a determining factor in infants' improved learning from IDS relative to ADS, our findings highlight an important role for attention to language in infants' learning from ADS.

We also note that our results may appear contrary to previous studies reporting differences in infants' segmentation of words from IDS and ADS (Thiessen, Hill, & Saffran, 2005; Singh, Nestor, Parikh, & Yull, 2009). One possible explanation for the difference in the results is likely the extended exposure to the words that infants received in both registers. Thus, given additional exposure, infants appear to be able to extract words from speech presented in IDS and ADS. Furthermore, studies examining infant learning from artificial language stimuli find that even young infants are able to segment an artificial language speech stream, when it is presented in a monotonous, non-infant-directed style of speech (e.g., Saffran, Aslin, & Newport, 1996). While studies touting the beneficial nature of IDS may stand in apparent contrast to these studies with artificial language stimuli, infants may utilize and require different cues when attending to naturalistic language stimuli relative to artificial language stimuli. Thus, for instance, when presented with a nonsense speech stream, the novelty of the speech stream may be sufficient to maintain infants' attention despite it being presented in ADS, thus promoting learning.

Alternatively, the stimuli might be so different to what the infant is used to that the infant must listen more attentively to the information being presented in order to learn anything, thereby being better able to track regularities in the stream compared to naturalistic language stimuli. Thus, this explanation – again – puts the focus on infant-driven learning from ADS.

2.5.3. Infants' flexibility in recognizing words

The flexibility of early representations of extended-exposure words displayed in the current study is worth further discussion. First, we note that infants received early exposure to the words in sentence contexts alone (embedded in stories). Despite never hearing the words in isolation, infants displayed considerable flexibility in recognizing these words when presented in novel sentence contexts (lab-familiarization phase) and in isolation. This is particularly impressive since studies on older children's word referent mapping finds that 17-month-olds find it difficult to recognize a word (and its referent) in unfamiliar sentence contexts due to coarticulation with the surrounding sounds (Plunkett, 1997). When not required to access the meanings of the words, however, our studies show that young infants, given adequate exposure to the sounds of the words, can recognize these words in unfamiliar sentence contexts despite differences in the surface form of the words due to coarticulation (see Junge et al., 2014, for similar results with older children).

Second, we note that infants displayed successful recognition of these words even when the register at test did not match that of the extended-exposure at home phase. Thus, infants who had been presented with the stories in ADS were able to recognize these words in sentence contexts and isolation in IDS. It would be interesting to see whether the change in register would impact recognition in the reverse direction, namely, going from IDS to ADS. We anticipate that this would negatively impact recognition given the findings of previous studies showing differences in infants' segmentation of IDS and ADS (Thiessen, Hill, & Saffran, 2005; Singh, Nestor, Parikh, & Yull, 2009). This is especially so given that German infants appear to have difficulties segmenting and recognizing words even from fluent IDS at an early age (lab-familiarization phase, this study; Altvater-Mackensen & Mani, 2013; Höhle & Weissenborn, 2003).

Finally, we note that the extended-exposure at home phase and the lab-familiarization phase were recorded by two different female speakers. Thus infants were able to recognize the previously familiarized words despite the lexically irrelevant acoustic differences caused by a change in the speaker (see Schmale & Seidl, 2009 for similar results; Houston & Jusczyk, 2000, 2003). Hence, infants in the current study successfully accomplished a generalization task, which required them to recognize target words despite changes in register and speaker. Taken together, these findings highlight the flexibility in infants' representations of the extended exposure words and supports the notion that phonological representations of words have become more resistant to variation by the age of 9 months (Johnson, Westrek, Nazzi, & Cutler, 2011; Van Heugten & Johnson, 2012; Schmale, Christia, Seidl, & Johnson, 2010; Johnson, Seidl, & Tyler, 2014).

2.6. CONCLUSION

In conclusion, the current study suggests that being exposed to a word in fluent speech over an extended period of time helps infants to segment this word from the continuous input, to retain this word in long-term memory and to recognize this word with remarkable flexibility. Two aspects of our results stand out. First, given lengthy exposure to words in a naturalistic setting outside of the laboratory, infants are able to segment words from either speech register, IDS and ADS. As we have explained above, this has important implications for our understanding of the kind of language input that infants can learn from in daily life. Second, we found that the amount of attention infants paid to ADS, but not to IDS, correlated with their segmentation success. This finding is compatible with, and extends, models of language acquisition that view the infant as an active participant in learning, whose attention to different kinds of stimuli drives successful learning.

CHAPTER 3: LISTEN UP! DEVELOPMENTAL DIFFERENCES IN THE IMPACT OF IDS ON SPEECH SEGMENTATION

3.1. ABSTRACT

While American English infants typically segment words from fluent speech by 7.5-months, studies of infants from other language backgrounds have difficulty replicating this finding. One possible explanation for this cross-linguistic difference is that the input infants from different language backgrounds receive is not as infant-directed as American English infant-directed speech (Floccia et al., 2016). Against this background, the current study investigates whether German 7.5- and 9-month-old infants segment words from fluent speech when the input is prosodically similar to American English IDS. While 9-month-olds showed successful segmentation of words from exaggerated IDS, 7.5-month-olds did not. These findings highlight a) the beneficial impact of exaggerated IDS on infant speech segmentation, b) cross-linguistic differences in word segmentation that are based not just on the kind of input available to children and suggest c) developmental differences in the role of IDS as an attentional spotlight in speech segmentation.

3.2. INTRODUCTION

One of the critical aspects of acquiring a language is the ability to segment the fluent speech stream into its constituent units, i.e., words. In first language acquisition, this ability seems to be in place by approximately 7.5-months, at least for American English infants (Jusczyk & Aslin, 1995), with some studies showing even earlier evidence of segmentation (e.g., Bortfeld, Morgan, Golinkoff, & Rathburn, 2005). However, it has proved difficult for studies examining infants learning other native languages to replicate such findings at the same ages. For instance, one recent study finds that German 9-month-olds familiarized (in the laboratory) with words embedded in fluent speech, do not differentiate these familiarized from unfamiliar control words (Schreiner, Altvater-Mackensen, & Mani, in press). Studies with Dutch (Kooijman, Hagoort, & Cutler, 2005) and French infants (Nazzi, Mersad, Sundara, Iakimova, & Polka, 2014) find similar inconsistencies with the pattern of results reported with American English infants. Thus, French 8-month-olds familiarized with words in isolation seem unable to recognize the same words in fluent speech, while German 9-month-olds perform successfully in this task so long as the words tested are highly frequent function words (Höhle & Weissenborn, 2003). In contrast, French 8-month-olds do recognize words in isolation when previously familiarized with the same words in fluent speech. Thus, there appears to be considerable variation in the circumstances under which infants successfully segment words from fluent speech across languages.

Why do we find such differences? While there are likely to be considerable cross-cultural phenomena that may underlie such behavioral differences, we focus here on one possible explanation for the differences found across language cultures, namely, the differences in the kind of speech presented to infants in the studies, and in their native language, at large. Importantly, the speech presented to infants in the

Jusczyk and Aslin (1995) study, and indeed, in most studies on speech segmentation, was in the infant-directed speech register (hereafter, IDS), the speech register typically used in communication with young infants. It differs from speech used in normal communication between adults, i.e., adult-directed speech (hereafter, ADS): Speech addressed to infants is slower, higher in pitch, with longer pauses between words, and greater pitch variation within utterances (Kuhl et al., 1997).

The use of IDS in studies with infants is well-grounded: Not only do infants show a preference for IDS from birth onwards (Cooper, Abraham, Berman, & Staska, 1997; Werker, Pegg, & McLeod, 1994) but they also seem to be better in extracting words from fluent IDS compared to ADS (Singh, Nestor, Parikh, & Yull, 2009; Thiessen, Hill, & Saffran, 2005). Furthermore, IDS appears to facilitate word learning (Graf-Estes & Hurley, 2013; Song, Demuth, & Morgan, 2010), and its use in communication with infants can predict vocabulary growth (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2013; Weisleder & Fernald, 2013). However, it is important to note that most of this research has been conducted with American English infants using American English IDS.

There is considerable variation in the prosodic characteristics of IDS across languages, with different studies finding that American English IDS is the most modified compared to ADS amongst the languages tested (Cooper, et al., 1997; Fernald et al., 1989, Shute & Wheldall, 1989). Against this background, is it possible that above-mentioned studies with infants of other languages (e.g., French, Dutch, German) fail to replicate the pattern of segmentation reported in American English infants due to the characteristics of IDS in the different languages? Therefore, given that infants show improved segmentation of fluent speech from IDS relative to ADS (Singh et al., 2009; Thiessen et al., 2005) and that American English IDS is more exaggerated relative to IDS in other languages (Cooper et al., 1997, Ferguson, 1964), would we find similar segmentation abilities in infants learning other languages if the speech input presented to them is as exaggerated as American English IDS?

One recent study testing speech segmentation in British English infants offers considerable support for this possibility (Floccia et al., 2016): Only one of 13 experiments found successful word segmentation, and only when the stimuli were presented to 10.5-month-old infants in exaggerated IDS. This suggests that the different styles of IDS used to address infants of different dialects and different languages critically impacts their performance in segmentation tasks[2]. Nevertheless, this study finds successful segmentation in infants three months later than similar findings have been reported with American English infants. The possibility remains, therefore, that infants of other languages, e.g., German, may not be able to segment words at this younger age even given more exaggerated IDS.

Examining this possibility is critical for the following reason. On one side, were infants learning other languages, e.g., German, able to segment words from fluent speech at 7.5-months given exaggerated IDS, this would suggest that the differences between the studies reported to-date with infants learning other languages and American English infants come down to the input presented. In other words, infants from different language backgrounds would be able to segment words from fluent speech at the same age as American English infants as long as the input is adequately exaggerated and engaging. While this might have consequences for lexical development in infants hearing such less engaging input on a regular basis, this would at least suggest that there is no long-term cognitive impact of hearing such less exaggerated IDS on day-to-day language processing. Conversely, were we to find that infants learning German are unable to segment words at 7.5-months, even

[2] Note that the lack of segmentation abilities in 9-month-old British English tested with American English IDS suggests that exaggeration might not be sufficient but that the native accent is required to succeed in segmenting speech.

given exaggerated input, this would suggest that merely exaggerated input is inadequate to drive successful segmentation, at least in German infants. This would further imply that there may be other cross-cultural (including cross-linguistic) differences between infants from different language backgrounds that induce more long-term differences in the language behavior of these infants. Against this background, the current study sets out to explore German 7.5- and 9-month-olds' segmentation abilities given exaggerated IDS resembling that presented to American English infants.

3.3. METHOD

3.3.1. Participants

Twenty-two 7.5-month-old, and 22 9-month-old monolingual German infants participated in the study (APPENDIX B).

3.3.2. Material and Design

Four passages with one of four phonotactically legal German monosyllabic pseudowords, *Jopp [ˈjɔp]*, *Riel [riːl]*, *Mauf [mauf]*, and *Lenn [lɛn]*, were recorded in an exaggerated speech register resembling American English IDS (Table 3). The same female speaker recorded five different isolated tokens of each pseudoword which were repeated three times to form lists of 15 tokens. Stimuli were selected for their acoustic properties to match those of American English IDS (Figure 8).

Table 3 Mean, minimum, and maximum fundamental frequency in Hz and mean duration in s for the passages and isolated tokens of the study. Standard deviations are provided in brackets. For the recordings of the exaggerated German IDS stimuli, a female native speaker of German imagined herself as speaking to a child. In addition, she was asked to produce the passages and isolated tokens in a slower and more exaggerated way than she typically would.

	mean F0	min F0	max F0	mean duration
passages	299.33 (22.06)	149.13 (36.76)	440.61 (31.53)	35.12 (3.24)
isolated tokens	322.63 (80.01)	266.65 (86.33)	377.02 (96.67)	22.77 (0.33)

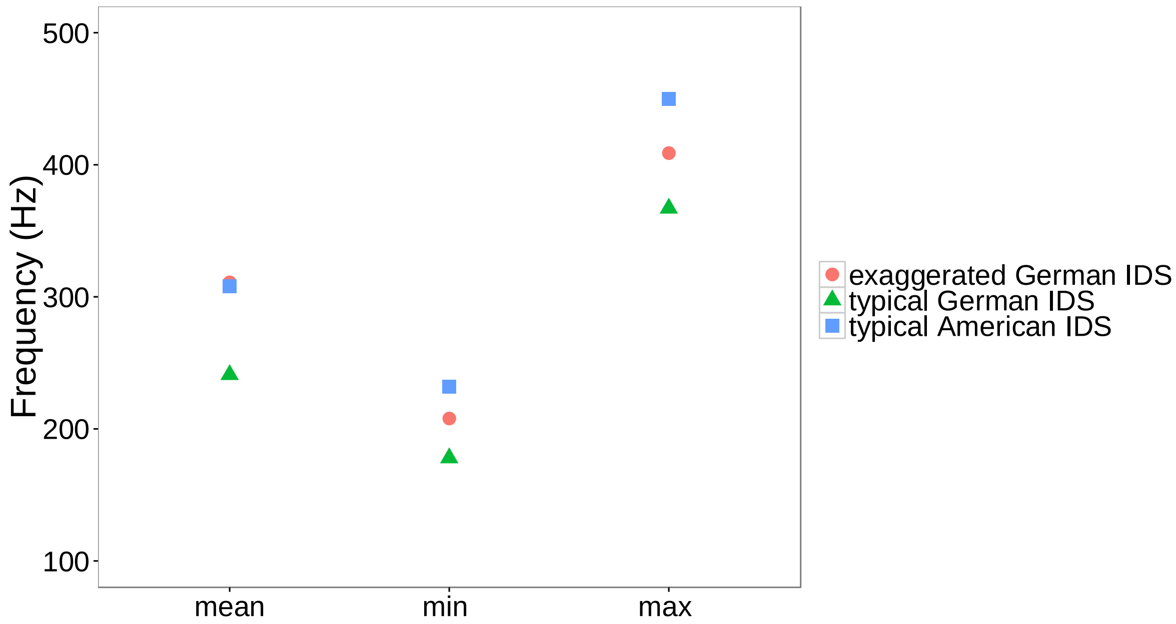


Figure 8 Mean, minimum and maximum fundamental frequency for typical German IDS, typical English IDS (taken from Fernald et al., 1989), and the exaggerated German IDS stimuli used in the current study.

3.3.3. Procedure

A trained experimenter controlled the experiment from the adjacent room using the stimulus-presenting software Look (Meints & Woodford, 2008). During each trial, infants were presented with a blinking checkerboard on screen whilst simultaneously being presented with an auditory stimulus. Using silent video images of the infant, the experimenter initiated a trial when the infant looked towards the screen and continued to indicate throughout the remainder of the trial whether the infant was looking towards the screen or away by pressing a corresponding button on the keyboard. The auditory and visual stimulus continued to play either until the trial was complete or until the infant looked away for more than 2 s (see Mani & Paetzold, 2016, for an identical procedure). The experimenter was blind to the experimental condition as no information on the condition was provided by the computer and the stimuli played in the adjacent booth were masked by music.

Familiarization Phase. Infants listened to alternating blocks of two passages in exaggerated IDS. Passages were either repeated for a total of 12 times or until the child had accumulated 100 s of listening time for both passages.

Test Phase. Infants were presented with isolated tokens of the words they had heard embedded in passages during the familiarization phase and control words they had never heard before. Each infant received three trials of isolated tokens of either the two familiarized, or the two control words, i.e., totalling 12 trials. Trial order within test blocks was randomized.

3.4. RESULTS

Test Phase. A repeated-measures ANOVA with the within-subject factor familiarity (familiarized vs. control word) and the between-subject factor age (7.5 vs. 9 months) revealed a significant interaction of familiarity and age ($F(1, 42) = 4.71$, $p = 0.036$, $\eta_p^2 = 0.10$) and a significant main effect of age ($F(1, 42) = 4.44$, $p = 0.041$, $\eta_p^2 = 0.10$). There was no significant main effect of familiarity ($F(1, 42) = 1.48$, $p = 0.230$, $\eta_p^2 = 0.03$). Hence, we ran planned contrasts within each age-group to further examine infants' segmentation abilities. For the 7.5-month-olds, there were no significant differences between listening times to familiarized and control items ($t(43) = -0.91$, $p = 0.365$, $d = -0.14$). However, 9-month-olds listened significantly longer to the familiarized relative to the control words ($t(43) = 3.25$, $p = 0.002$, $d = 0.49$) indicating successful word segmentation (Figure 9; APPENDIX B). Thus, our results suggest that German infants at 9-months benefit from exaggerated speech in segmenting the speech stream, whereas 7.5-month-olds did not show a similar benefit.

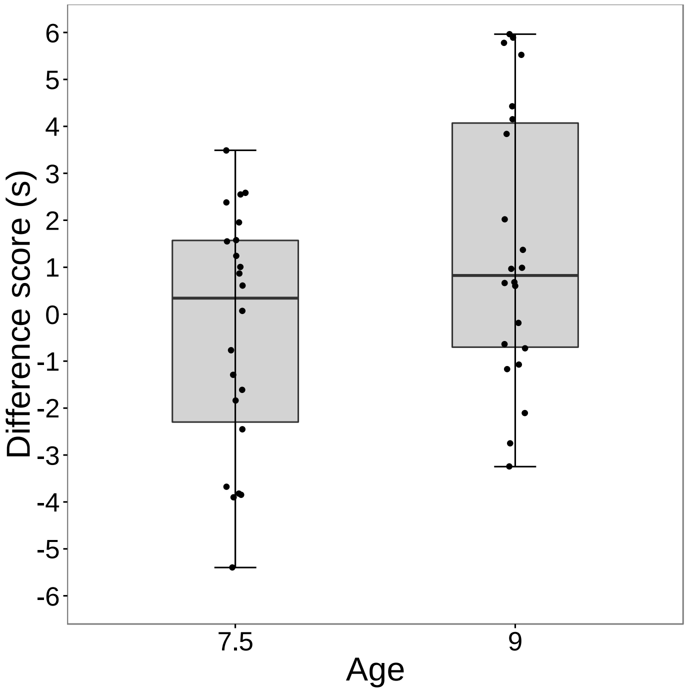


Figure 9 Difference scores for the mean listening times of the familiarized and the novel control words for the 7.5- and 9-month-old infants.

Familiarization Phase. Comparing infants' mean listening times to the familiarization trials (Table 4), an independent-samples t-test revealed a significant difference between 7.5- and 9-month-olds ($t(42) = 3.67$, $p = 0.001$, $d = 1.106$). In addition, independent-samples t-test revealed a significant difference in the number of familiarization trials between the two age groups ($t(42) = -3.07$, $p = 0.004$, $d = -0.925$). Thus while 7.5-month-olds listened longer to the familiarization trials relative to the 9-month-olds, it appears that they looked away less than the 9-month-olds, thereby initiating fewer trials during the familiarization phase.

Table 4 Infants' mean listening times (s) for the familiarization phase. Standard deviations are provided in brackets.

age group	mean listening time	mean number of trials
7.5	26.85 (8.48)	4.68 (2.38)
9	18.41 (6.67)	6.95 (2.54)

3.5. DISCUSSION

Previous studies on infants' speech segmentation report that infants from language backgrounds other than American English do not seem able to segment words from fluent speech to the same degree as American English infants (e.g., British English: Floccia et al., 2016; Dutch: Junge, Cutler, & Hagoort, 2014; however, note Spanish and Catalan: Bosch, Figueras, Teixidó, & Ramon-Casas, 2013). For instance, German infants are able to successfully segment words from fluent speech only under certain conditions, e.g., when familiarized with isolated tokens of highly frequent function words (9 months: Höhle & Weissenborn, 2003), presented with accentuated words (10 months: Braun, Pohl, & Zahner, 2014), previously familiarized with similar-sounding words (Altvater-Mackensen & Mani, 2013), or tested with words previously familiarized at home (Schreiner et al., in press). Similarly, British infants showed segmentation of words from fluent speech only when presented with exaggerated IDS, similar to American English IDS (Floccia et al., 2016), but again, only at 10.5-months. In contrast, American English infants succeed in this task already at 7.5-months without any additional cues (Jusczyk & Aslin, 1995). Against this background, we examined whether more pronounced IDS also facilitates word segmentation in younger German-learning infants.

The main finding of the study was that 9-month-old infants listened longer to the familiarized words relative to the control words suggesting that infants indeed recognized these words after an exaggerated IDS familiarization phase. Seven-and-a-half-month-old infants did not listen longer to familiarized words, even when familiarized in exaggerated IDS.

On one side, the findings with the 9-month-olds contrast previous studies with German infants (Schreiner et al., 2016 for instance, with 9-month-olds only listening longer to familiarized relative to control words when familiarized with these words embedded in stories over at home but not when presented with a brief 100s familiarization phase. The stimuli in the Schreiner et al. (2016) study were, however, in standard German IDS and not the exaggerated IDS presented to infants in the current study. Thus, it is likely, that the difference in the findings can be attributed to the speech register presented to infants across the two studies. This echoes findings from British 10.5-month-olds (Floccia et al., 2016) while highlighting that even at a younger age, exaggerated IDS positively impacts speech segmentation.

The results of the current study, taken together with the results reported by Floccia et al. (2016) point to at least one potential factor underlying the cross-linguistic/dialectal differences in speech segmentation in infants from different language backgrounds and highlight again, the importance of IDS in early language development.

Our findings reveal differences in the ability to segment words from fluent speech at 7.5- and 9-months as infants in the younger group failed to show significant differences in listening times to familiarized and control tokens. This finding has important implications for our understanding of the cross-linguistic differences in early speech segmentation. Firstly, this suggests that – at the same age at which American English infants successfully segment words from fluent speech – German infants fail to show evidence of segmentation despite being provided with exaggerated speech input. This places some limitations on the conclusions drawn by Floccia et al. (2016) and the results with 9-month-olds in the current study as to the facilitatory impact of exaggerated IDS on speech segmentation. Thus, it does not appear that presenting exaggerated IDS alone induces successful segmentation in younger infants. What, then, might explain the differences in performance between German and American English infants?

One possibility for the difference between the 7.5-month-olds and the 9-month-olds in the current study is the difference in looking times during the familiarization phase. 7.5-month-olds listened longer to the familiarization trials initiating fewer look-aways than the 9-month-olds. Hence, 7.5-month-olds might not have gotten acquainted with the contingency of their look-aways and the stimulation. It might, therefore, be that the absence of a difference between listening times to familiarized and control words at 7.5-months of age is due to their not performing as required in the task. However, we note, that even 7-month-old German infants successfully discriminate between familiarized and control words in this task given additional familiarization input (Altvater-Mackensen & Mani, 2013). Thus, while we cannot exclude the possibility that the 7.5-month-olds in the current task were not, in general, performing as expected, it is unlikely that the lack of a significant difference in listening times to familiarized and control words is solely due to this factor.

A second, more tantalizing, possibility is that the difference may lie in the language backgrounds of the two groups of infants, including very likely, the speech register used to address infants in the two languages. Might the absence of evidence for segmentation in 7.5-month-olds be indicative of more long-lasting differences between infants from the two language backgrounds that cannot be nullified by merely presenting infants with more exaggerated speech input, as at 9-months of age? Here, we include not just the differences in the kind of IDS presented to infants from the two language backgrounds but also the degree of lexical and morphosyntactic complexity in the two languages, as well as cultural differences in parent-child interactions. At the very least, the difference between the 7.5- and 9-month-olds suggests that merely the presentation of more exaggerated input does not induce successful segmentation in German infants across development. This raises the question whether the findings of Floccia et al. (2016) could be replicated with younger British infants, e.g., at 7.5-months, and the extent to which exaggerated IDS induces successful segmentation in British infants across development.

It is, however, important to note that we – in no way – imply that German infants are unable to segment words at the same age as American English infants.

Indeed, previous results from our lab suggest that even younger German infants are able to segment words from fluent speech provided they have additional cues. Thus, our findings can only be taken to conclude that German infants may require different kinds of exposure to speech relative to American English infants to show successful segmentation in that task.

The results of the current study speak to the role of IDS as an attentional spotlight in speech processing (Kuhl, 2007; Zangl & Mills, 2007). In Altvater-Mackensen and Mani (2013), the ability to segment similar-sounding words from fluent speech was interpreted in terms of word-form familiarity bootstrapping segmentation. The similarity of the to-be-segmented words to the previously familiarized words captures infants' attention in the otherwise unfamiliar speech stream and drives segmentation. In Schreiner et al. (in press), recognition of familiarized words correlated significantly with infants' attention to the stories in ADS highlighting again the importance of attraction to speech in order to learn. Similarly, our finding that IDS influences – at least – 9-month-olds segmentation of speech can be interpreted as the exaggerated speech input facilitating segmentation by capturing infants' attention to a greater extent than other less exaggerated input.

IDS may therefore function as an ostensive cue that alerts the infant to a referential communication that is directed towards her (Saint-Georges et al., 2013), even during sleep – at least in neonates (Saito, Aoyama, Kondo, Fukomoto, & Konishi, 2007). Our findings with the 9-month-olds support the idea that prosody is an important contributor to early language processing that assists infants' development of segmentation abilities (Morgan, 1996). We note that these findings are similar to those reported with British English infants (Floccia et al., 2016), albeit at a younger age. Our findings with the 7.5-month-olds, in contrast, suggest that merely exaggerated speech may not be adequate at all ages to drive segmentation of speech, at least in infants from German language backgrounds and highlight the need for future studies to examine the reasons for the differences in segmentation in infants from different language backgrounds.

CHAPTER 4: THE IMPACT OF THE QUALITY OF MOTHER'S SPEECH ON INFANTS' SEGMENTATION ABILITIES

4.1. ABSTRACT

Across a large number of cultures, infants are typically addressed using a special register of speech, sometimes called infant-directed speech (IDS). The amount of IDS addressed to a child has been shown to predict infants' later language skills. Against this background, the current study, therefore, takes a more specific look at whether maternal input – in particular, the infant-directedness of individual mothers' speech to their children – impacts infants' early language acquisition. Mother-child interactions were recorded to investigate the properties of each mother's speech to her child and showed that 7.5-month-old infants' ability to segment speech correlated with the quality of their mother's input, i.e., pitch range and utterance length. In addition, using electrophysiological measures, the study explored infants' ability to segment words from fluent exaggerated and typical German IDS. We found that infants demonstrated successful segmentation of the exaggerated IDS register through an increased negativity in their neural response to familiarized compared to novel control words but not for typical German IDS, Hence, the current study a) underlines the importance of IDS in early language acquisition, b) demonstrates successful exaggerated IDS segmentation abilities in 7.5-month-old German infants, and c) presents a possible explanation for cross-linguistic differences in infants' segmentation abilities reported in the literature.

4.2. INTRODUCTION

When addressing infants, adults and children generally modify their input to the child, i.e., they tend to use a higher pitch, wider pitch range and a slower speaking rate (Grieser & Kuhl, 1988; Kuhl et al., 1997). This type of speech is called infant-directed speech (hereafter, IDS) and differs from the language typically used when adults address each other with the so called adult-directed speech (hereafter, ADS). These modifications of the speech used when addressing infants have been identified in caregivers from a large number of languages (Ferguson, 1964; Fernald et al., 1989; Soderstrom, 2007).

4.2.1. Influence of the input of the mother on infant's language acquisition

The use of this modified speech register when communicating with infants seems to be beneficial for infants' language acquisition. Whereas newborns already show a preference for IDS over ADS (Cooper & Aslin, 1990; Werker & McLeod, 1989), the use of IDS has also been shown to facilitate early language acquisition (Graf-Estes & Hurley, 2013; Ma, Golinkoff, Houston & Hirsh-Pasek, 2011) and to increase infants' vocabulary (Fisher & Tokura, 1996; Vosoughi, Roy, Frank, & Roy, 2010; Weisleder & Fernald, 2013). Infants with smaller vocabularies seem to be spoken to less by by their parents (Greenwood et al., 2011; Hart & Risley, 1995) and the use of IDS in communication with infants is predictive of improved language outcomes later in life (Shneidman & Goldin-Meadow, 2012; Weisleder & Fernald, 2013).

A number of studies have examined the acoustic characteristics of IDS (Ferguson, 1964; Fernald et al., 1989; Grieser & Kuhl, 1988) and these studies have typically concluded that IDS is higher in pitch, has a wider pitch range and a slower speaking rate and shorter utterances with greater repetition. Subsequent research has also examined which characteristics of IDS are particularly important for early language acquisition. Kemler Nelson et al. (1989) suggest that the synchrony between prosodic cues and grammatical units founds in IDS may facilitate the detection of clause boundaries, with infants being more sensitive to prosodic segment-marking cues in IDS relative to ADS. However, Song, Demuth and Morgan's (2010) study suggests that only some of the characteristics of IDS might be beneficial for language acquisition. In particular, they found that only speaking rate and the hyperarticulation of vowels facilitated infants' ability to recognize words, whereas a wider pitch range did not.

Moreover, the analysis of mother-child dyads of 12- to 30-month-old infants revealed individual variations in the acoustic features of the mother's and infant's speech, in particular with regards to the extent to which they influence one other (Ko et al., 2015). Specifically, duration, speaking rate, mean pitch, minimum pitch, and maximum pitch of the mother correlated significantly with those of the infant, while pitch range did not. Another longitudinal study of mothers' speech to their infants revealed remarkable individual variation in how much mothers modify the prosodic characteristics of their speech to infants, e.g., speech rate and pitch range (Narayan & McDermott, 2016), with some mothers showing no modulation of speech rate, and others showing no modulation of mean pitch or pitch range in their speech to infants. The study concludes, therefore, that prosodic modifications to IDS are perhaps best characterized as "individualized predispositions of caregivers" rather than a general characteristic of IDS (p.1280). Given the considerable influence of IDS on language acquisition established in the literature to-date, this degree of individual variability in speech to infants begs the question of the extent to which this variability impacts language acquisition. Are these infants, exposed to less exaggerated input, equally able to acquire their mother tongue?

Taken together, the current study aims to investigate the individual variation in the properties of individual mothers' speech to their infants, which the infants have been exposed to from birth, and the influence of such variation on infants' language skills. In particular, we will explore the prosodic characteristics of the IDS of each individual mother and their impact on infants' ability to segment words from fluent speech.

4.2.2. Word segmentation from typical and exaggerated IDS

Over two decades ago, Jusczyk and Aslin (1995) examined American infants' ability to extract words from fluent IDS and found that infants as young as 7.5-months of age were able to segment words from fluent speech, and recognize these words when presented in isolation later on. Here, infants were familiarized with two different words embedded in sentences and tested on their recognition of these phonological forms as isolated tokens relative to novel control words infants had never heard before. In a second experiment, infants were familiarized with isolated tokens of words and tested on the recognition of these familiarized words and novel control words in sentential contexts. Longer listening times (as indexed by increased looking towards a blinking light during auditory presentation) towards the familiarized words or sentences containing the familiarized words – relative to control words – suggested that infants were able to segment words from fluent speech.

Since then, a number of studies have investigated and confirmed the beneficial effects of IDS on infants' segmentation abilities (Singh et al., 2008; Thiessen, Hill, & Saffran, 2005, Schreiner & Mani, 2017). These studies find that infants are better able to segment words from fluent speech when the speech is presented in an exaggerated infant-directed register relative to a less exaggerated or adult-directed register, although infants are able to segment words from ADS as well (Mani & Pätzold, 2016).

However, investigating segmentation abilities of infants learning languages other than American English has revealed several cross-linguistic differences in infants' segmentation of fluent speech. Whereas Spanish-Catalan infants appear to be able to segment speech by as early as 6-month of age (Bosch, Figueras, Teixido, & Ramon-Casas, 2013, but see also Bortfeld, Morgan, Golinkoff, & Rathbun, 2005), infants of other languages seem to need additional cues in order to successfully segment speech at a similar age as American English infants (Jusczyk & Aslin, 1995). German infants, for instance, show successful segmentation of words from fluent speech only if they have previously been familiarized to similar sounding words (Altvater-Mackensen & Mani, 2013) or have been provided with extended exposure to these words in stories at home (Schreiner, Altvater-Mackensen, & Mani, 2016) or are exposed to the words in isolation first before hearing these words embedded in sentences (Höhle & Weissenborn, 2003). Taken together, these studies suggest that German infants do not differentiate between familiarized words and control words, when they were exposed to the familiarized words in fluent speech prior to test, i.e., in the standard laboratory familiarization task.

Studies with British English infants failed to find successful speech segmentation in a series of 12 experiments at various ages (Floccia et al., 2016). The only condition where 10.5-month-old infants showed successful segmentation of fluent speech was when they were presented with exaggerated IDS, i.e., where the prosodic properties of the stimuli presented to infants were more similar to American English IDS relative to British English IDS. More importantly, Schreiner & Mani (2017) found that even when presented with exaggerated IDS, German infants fail to show successful segmentation of words from fluent speech at the same age as American English infants (i.e., at 7.5-months of age) and only show segmentation at the later age of 9-months – younger than current research findings in British English infants but still older than the results reported for American English infants.

Studies with Dutch infants similarly find that 7.5-month-old Dutch infants show successful segmentation of words with an initial strong syllable in neither Dutch nor English stimuli (Kuijpers, Coolen, Houston, & Cutler, 2008), and that – like the German infants – it is only at 9 months, that Dutch infants were able to demonstrate the ability to extract familiarized words out of fluent speech.

Taken together, the literature on speech segmentation suggests the following: First, there is a considerable influence of IDS on speech segmentation with even American English infants showing improved segmentation of words from fluent IDS relative to other speech. Second, there are considerable cross-linguistic differences in infants' speech segmentation abilities, which partly may be related to the quality, i.e., exaggerated nature of the IDS that the child is tested on, with even infants from other language backgrounds showing improved segmentation of exaggerated IDS relative to the IDS typical to caregivers of their native language. Furthermore, given the variability in maternal IDS to infants (reviewed in the earlier section), the current study seeks to examine whether the degree of variability in maternal IDS, i.e., the variability in the exaggerated nature of the IDS of individual mothers, influences the segmentation abilities of young German-learning infants. We will examine infants' segmentation of both exaggerated and language-typical IDS to investigate the potentially separable influences of the IDS that the infant is exposed to – with regards to maternal IDS – and the IDS that the infant is tested on (exaggerated and typical IDS) in an attempt to characterize both individual and cross-linguistic variability in infants' speech segmentation.

4.2.3. Using electrophysiological measures to tap into infant's segmentation abilities

Aside from the two-stage behavioral familiarization-test method – known as the preferential looking paradigm or the headturn preference paradigm, EEG recordings have been used to assess infants' segmentation abilities. For instance, while it has been difficult to find successful segmentation in behavioral tasks with Dutch infants (Kuijpers, Coolen, Houston, & Cutler, 1998), studies using electrophysiological measures report that Dutch infants at 10-month-of-age are able to successfully segment words from fluent speech (Kooijman, Hagoort, & Cutler, 2005; 2009). But why might behavioral measures fail to tap into infants' speech segmentation abilities?

One possible explanation for the failure to tap into infants' segmentation abilities reported by some studies using the preferential listening method could be that infants are unable to show an overt response required by this paradigm. This might be especially problematic for younger infants who are less able to support their head by themselves yet. Alternatively, we note that the preferential looking method assumes that a difference in looking times is an index of infants' preference for one stimulus over another and hence, indicates their discrimination of two different kinds of stimuli. The lack of a behavioral response may, therefore, either be related to infants' inability to discriminate between the different stimuli or a lack of a preference for one stimulus over the other. In other words, the absence of a significant difference between listening times to familiarized and control words cannot be unambiguously interpreted as a failure to segment words from fluent speech. Finally, we highlight one additional explanation suggested by the pattern of results reported in Schreiner and Mani (2017). This study revealed significant differences in looking behavior between the 7.5- and 9-month-old infants tested, with 7.5-month-olds listening longer during familiarization trials and showing fewer switch aways from the visual stimulus. The authors interpreted this difference as possibly suggesting that the younger infants were not on task and that the preferential looking design may not be appropriate for all kinds of stimuli and all age groups. Against this background, we will reinvestigate word segmentation in German 7.5-month-olds using a more sensitive neurophysiological measure that does not require an overt response of the infant and may provide a more reliable estimate of the onset of speech segmentation in German infants.

4.2.4. Current Study

The current study set out to investigate individual variation in mothers' speech towards their 7.5-month-old German learning infants and the extent to which this individual variation impacts infants' ability to segment words from fluent speech as indexed by their electrophysiological response to previously familiarized words. Importantly, we will examine infants' segmentation of both exaggerated and language-typical IDS to investigate the influence of the IDS that the infant is habitually exposed to and the IDS that the infant is tested on.

We hypothesize that infants, whose mothers use extremely enhanced prosodic modulations in their IDS, might show increased segmentation of words presented in the exaggerated register relative to the standard German register. In contrast, infants whose mothers use more standard German IDS ought to show segmentation of the less exaggerated register. Nevertheless, if the main function of IDS is to attract infants' attention to language, it is likely that even those infants whose mothers use more standard German IDS will benefit from the exaggerated nature of the other register, and show segmentation of words in both registers.

With regard to infant speech segmentation, we expect two components to be modulated by infants' familiarity with the words presented in the segmentation task.

First, we expect an early sustained left frontal negativity starting as early as 200ms, with increased negative deflections in brain activity to familiarized words relative to unfamiliar control words (c.f., Goyet, de Schonen, & Nazzi, 2010; Kooijman, Cutler, & Hagoort, 2008; Männel & Friederici, 2010). This effect is typically interpreted as indexing the increased ease of processing the familiarized words, due to infants having segmented these words from fluent speech during the familiarization phase. The second component of interest is an anterior negativity beginning around 600ms, with similarly increased negativity to familiarized words relative to unfamiliar words (c.f., Conboy & Mills, 2006; Junge, Cutler, & Hagoort, 2014; Mills, Coffey-Corina, & Neville, 1997; Mills et al., 2005; Torkildsen et al., 2008; Zangl & Mills, 2007), typically assumed to index attention. Of interest in this latter window is also a potential reversal in polarity of the responses, with younger infants showing more positive neural responses, and older infants (around 9-months) tend to show more negative neural responses for familiarized words than for novel control words. This difference in the polarity of the ERP responses across different age groups has also been identified in other studies (Junge, Hagoort, Kooijman, & Cutler, 2010; Zangl & Mills, 2007) and might be a consequence of infants' linguistic development and the maturation of infants' cortex.

4.3. METHOD

4.3.1. Participants

Twenty-one 7.5-month-old monolingual German infants were recruited for the study (8 female). Infants ranged in age from 221 to 244 days (7 months 9 days to 7 months 30 days) with a mean age of 232 days (approximately 7 months 22 days). An additional 16 children were tested but had to be excluded for different reasons: insufficient data collection with less than 10 trials per condition ($n = 14$), technical problems (n = 1), and refusal to wear the cap (n = 1). Prior to the study, all parents were asked for written consent of their infant's participation. Infants were given a t-shirt, a book, and a certificate as appreciation for their participation in the study.

4.3.2. Material and Design

Forty different monosyllabic words, which were likely to be novel to 7.5-month-old infants, were selected for the study. The occurrence of these words was counterbalanced across the familiarization and the test phase. For the familiarization phase, passages with eight different sentences including the 40 different words to be familiarized were recorded by a female speaker in two different speech registers, namely in exaggerated IDS and standard German IDS (see Table 5 for prosodic characteristics). For the standard German IDS stimuli, the female speaker was asked to imagine herself speaking to an infant, whereas for the exaggerated IDS stimuli, she was coached to produce the words and sentences in an exaggerated manner, after listening to other stimuli produced in a similarly exaggerated manner (c.f., Schreiner & Mani, 2017). Finally, the female speaker was asked to record each word in isolation in a manner between the typical German IDS and the exaggerated IDS register.

Table 5 Prosodic characteristics in Hz and duration in s for the stimuli of the familiarization and test phase.

	mean pitch		**duration**	
	M	*SD*	*M*	*SD*
familiarization typical German IDS	236.54	20.18	3.87	0.92
familiarization exaggerated IDS	314.67	26.75	4.19	0.97
isolated tokens at test	277.28	25.84	0.70	0.11

4.3.3. Procedure

The study consisted of a familiarization and a test phase (see Figure 10). During the familiarization phase, infants were presented with passages of eight different grammatically correct German sentences that contained one and the same monosyllabic target word (see APPENDIX C). Half of the passages were presented to the infant in IDS, and the other half in exaggerated IDS. Sentences of the familiarization phase were separated by 1000 ms of silence. Each familiarization passage was directly followed by a test phase. During the test phase, infants listened

to two blocks of two randomized trials with each trial representing one isolated token of the familiarized word of the familiarization passage and a novel control word that infants had not heard before. The interstimulus interval of the test trials lasted 2000 ms.

Phase	Auditory stimuli
Familiarization Phase	Aus **Zink** stellt man dünnen Draht her. Das **Zink** ist ein Element. Er löffelte **Zink** in ein Gefäß aus Plastik. Er stellte das **Zink** in ein Regal. Der Professor zündete das **Zink** an. Manche Menschen nehmen viel zu wenig **Zink** zu sich. Er füllte das Glas mit **Zink**. Auf dem Tisch stand **Zink**.
Test Phase	Zink Nut Nut Zink

Figure 10 Schematic of the experimental procedure.

Each infant was tested individually in a separate, quiet room seated on their parents' lap about 60 cm apart from a laptop monitor which was playing a silent children's movie. In addition, one of the experimenters stayed in the room playing silently with the infant for the entire duration of the experiment. The stimuli were presented by a loudspeakers located above the laptop computer.

Across infants, we counterbalanced which words were presented during the familiarization phase, and which were presented as novel control words in the test phase. Furthermore, we counterbalanced across infants which words were presented in standard German IDS, and which were presented in exaggerated IDS. Hence, any differences in ERPs to the isolated tokens of the familiarized words and novel control words could not be a result of a preference for the sounds of one word relative to the other, but rather due to infants' exposure to the words alone.

4.3.4. EEG recording and analysis

Data were recorded with a Biosemi Active Two Amplifier System using infant brain caps with 32 Ag/Ag-CL electrodes according to the 10-20 international convention at a sampling rate of 2048 Hz. Impedances were kept below 30 kΩ. Electrodes were re-referenced offline to the right and left mastoid. Data were filtered offline using a 0.1 Hz high-pass and 30 Hz low-pass filter. The sampling rate was reduced to 250 Hz. Baseline correction was performed with regard to pre-stimulus activity from 200 ms before the stimulus onset to the stimulus onset. For each trial, an automatic artifact rejection excluded trials where the voltage threshold exceeded 150 µV for the mastoid electrodes and the left eye electrode from 200 ms before the stimulus onset to 800 ms after the stimulus onset. In addition, all trials were manually screened for drifts and movement artifacts. Importantly, we only included data of infants who contributed at least 10 trials for each condition.

ERPs were time-locked to the onset of the words in the test phase and averaged across familiarized and control words separately for the exaggerated and standard German IDS condition. We focused our analyses on two time windows based on the ERP literature on speech segmentation reviewed above. In particular, we examined an early window (200-300ms), and a late time window (600-700ms) in each condition. For analyses, we combined four electrodes of three different regions:

Frontal and fronto-central (F3, F4, FC1, FC2), central and central-parietal (C3, C4, CP1, CP2), and parietal and parietal-occipital electrodes (P3, P4, PO3, PO4). These three different quadrants were included in a 3x2x2x2 repeated-measures ANOVA with the within-subject factors *region* (fronto-central, central-parietal, parietal-occipital), *hemisphere* (left, right), *register* (exaggerated IDS, typical IDS), and *word familiarization* (familiarized, novel control) for each of the two time windows.

4.3.5. Mother-child interaction

Prior to each EEG recording, the mother and the infant were left alone and video-recorded for the duration of 8 minutes. For the first four minutes, mothers were asked to look at a children's book together with their child whereas during the second half, mothers were given toy cubes to play with their infant (see Figure 11). Importantly, mothers were not told the purpose of the recording.

Figure 11 Mother and infant looking at a book during the mother-child interaction.

All utterances of the mother were transcribed for each mother-child interaction. Trained coders identified the number of syllables within each utterance, the number of isolated target words, repetitions of isolated target words, as well as the number of target words in sentences and repetitions of those target words within sentences. All recordings were also analyzed for mean, minimum, and maximum pitch, pitch range and utterance duration. In addition, a coder scored the number of times mothers pointed at different objects throughout the entire interaction, the number of times infants followed their mothers' pointing and the amount of time infants took to react to the point through an adjustment of their gaze to the area pointed at.

4.3.6. Vocabulary assessment

Parents were asked to complete the ELFRA, a German vocabulary checklist for infants aged 12 to 24 months, when infants turned 12 and when infants turned 18 months. The questionnaire provides an estimate of infants' receptive and productive vocabulary at these ages respectively.

4.4. RESULTS

According to previous neurophysiological research on infant speech segmentation, we analyzed infants' ERP responses during an early (200-300ms), and a late time window (600-700ms).

4.4.1. Early window: 200 to 300 ms

A 3x2x2x2 repeated-measures ANOVA of the 200 to 300 ms epoch with the within-subject factors *region* (fronto-central, central-parietal, parietal-occipital), *hemisphere* (left, right), *register* (exaggerated IDS, typical IDS), and *word familiarization* (familiarized, novel control) revealed a significant main effect of *region*, $F(2, 40) = 36.91$; $p < .001$; $\eta_p^2 = 0.649$, a marginally significant interaction between *register* and *word familiarization*, $F(1, 20) = 4.27$; $p = .052$; $\eta_p^2 = 0.176$, and a significant interaction between *region* and *hemisphere*, $F(2, 40) = 5.47$; $p = .008$;

η_p^2 = 0.215. There were no other main effects or interactions found (all *p* values > .195).

Splitting by register, a 3x2x2 repeated-measures ANOVA with the within-subject factors *region* (fronto-central, central-parietal, parietal-occipital), *hemisphere* (left, right), and *word familiarization* (familiarized, novel control) revealed a significant main effect of *region,* $F(2, 40) = 25.71$; $p < .001$; $\eta_p^2 = 0.562$, a significant main effect of *word familiarization,* $F(1, 20) = 4.43$; $p = .048$; $\eta_p^2 = 0.181$, a marginally significant main effect of *hemisphere,* $F(1, 20) = 4.27$; $p = .052$; $\eta_p^2 = 0.176$, and a significant interaction between *region* and *hemisphere,* $F(2, 40) = 4.33$; $p = .020$; $\eta_p^2 = 0.178$, for the exaggerated IDS register. ERPs to familiarized words were more negative relative to control words 200-300 ms after test word onset. This indicates that infants successfully segmented the familiarized words from the exaggerated IDS sentences and recognized these words later in the test phase. No other main effects or interactions were found (all *p* values > .632).

For the typical IDS register, a 3x2x2 repeated-measures ANOVA with the within-subject factors *region* (fronto-central, central-parietal, parietal-occipital), *hemisphere* (left, right), and *word familiarization* (familiarized, novel control) revealed a significant main effect of *region,* $F(2, 40) = 17.84$; $p < .001$; $\eta_p^2 = 0.471$, and a significant interaction between *region* and *hemisphere,* $F(2, 40) = 3.74$; $p = .032$; $\eta_p^2 = 0.158$. No other main effects or interactions were found (all *p* values > .149). This suggests that infants were not able to segment the familiarized words from typical German IDS sentences.

Furthermore, we conducted paired-samples t-test to compare infants' neural responses to the exaggerated IDS register and the typical IDS register. There was a significant difference in neural responses to the test words of the exaggerated IDS register and the typical IDS register, $t(21) = -2.46$; $p = 0.023$; $d = 0.621$. However, neural responses to the control words did not differ between the two registers, $t(21) = 0.50$; $p = 0.621$; $d = -0.146$. This confirms that infants processed the test words of the exaggerated IDS register differently than the test words familiarized in the typical IDS register and ensures that the control words of the two different registers were perceived similarly.

4.4.2. Late window: 600 to 700 ms

For the 600 to 700 ms epoch, a 3x2x2x2 repeated-measures ANOVA of the 200 to 300 ms epoch with the within-subject factors *region* (fronto-central, central-parietal, parietal-occipital), *hemisphere* (left, right), *register* (exaggerated IDS, typical IDS), and *word familiarization* (familiarized, novel control) was conducted and revealed a marginally significant interaction between *region* and *register* $F(2, 40) = 3.21$; $p = .051$; $\eta_p^2 = .138$, and a marginally significant main effect of region, $F(2, 40)=3.22$; $p = .076$; $\eta_p^2 = .139$. There were no other main effects or interactions (all p values > .124). This indicates that there were no differences in the ERPs for the familiarized words and the novel control words for both the exaggerated and the typical IDS register.

4.4.3. Relationships between infants' speech segmentation abilities and the quality of mother's input

We ran bivariate correlations between the difference in ERPs to familiarized words in the exaggerated IDS register and the familiarized words in the typical IDS register and the physical and social characteristics of mother-child interactions to investigate the impact of the quality of mother's input on infants' ability to segment words from fluent speech. Thus the difference in ERPs to familiarized words in the exaggerated IDS register and familiarized words in the typical IDS register across the three different quadrants in the 200-300ms time window was our measure of infants' speech segmentation ability. There was a significant positive correlation between infants' speech segmentation and the duration of mother's utterances, $r(21) = 0.50$, $p = .021$. Since speech segmentation is indexed by increased negative potentials to familiarized words relative to control words, this positive correlation implies that infants, whose mothers tend to use longer utterances, were better at segmenting typical German IDS. Furthermore, infants' segmentation skills in also correlated significantly with pitch range, $r(21) = -0.48$, $p = .028$. Hence, infants, whose mothers use a wider pitch range, were better able to segment typical German IDS.

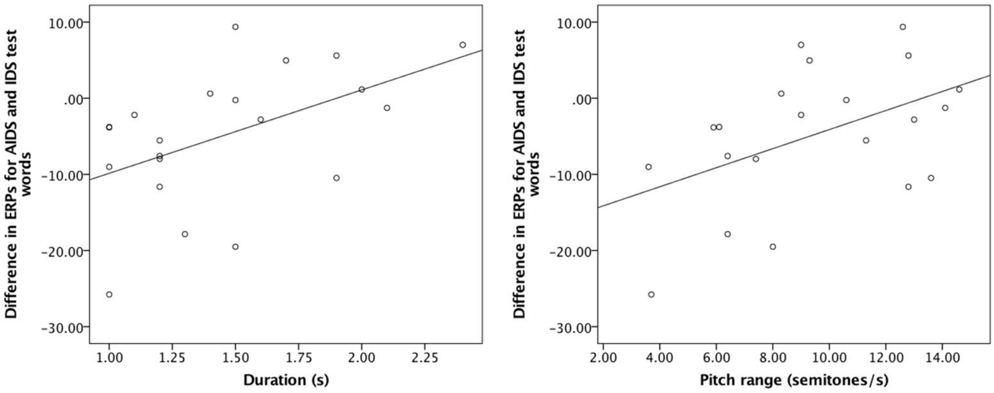


Figure 12 **Correlation between infants' segmentation ability at the central-parietal area and the duration and pitch range of their mothers' speech.**

4.4.4. Relationship between speech segmentation abilities and later vocabulary size

A number of studies report that infants who are better able to segment words at a particular time-point have larger vocabularies later in life (Junge et al., 2012; Kooijman, Junge, Johnson, Hagoort, & Cutler, 2013; Newman et al., 2006). To test this possibility, we collected parental reports of infants' receptive and productive vocabularies at 12 and 18 months (see Table 6). We found only one marginally significant correlation of segmentation of exaggerated IDS (as indexed by ERPs) and infants' overall vocabulary at 12 months, ($r(19) = 0.43$, $p = .065$). This suggests that infants, who were better able to segment exaggerated IDS at 7.5 months, had lower vocabulary sizes at 12 months. There were no other significant correlations between infants' vocabulary scores and their ability to segment words from exaggerated IDS and typical German IDS (all *p* values > .108).

Table 6 Receptive, productive and overall vocabulary scores reported by parents for their infants at 12- and 18-months of age.

	12		18	
	M	*SD*	*M*	*SD*
Receptive vocabulary	43.22	36.09	32.59	29.28
Productive vocabulary	4.44	4.29	32.59	29.10
Overall vocabulary	47.67	38.17	107.82	20.09

4.4.5. Relationship between structural features of the mothers' speech and infants' later vocabulary size

We further examined the frequency with which mothers produced target words in isolation and repeated these target words, and the extent to which such structural features of mother-child interaction correlated with later vocabulary development (see Table 7). Infants' productive vocabulary size at 12-months was positively correlated with the number of target words produced by the mother in isolation at 7 months, $r(19) = 0.53$, $p = .019$. However, at 18 months, infants' receptive vocabulary size was negatively correlated with the number of target words produced in isolation at 7 months, $r(18) = -0.61$, $p = .008$. That is, the more target words the mother had used in isolation at 7 months, the fewer words were reported to be understood by the child at 18 months of age. In addition, overall vocabulary size at 12 months correlated marginally significantly with the number of repetitions of target words produced by the mother at 7 months, $r(19) = 0.45$, $p = .051$). Hence, infants, who were presented with more repetitions of words at 7 months, had higher overall vocabulary knowledge at 12 months. Similarly, the number of repetitions of target words was significantly correlated with the productive vocabulary outcome at 18 months, $r(18) = 0.47$, *p* = .049. Furthermore, productive vocabulary outcome at 18 months correlated significantly with the number of repetitions of target words produced by the mother at 7 months, $r(18) = 0.53$, $p = .024$.

Table 7 Mothers' use of target words in isolation and in sentences and repetition of these in isolation and in sentences.

	number of target words	
	M	*SD*
in isolation	4	2.56
in sentences	14.62	6.90
repeated in isolation	1.57	3.13
repeated in sentences	14.14	9.06

4.5. DISCUSSION

Previous research examining the quality of maternal input to infants has revealed considerable individual variation in the prosodic characteristics of speech to infants. Furthermore, given that infants are better able to segment words from fluent speech that is more exaggerated, the current study set out to evaluate the extent to which individual variation in the quality of mother's input impacts infants' segmentation of words from fluent speech. In particular, we examined infants' segmentation of words from fluent speech in two different kinds of speech registers: Exaggerated IDS and standard German IDS. Studies using behavioral paradigms suggest that German infants at the age of 9 months are able to segment words from fluent exaggerated IDS, but not, however, at 7.5 months of age (Schreiner & Mani, 2017). Furthermore, German infants around this age only seem to be able to segment words from typical German IDS when also presented with additional cues, e.g., prior familiarity with similar-sounding words, longer familiarization with the words (Altvater-Mackensen & Mani, 2013; Schreiner, Altvater-Mackensen, & Mani, 2016). Against this background, by examining infant ERPs to familiarized words in fluent speech we hoped to obtain a more sensitive measure of infant speech segmentation. In addition, we recorded mother-child interactions to examine the physical and social characteristics of individual mother's speech to their infant. Correlations between infants' segmentation abilities and the prosodic and structural characteristics of mothers' speech explored potential relationships between the infants' ability to segment speech and the quality of their mother's input.

4.5.1. Infant word segmentation and the quality of mother's input

Since previous work suggests potential relationships between the quantity and the quality of the input and infants' language outcomes (Greenwood et al., 2011; Hart & Risley, 1995; Shneidman & Goldin-Meadow, 2012; Song, Demuth & Morgan, 2010; Weisleder & Fernald, 2013), we asked whether the quality of the mothers' input to her child might also impact infants' ability to segment words from fluent speech. The results of the current study suggest that infants benefit from certain characteristics of IDS. In particular, infants whose mothers used longer utterances were better able to segment words from fluent typical IDS. What remains to be seen, however, is the extent to which longer utterances are indicative of a slower speech rate or increased number of words per utterance. On the one hand, a slower speech rate has been identified as a critical feature of IDS and is also found to improve infants' ability to recognize the referent of a label (Song, Demuth & Morgan, 2010. This would suggest that infants are better able to segment words from typical German IDS when their mothers tend to speak slower. On the other hand, increase in the number of words presented in an utterance increases the amount of statistical information that is available to the child, and therefore, offers greater opportunity for learning (c.f., Saffran, Aslin, & Newport, 1996). Furthermore, longer utterances may also provide more syntactical and contextual cues and, hence, facilitate infants' ability to segment words from fluent speech.

Our study also found that the mothers' use of a wider pitch range positively impacted infants' segmentation of words from fluent speech. We explain this finding with recourse to attention-based theories of the impact of IDS on language learning (Kuhl, 2007). In particular, we suggest that this wider pitch range might increase infants' attention to the presented stimuli due to the greater salience of the changing pitch of the speech presented, and, consequently, help the infant to better extract words from fluent speech.

In addition to the prosodic features analyzed above, the structural characteristics of mothers' speech to her infant also impacted infants' vocabulary skills later in life. In particular, we found that the use of isolated tokens and the amount of repetition of isolated tokens significantly influenced infants' later vocabulary outcomes. Infants whose mothers produced more isolated tokens in speech and who repeated these tokens more had larger vocabularies at both 12- and 18-months of age. This, in part, supports the findings of Brent and Siskind (2001) who suggest that exposure to isolated words boosts later vocabulary skills and highlights the relevance of these structural characteristics of IDS. This is also in keeping with the findings of Lew-Williams, Pelucchi, and Saffran (2011) that similarly suggest that the use of isolated tokens in speech and – in the current study – lengthier utterances facilitate infant word segmentation.

Finally, we note that the analyses reported here are carried out on cross-sectional data, which does not allow us to draw strong conclusions about the direction of the influences reported. For instance, it is possible that infants who are better able to segment words from fluent speech drive their mothers to use longer utterances, due to their being able to understand such utterances. It remains critical, therefore, that in addition to analyzing the prosodic and structural features of the mother's input at a certain time, we further need to collect longitudinal data to unravel the relationship between infants' speech development and the impact of the mother's speech on the aforementioned.

4.5.2. Infant word segmentation from exaggerated German IDS

Another important finding of the current study was that infants of 7.5 months of age showed a different neural response to familiarized compared to novel control words. In particular, they had a more negative neurophysiological response to familiarized words than to novel control words, which suggests that infants succeeded in recognizing the words previously presented to them in the familiarization phase. Importantly, infants succeeded in segmenting words only from the exaggerated IDS register.

In comparison with other ERP word segmentation studies, it appears to be the case that the time window showing significant differences between familiarized and control words is rather small. However, we note that other studies have also reported two separate effects similar to the ones in the current study (Junge, Cutler, & Hagoort, 2014; Zangl & Mills, 2007). In particular, the N200-300 found in our study has been previously linked to word recognition and has been reported in other infant studies (Kooijman, Junge, Johnson, Hagoort, & Cutler, 2013; Männel & Friederici, 2013). Furthermore, the finding that the direction of this effect replicates that found in previous studies, with increased negative potentials to familiarized words relative to control words supports the comparison of the current findings to previous studies.

The results of successful segmentation only from exaggerated IDS underline the fact that German infants at 7.5 months might need additional cues in order to segment words from fluent speech. This finding is in line with previous behavioral studies on German infants' speech segmentation. For instance, Altvater-Mackensen and Mani (2013) found that infants were only able to demonstrate segmentation of words from fluent speech if they had been previously familiarized with similar sounding words. Similarly, even older infants at 9 months of age in Schreiner, Altvater-Mackensen, and Mani (2016) were only able to segment words from fluent speech when they had been familiarized with these words over a 6-week-period at home. Finally, infants at 7.5 months of age did not show successful segmentation of words from fluent speech even when tested on a more exaggerated IDS register, similar to that of American English, while 9-month-olds were able to (Schreiner & Mani, 2017).

Hence, the finding of successful segmentation abilities from exaggerated IDS in 7.5-month-old German infants has important implications for our understanding of the linguistic development of German infants. First, it suggests that the cross-linguistic differences between American English and German infants' ability to segment speech may lie in the difference of IDS modulations in the two languages. In addition, it appears that German infants just seem to be unable to demonstrate this ability in the context of the preferential listening paradigm (Schreiner & Mani, 2017). Secondly, it underlines the fact that the use of different methodologies might yield different results.

The familiarity effect reported in the current study supports models of IDS as an attentional spotlight (Kuhl, 2007). That is, the use of a more exaggerated speech, such as a wider pitch range, which is very typical for IDS, may drive and maintain infants' attention to the relevant stimuli and, hence, enhance infants' ability to extract the individual words within a fluent speech stream.

The failure to find any potential relationship between infants' segmentation abilities of fluent speech and later vocabulary outcomes (e.g., Junge, Kooijman, Hagoort, & Cutler, 2012) may, in part, be due to the weak reliability of parents' reports on their infants' comprehension skills (Friedrich & Friederici, 2006, 2010; Mills et al., 2005; Rämä et al., 2013; Torkildsen et al., 2006, 2008, 2009). We suggest, therefore, that the absence of a significant relationship between infants' segmentation skills and later vocabulary sizes has to be treated with caution.

Nevertheless, the marginally significant correlation between infants' segmentation abilities of exaggerated German IDS and infants' later language outcomes might suggest that infants who need a more exaggerated IDS in order to process segment words from fluent speech, may have smaller vocabularies later in life. Since these infants show improved recognition of words in exaggerated IDS, a register which does not exist in typical German adult-infant dyads, they might be slower in their vocabulary development – given that they are not exposed to such exaggerated IDS in their daily interactions.

4.6. CONCLUSION

The current study explored the potential impact of the quality of the maternal input on 7.5-month-old German infants' word segmentation abilities using ERPs. Significant correlations between infants' segmentation abilities and the quality of the mothers' input highlight the importance of IDS in early language acquisition, while improved understanding of the relationship between these two variables, we suggest, requires further analyses of longitudinal data.

In addition, contrary to previous research on word segmentation abilities in German infants, the results suggest that German infants at 7.5 months of age are able to segment exaggerated IDS. This finding suggests that the cross-linguistic differences in infants' ability to segment fluent speech may lie in the difference of IDS modulations. In addition, it might also in part be due to methodological sensitivities, which should be considered in future research on infants' segmentation abilities.

CHAPTER 5: THE IMPACT OF TEST REGISTER – 18-MONTH-OLD INFANTS LEARN WORDS FROM FLUENT ADULT-DIRECTED SPEECH

5.1. ABSTRACT

Most studies on early word learning suggest that it is not until relatively late in development that young children are able to learn novel word-object associations from adult-directed speech. We suggest that these studies may underestimate children's *learning* from ADS given that they typically test word learning in ADS. The current study, therefore, examined whether 18-month-olds were able to learn words from IDS and ADS with similar ease by training them on novel word-object associations in either register, but critically testing learning in both registers. Indeed, we found that children were able to learn word-object associations regardless of the register in which they were pre-exposed to the words and trained the object associations in – as long as they were tested in infant-directed speech. This result supports the idea of the beneficial role of infant-directed speech in early language acquisition in engaging attention to language, but at the same time finds that young children are able to learn from a much greater range of input than previously suggested.

5.2. INTRODUCTION

Infants learn their mother tongue with incredible speed and with apparently little effort. By around 10-months, they already show comprehension of around 35 words (e.g., Bergelson & Swingley, 2012; Jusczyk, 1997; Swingley, 2005). By 18-months, their established mental lexicon rapidly expands with infants producing up to nine new words each day – the onset of the so-called vocabulary spurt (Benedict, 1979; Carey, 1978; Goldfield & Reznick, 1990; Nelson, 1973). Numerous studies have examined the mechanisms underlying infant word learning at different ages using varied methodologies. However, the diversity in the input that infants are exposed to when learning new words requires greater attention. Furthermore, the findings on the role of pre-exposure to words and objects in infant word learning have been ambiguous. Against this background, the current study compares infants' word learning from two different kinds of input, namely infant- and adult-directed speech, whilst also examining the effects of pre-exposure to the phonological form of a word on infants' ability to recognize the correct referent of a previously learned word-object association.

5.2.1. Infants' word learning from infant- and adult-directed speech

Typically, adult native speakers of a number of languages address infants using a particularly exaggerated register of speech (Kitamarua, Thanavishuth, Burnham, & Luksaneeyanawin, 2002). Infant-directed speech (hereafter, IDS) has been widely studied and differs from the register of speech employed in normal communication between adults, i.e., adult-directed speech (hereafter, ADS), across several dimensions (Ferguson, 1964; Grieser & Kuhl, 1988). IDS includes various prosodic modifications such as higher pitch, longer pauses, and greater pitch ranges (Kuhl et al., 1997; see Cristia, 2013, and Soderstrom, 2007, for comprehensive reviews). Furthermore, IDS typically presents with shorter utterances and more repetitions of words relative to ADS (Fernald & Cummings, 2003; Fernald & Simon, 1984; Papousek, Papousek, & Haekel, 1987).

It has been often suggested that IDS attracts and maintains infants' attention to speech (e.g., Soderstrom, 2007). For instance, infants prefer listening to IDS over ADS from birth (Cooper & Aslin, 1990; Werker & McLeod, 1989), a finding which even extends to IDS in languages that infants have never heard before (Werker, Pegg, & McLeod, 1994). In addition, IDS also drives infants' social preferences such that infants at 6 months of age choose their interlocutors according to the register of speech used by these speakers. Thus, infants prefer looking at speakers who previously spoke in IDS with them relative to unfamiliar speakers, while preferring unfamiliar speakers over speakers who previously addressed them in ADS (Schachner & Hannon, 2011). Moreover, IDS has been shown to facilitate language processing with infants finding it easier to segment words from fluent IDS over ADS (Thiessen, Hill, & Saffran, 2005), even after a 24-hour delay (Singh, Nestor, Parikh, & Yull, 2009). The use of IDS in communication with infants has also been reported to boost infants' vocabulary knowledge (Fisher & Tokura, 1996; Vosoughi, Roy, Frank, & Roy, 2010; Weisleder & Fernald, 2013) and to predict infants' vocabulary size at an older age (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2013).

Up until now, studies examining infants' learning of novel word-object associations have typically examined such learning from IDS (e.g., Mani & Plunkett, 2008; Swingley, 2007). While these studies underline the ease with which young infants learn words in such laboratory-based situations, IDS constitutes a small percent of the input that the average infant is exposed to (Soderstrom, 2007; van de Weijer, 1998). In contrast, the findings of previous studies on infants' learning of word-object associations from ADS are quite varied.

Schafer and Plunkett (1998) report that 15-month-old infants can learn novel word-object associations from ADS in a fast mapping task. However, these findings are tempered by at least two constraints. First, infants were only presented with single instances of the target word in this study. In other words, infants were not faced with the arguably difficult task of segmenting words from a fluent ADS stream (cf. Mani & Paetzold, 2016). Second, infants were presented with the same sound-tokens in the training and test phase, thus relieving them of the task of generalizing across perceptually different tokens.

Indeed, other studies examining this issue report severe constraints on children's learning of novel word-object associations from ADS (Graf-Estes & Hurley, 2013; Ma, Golinkoff, Houston & Hirsh-Pasek, 2011). For instance, Ma and colleagues (2001) examined 21-month-olds' learning of word-object associations from IDS and ADS. Infants in two groups were presented with the identical sentence stimuli, recorded in IDS or in ADS. They find that while infants exposed to IDS successfully learned the word-object associations, infants exposed to ADS did not, until at least 27-months of age.

Similarly, Graf Estes and Hurley (2013) explored infants' learning of word-object associations from IDS and ADS using the switch task. Infants were introduced to two novel word-object associations through the simultaneous presentation of a single object and its label during training. At test, infants were either presented with the word-object pairing they saw in the training phase, i.e., same trials, or a combination of the object of one previously introduced word-object association and the label of the other previously introduced word-object association, i.e., switch trials. The expected index of successful learning was a difference in looking times at the object in switch relative to same trials. Similar to Ma et al. (2011), the 17.5-month-olds tested in this study fail to show learning of word-object associations for words presented in ADS; demonstrating longer looking during switch trials, relative to same trials, only in the IDS condition.

In all of the studies reviewed above, however, the register of speech presented at test is confounded with the register of speech presented during training. Thus, infants who were exposed to the novel word-object associations in ADS were tested on their knowledge of these word-object associations in ADS, and similarly so in IDS. In other words, the question remains open as to whether children find it difficult to learn words from ADS or whether children find it difficult to demonstrate their learning when tested in ADS.

A number of factors speak to the likelihood of this disassociation. Studies suggest that two-year-olds are even capable of learning words from overhearing two adults talking to one another (Akhtar, Jipson & Callanan, 2001; Gampe, Liebal, & Tomasello, 2012). This suggests that the process of *learning* may not require the infant-directed nature of training provided in word-learning studies to-date. However, successful performance at *test* relies on one-shot responding, i.e., we measure the child’s response to a heard label a few milliseconds after the label has been presented, where attention to the presented stimulus is critical. This attention may be increased when tested in IDS relative to ADS, leading to improved performance at test when tested in IDS. Indeed, recent studies from our laboratory suggest that attention to the presented stimulus may be a critical factor in determining infant processing of language in ADS (Schreiner, Altvater-Mackensen & Mani, 2016) – these studies find that infant segmentation and retention of words presented in an adult-directed speech stream – but not IDS – improves given increased attention to the stimuli being presented. Against this background, the current study examines the impact of speech register on infants’ learning of novel word-object associations, by separately examining the role of speech register on performance during training and test.

5.2.2. The role of pre-exposure in word learning

Infants are not always simultaneously presented with words and their referents in daily interactions (Brent & Siskind, 2001). Thus, it is likely that before infants are introduced to a novel word-object association, they have either seen the object or heard the intended label already. A number of recent studies have examined the impact of such pre-exposure to object and/or label on word-learning, with varied success.

In a study with 19-month-olds, Swingley (2007) pre-exposed infants to the phonological form of a word, which was later used as the label for a novel object. While toddlers who had been previously exposed to the words performed similarly at test relative to toddlers without such pre-exposure to the word, toddlers with pre-exposure to the word were better able to detect small mispronunciations of the target label relative to toddlers without pre-exposure. Thus, pre-exposure may help infants to pay more attention to the phonological detail associated with the novel labels.

Fennell (2012), in contrast, investigated the impact of pre-exposure to the object on word learning success. In his study, 14-month-old infants were pre-exposed to a novel object, whose label they were only later presented with. Fennell reports a positive effect of pre-exposure in that only those infants who had previously been exposed to the object could learn a novel label for the object and discriminate the label from subtle mispronunciations of the same.

Kucker and Samuelson (2012) familiarized infants with an object and/or a label before a word-learning task and investigated infants' ability to learn as well as retain these word-object associations after a 5-min delay. 24-month-olds were able to recognize the referent of a word immediately after the word-learning phase regardless of whether they had been familiarized with the object or label in the pre-exposure phase. However, after a five-minute delay, infants showed retention of the word-object association only if they had been pre-exposed to the object but not if they had been pre-exposed to the label. Furthermore, at a younger age, between 15- to 17-months, only infants who were pre-exposed to object and label showed learning of the word-object association at test (Altvater-Mackensen & Mani, 2013).

While the studies reviewed above have not explicitly examined the effect of pre-exposure in fluent speech, Graf Estes, Evans, Alibali, and Saffran (2007) investigated word learning following pre-exposure to words in fluent ADS. Here, 17-month-old infants were exposed to two different artificial language speech streams. Following this, infants were introduced to two novel word-object associations using the switch paradigm, where the labels had been previously presented to infants in the artificial language speech streams. At test, infants looked significantly longer at switch trials relative to same trials suggesting that they had learned the word-object association. This study suggests that 17-month-olds may use newly segmented words for later word learning.

In conclusion, the literature is divided with regard to the impact of pre-exposure on later learning. While some studies find positive effects of pre-exposure on learning itself, others find increased attention to the phonological detail associated with words or improved retention of these words with pre-exposure. Against this background, and given the focus of this study on examining infants' learning from fluent IDS and ADS, the current study will systematically examine the role of pre-exposure on infant word learning by presenting infants with pre-exposure to the label of one of the two novel word-object associations. Pre-exposure will be either in IDS or ADS before infants are trained and tested on their learning of the object associations for these labels.

5.2.3. The current study

In particular, we presented 18-month-old German infants with a word segmentation and word learning task, one after the other. Half of the infants were presented with one of the words-to-be-learned embedded in fluent ADS in the word segmentation task while the other half of infants were presented with the same stimuli in fluent IDS. Following this, those infants who were presented with fluent ADS were then trained on the object associations for the label they had been pre-exposed to as well as an additional novel label, in ADS. Similarly, those infants who were presented with fluent IDS were trained on the object associations for the two labels in IDS. We then tested infants on their recognition of *both* word-object associations in *both* IDS and ADS.

Based on studies examining infants' learning from overheard speech, we hypothesized that infants would learn the word-object associations regardless of whether they were introduced to these in IDS or ADS, albeit perhaps showing improved learning from the former register. We further predict an important role for the register at test in modulating infant performance, given that infants attend more to IDS relative to ADS and, therefore, may show improved performance in the former register. Given that infants at this late stage of development are not typically introduced to a speech segmentation task, it is difficult to predict performance in the pre-exposure phase. However, regardless of performance during pre-exposure, we predict that those infants who attend more to the stimuli during pre-exposure will show improved performance at test, perhaps more so in ADS relative to IDS (as found in Schreiner, Altvater-Mackensen & Mani, 2016). Finally, based on the studies reviewed above, we predict that infants will show improved learning of words they had been pre-exposed to relative to words they have not heard previously in the segmentation task. Of interest is whether pre-exposure to the labels interacts with the register of speech being tested and the outcome of such interactions.

5.3. METHOD

5.3.1. Participants

Forty-eight 18-month-old monolingual German infants comprised the final sample of children included in the study. Half of the children were boys and half were girls. Infants ranged in age from 524 to 592 days (17 months 6 days to 19 months 14 days) with a mean age of 551 days (18 months 8 days). An additional 21 children were tested but had to be excluded for different reasons: Failure to complete both word segmentation and word learning tasks (*n* = 14), insufficient eye-tracking data collection (*n* = 6), and distractions caused by a sibling (*n* = 1). Prior to the study, all parents were asked for written consent of their infant's participation. Infants were given a t-shirt or a book as appreciation for participation in the study.

5.3.2. Material and Design

Three different monosyllabic pseudo words were selected for the study: *Tork [tɔːk], Melp [mɛlp],* and *Narf [narf]*. One of these words was presented to infants in the familiarization and test phases of the segmentation task as the pre-exposed word. The other word was first presented to infants in the test phase of the segmentation task as a control word. The third word was presented only in the word learning task as a completely novel word whose referent association was to be learned. During this task, infants also learned a referent association for the word presented to them in the familiarization phase of the segmentation task. The occurrence of the novel words was counterbalanced across the speech segmentation task and the word learning task.

Two novel objects that infants were unlikely to be familiar with were used in the play phase so infants could play with the objects to be learned, while images and videos of these two objects were presented on-screen to infants during the word learning task.

The familiarization sentences of the segmentation task were recorded by a female speaker in two different speech registers, namely in typical German ADS and IDS (see Table 1 for prosodic characteristics). For the ADS stimuli, the female speaker was asked to produce the words and sentences as if speaking to an adult. Conversely, for the IDS stimuli, the female speaker was asked to imagine herself speaking to an infant. Each infant was randomly assigned to one of the two conditions: the ADS condition or the IDS condition. The same speaker also recorded the stimuli for the word learning task (see Table 8) in either IDS or ADS.

Table 8 Prosodic characteristics in Hertz and duration in seconds for the stimuli of the speech segmentation and word learning task.

	mean pitch		**duration**	
	M	*SD*	*M*	*SD*
IDS	242.79	27.52	3.87	0.59
ADS	178.07	10.80	2.12	0.34

5.3.3. Procedure

The study consisted of two parts that were completed one after another on the same day. During the first part, infants were presented with a modified version of a speech segmentation task (see Schreiner, Altvater-Mackensen, & Mani, 2016; for a similar procedure), whereas during the second part, infants participated in a word learning task (see Figure 13 Schematic of the experimental procedure.).

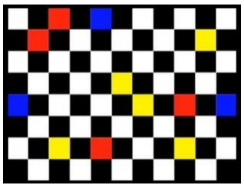
Task	Phase	Visual stimuli	Auditory stimuli
SEGMENTATION TASK	*Familiarization Phase*		The Narf has a brilliant idea. The Narf wants to be on the chair. Excited the Narf opens the present. The Narf doesn't like the music. Many people know the nice Narf. The game was won by the Narf.
	Test Phase		Narf, Narf, Narf, ... Melp, Melp, Melp, ... Narf, Narf, Narf, ... Melp, Melp, Melp, ...
WORD LEARNING TASK	*Interactive Play Phase*		none
			
	Familiarization Phase		Oh, look. You know this!
			Hey, watch. Do you remember this?
	Training Phase		This is a Narf. The Narf.
			This is a Tork. The Tork.
	Test Phase	 	Where is the Narf? The Narf!
		 	Where is the Tork? The Tork!

Figure 13 Schematic of the experimental procedure.

Each infant was tested individually in a separate, quiet room either seated by herself strapped into a car seat or on the parents' lap about 60 cm apart from a large monitor. In addition, two digital video cameras above the monitor recorded infants' eye-movements during the experiments. Synchronized signals from the two cameras were transmitted via a digital splitter to provide two separate time-locked images of the infant, which were used for online scoring during the segmentation task. At the same time, an automated eye-tracker continuously monitored children's eye movements across the screen throughout the experiment.

5.3.4. Task 1 – Speech segmentation task

A blinking checkerboard was displayed on-screen throughout the presentation of the auditory stimuli through loudspeakers that were situated above the television screen. We monitored infants' fixations to the screen as an index of infants' preference for listening to the auditory stimuli. During the first half of the speech segmentation task, infants were presented with a single novel word embedded in sentences. Infants listened to a total of 12 familiarization trials or until they accumulated 100 s of listening time to the sentences. Each trial consisted of six familiarization sentences and continued until the end of the passage of six sentences or infants looked away from the screen for more than 2 s. Infants were presented with two different kinds of trials, each of which presented them with passages of six sentences containing one and the same novel word (see Appendix). Following this phase, infants listened to three test blocks containing two trials each. One trial presented infants with isolated tokens of the familiarized word and the other trial presented infants with isolated tokens of a novel control word. Five different isolated tokens were selected and repeated three times leading to a total of 15 repetitions of the isolated word in each trial. As in the familiarization, each test trial continued until the end or infants looked away from the screen for more than 2 s. Parents wore head phones during the experiment to limit any systematic influence on their infant's behavior.

5.3.5. Task 2 – Word learning task

Following completion of the speech segmentation task, infants returned to the play room to start with the second task, a word learning task.

Interactive play phase. Back in the play room, the experimenter introduced two novel objects one after another to the infant and interacted freely with her. Importantly, the experimenter did not speak with the infant - as far as possible - in order to prevent any object preferences that could be driven by the use of IDS. A camcorder was used to record the interactive play phase. After the infant and experimenter had played with each object for 2.5 min, the experimenter asked the infant and the parent again to move to the adjacent experimental room. Once more, the infant was either seated individually in a car seat or on the parent’s lap. Again, parents were asked to wear headphones during the experimental procedure.

Familiarization phase. Next, infants were presented with on screen images of the two different novel objects they had just been exposed to during the interactive play phase. The images were displayed individually in the center of the screen. The object remained still for the first 1000 ms, while rotating on the vertical axis of the screen for the remaining 4000 ms. Each object was presented once during the familiarization phase. During the visual presentation of the objects, a female voice directed infants to look at the objects in either an adult- or an infant-directed manner.

Training phase. During training, infants were introduced to two different novel word-object-associations. Importantly, the infant had already been exposed to one of the two words used for the word-object association during the speech segmentation task. The two objects were individually displayed on the center of the screen for 5000 ms. The object remained still for the first 1000 ms, while rotating on the vertical axis of the screen for the remaining 4000 ms. Sometime after the onset of the visual stimulus, infants were presented with the label for this object embedded in a sentence with the first presentation of the label at 2500 ms and the second token of the novel word at 4000 ms. The register of speech was identical to the register of speech used in the speech segmentation task. Each of the novel word-object-associations was presented twice.

Test phase. At test, both objects were presented simultaneously side-by-side on screen for 5000 ms. Infants were then directed to look at one of the objects using its label embedded in a carrier phrase such that the first instance of the label was at 2500 ms, followed by a single instance of the label in isolation at 4000 ms. Infants were tested on each of the two word-object associations twice in each speech register leading to eight different trials: Two for the first word-object association in ADS, two for the second word-object association in ADS, two for the first word-object association in IDS, and two for the second word-object association in IDS.

The training trials and the testing trials were presented in a block, with each block being presented twice. Importantly, the familiarization and the training phase of the word learning task were presented in the same speech register as the segmentation task. Hence, infants who had listened to the novel words in ADS during the segmentation task were also presented with the familiarization and training phase in ADS. Infants who had been exposed to IDS in the speech segmentation task were also exposed to IDS in the familiarization and training phase of the word learning task. The only phase that did not differ across conditions was the testing phase. Babies were tested on the two word-object associations in both ADS and IDS, regardless of what they had listened to earlier.

Across infants, we counterbalanced which word was presented during the familiarization phase, which was presented as novel control word in the test phase of the segmentation task, and which was presented as unfamiliar novel word in the word learning task. Thus, any differences in listening times to the isolated tokens of the words and differences in PTL could not be a result of a preference for the sounds of one word relative to the other, but rather due to infants' previous exposure to the words alone.

5.3.6. Coding and analysis

Segmentation task. The looking behavior of infants was assessed online using the digital stimulus presentation and scoring system Present (Meints & Woodford, 2008). The experimenter coded online whether the infant was looking at the screen or away at any point during the experiment. She was blind to the experimental condition as she wore headphones during the whole experiment. Later, the coding output was aligned with information about the phase and the condition of the experiment. For each infant, we calculated the mean listening times during the test phase for the isolated tokens of the familiarized word and novel control word.

Word learning task. Infants' eye-movements were analyzed using a Tobii eye-tracker which automatically provided us with data as to whether infants were looking at the left or right area of interest for each 8 ms frame of the trial. Based on this, we separately calculated the proportion of time that infants spent looking at the target object before the target word was named, i.e., the pre-naming phase, and after it was named, i.e., post-naming phase. In particular, for each test trial, we calculated the proportion of target looking (hereafter, PTL) for the pre- and post-naming phase by dividing the time infants spent looking at the target by the time infants spent looking at both, target and distractor. The pre-naming window counted all eye-movements that took place one second before the onset of the target word, whereas the post-naming window included all eye-movements beginning 233 ms after the onset of the target word till the end of the trial at 5000 ms. It is standard in the infant literature to use a delay to account for the time required to respond to a stimulus (e.g., Ballem & Plunkett, 2005). Recognition of the intended referent of the heard label was indexed by an increase in fixations to the labeled object from the pre- to the post-naming phase, $PTL_{post\text{-}naming}$ - $PTL_{pre\text{-}naming}$. We only included trials where infants looked at least once at the target and the distractor in the pre- and post-naming phase.

5.3.7. Vocabulary assessment

Parents were asked to complete a FRAKIS, a German vocabulary checklist for infants aged 18 to 30 months, on the testing date.

5.4. RESULTS

5.4.1. Segmentation task

We conducted separate t-tests for each condition to examine whether infants reliably segmented words from infant- and adult-directed fluent speech. For both the IDS and the ADS condition, there were no significant differences in looking times to familiarized versus control trials ($p_s \geq .77$; see Table 9).

Table 9 Infants mean looking times and standard deviations for test and control words in seconds.

	test		control		statistic	
	M	*SD*	*M*	*SD*	*t*	*df*
IDS	13.06	4.13	13.23	4.01	-0.18	24
ADS	12.61	4.44	12.90	4.13	-0.34	22

Investigating infants' listening times across the two different registers, IDS and ADS, an independent-samples t-test revealed significant differences in listening times in the familiarization phase ($t(38.733) = 5.82$; $p < 0.001$; $d = 1.66$). Infants in the IDS condition ($M = 18.66$, $SD = 5.05$) listened longer to the familiarization trials than infants in the ADS condition ($M = 11.82$, $SD = 2.89$).

5.4.2. Word learning task

A mixed-factorial ANOVA with the within-subject factors naming (pre-naming and post-naming), familiarity (familiar and unfamiliar label), and test register (IDS and ADS), and the between-subject factor familiarization register (IDS and ADS) found a significant interaction between naming and test register ($F(1, 46) = 6.28$, $p = 0.016$, $\eta_p^2 = 0.12$). Hence, we conducted further analyses for each test register separately running mixed-factorial ANOVAs with the within-subject factors naming (pre-naming and post-naming) and familiarity (familiar and novel label), and the between-subject factor familiarization register (IDS and ADS).

There was a significant main effect of naming when infants were tested in the IDS register ($F(1, 46) = 8.74$, $p = 0.006$, $\eta_p^2 = 0.16$), with infants looking more at the target in the post-naming phase relative to the pre-naming phase ($t(48) = -3.00$, $p = 0.004$, $d = -0.65$; see Figure 14). Importantly, there were no interactions between naming and familiarity or between naming and familiarization register, suggesting limited effects of pre-exposure to the label and familiarization register on learning success.

Analyses of the data from the ADS test register found no significant main effects or interactions between the factors examined ($p_s > 0.05$).

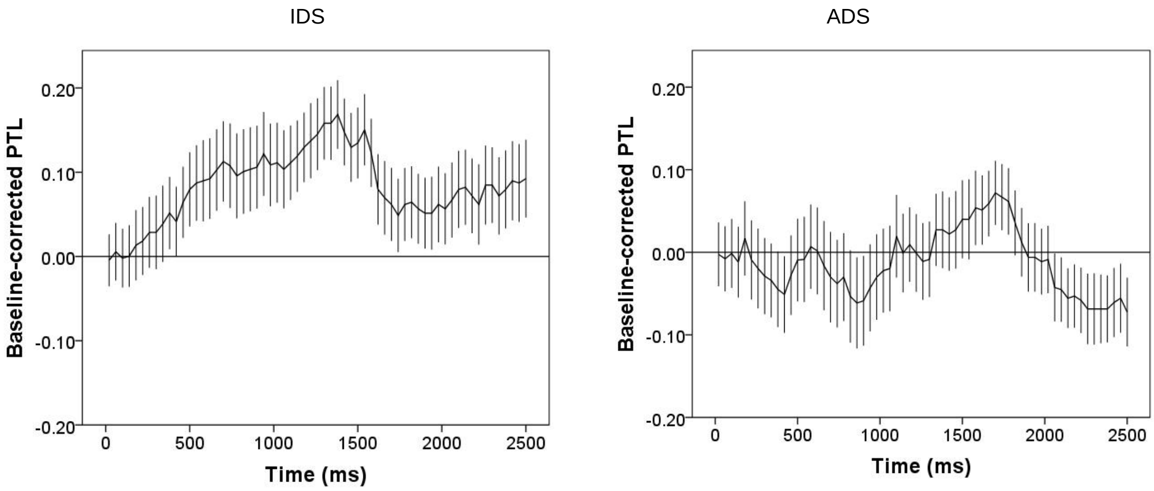


Figure 14 Baseline-corrected time course of infants' PTL in the IDS and ADS test register from onset of the label (error bars: +/- 1 SE).

We also examined infants' individual performance in the word segmentation and word learning tasks with regard to their receptive and productive vocabulary sizes. Parents reported receptive vocabulary sizes ranging from 68 to 573 words (*M* = 285.38, *SD* = 112.43) and productive vocabulary sizes ranging from 0 to 265 words (*M* = 74.81, *SD* = 79.15). Neither receptive nor productive vocabulary size correlated significantly with infants' ability to segment words from fluent speech, i.e., difference scores in listening times to the familiarized and control words in the segmentation task, and learn words from IDS or ADS ($p_s > 0.5$), i.e., difference scores in target looking times during the post-naming and pre-naming phase of the word learning task.

We further investigated the correlation between infants' performance in the word segmentation task and their performance in the word learning task. Difference scores in listening times to familiar and control words in the segmentation task correlated significantly with the naming effect for the pre-exposed label in the ADS condition ($r(23) = 0.46$, $p = 0.027$). This suggests that infants in the ADS condition, who were better able to segment the target word from fluent ADS in the speech segmentation task, were also better able to learn a referent for this pre-exposed word in ADS and more likely to demonstrate their knowledge of the object-label association when tested in ADS during the word learning task (see Figure 15). No such correlation was found for the IDS condition ($r(25) = 0.15$, $p = 0.462$).

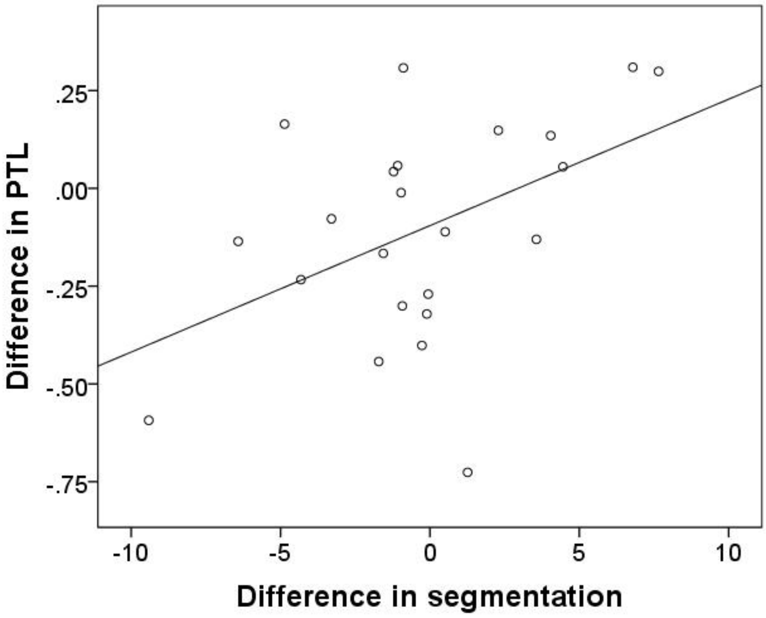


Figure 15 Relationship between difference scores for the segmentation task (in s) and difference scores for the word learning task in the ADS condition.

5.5. DISCUSSION

A number of studies have suggested that young children are better able to learn word-object associations from IDS relative to ADS (Graf-Estes & Hurley, 2013; Ma et al., 2011). Such constraints on early word learning stand in contrast to findings suggesting that children can even learn words by overhearing speech between two adults (Akhtar, Jipson & Callanan, 2001; Gampe, Liebal, & Tomasello, 2012) while implying severe limitations on the quality and quantity of input that infants can learn from. Against this background, the current study set out to re-examine infants' word learning from IDS and ADS. In particular, we asked whether infants' failure to display learning from ADS in earlier studies is a result of their inability to learn words from ADS or their inability to demonstrate this learning when tested in ADS. We examined this by training infants on word-object associations in either IDS or ADS and then testing their recognition of these learned associations in both IDS and ADS. We found that young children are, indeed, capable of learning from both kinds of input but that they are able to demonstrate this learning only when tested in IDS. Indeed, we found that the only factor that modulated learning success was the register at test – regardless of the register in which children were introduced to the label-object pairings or the amount of pre-exposure to the labels provided to the children. In what follows we discuss each of these findings in greater detail.

5.5.1. Learning words in IDS and ADS

Our finding that infants are able to *learn* words from IDS and ADS so long as their word knowledge is *tested* in IDS has important implications for our understanding of the kinds of input that infants are able to learn from. First, as noted above, this finding is consistent with studies showing that young children can even learn from overhearing speech between two adults (Akhtar, Jipson & Callanan, 2001; Gampe, Liebal, & Tomasello, 2012). In general, it appears that even young toddlers at 18-months of age are able to learn from both infant- and adult-directed input at least with regard to the acoustic characteristics of such input. In conjunction with the results of the current study, these findings suggest that infants are able to learn from a much greater range of input than was previously assumed and might go some way to explaining the explosion in children's vocabulary that takes place during the second year of life.

Our results also speak to models of language processing that, for instance, suggest that the child needs to be interested and attracted to speech in order to learn (Kuhl, 2007). Typically, children tend to be less interested and attracted to ADS relative to IDS (Cooper & Aslin, 1990; Pegg, Werker, McLeod, 1992). The fact that we found successful learning from ADS suggests either, that children can learn from interactions they may not be as interested in, or that older children may begin to attend to even such less engaging interactions. At least by 18-months, learning is not merely restricted to child-oriented interactions carried out in an infant-directed manner.

Indeed, this finding qualifies much of the previous literature on the benefits of IDS – suggesting an important distinction that has been missed to-date. It appears not to be the case that infants learn less robustly from less engaging speech registers but rather that they do not demonstrate such learning unless tested in a more engaging register of speech. In other words, while there are obvious benefits associated with IDS being addressed to infants, young children are able to learn with considerable ease from different kinds of input that have typically attracted less attention in the infant learning literature.

Nevertheless, the finding that the register at test is critical to demonstration of learning success highlights the benefits of such child-directed interactions. On the one hand, this finding is in keeping with research arguing for an important role for IDS in early language acquisition (Graf-Estes & Hurley, 2013; Ma et al., 2011; Singh, Nestor, Parikh, & Yull, 2009; Song, Demuth, & Morgan, 2010; Thiessen, Hill, & Saffran, 2005). Thus, while children may learn from speech presented in engaging and less engaging registers, children respond better to more engaging speech. One reason for improved performance when tested in IDS may be that the prosodic characteristics and simple, repetitive structure of IDS elicited infants' attention more than ADS (Kuhl, 2007), driving infants to respond to the task. Indeed, the fact that we found longer looking times in the familiarization phase for IDS relative to ADS in the segmentation task of the study supports this explanation for the results of the word learning study. Taken together, the increased attention to IDS across the two tasks of the study suggest that it remains critical to parent-child interactions to employ a more exaggerated register of speech in communications with young children.

Furthermore, we note that IDS is routinely directed to the infant while ADS is not (Cristia, 2013). While infants are frequently exposed to ADS (van de Weijer, 1998), and appear also to be able to learn from this register, they are rarely directly addressed using ADS. Thus, infants may learn over time that they are being directly spoken to in IDS and may consequently respond to this input with greater attention and be more engaged in responding to a conversational partner according to the register of speech they employ (Schachner & Hannon, 2011).

We also note that infants in the current study were able to generalize across speech registers, in showing recognition of a word they had been exposed to in one register when they heard it in a different register. Thus, infants who had only heard a word in ADS before, showed recognition of this same word in IDS and also recognition of the object association for this word in this new register. This finding is particularly remarkable especially given that research on infants' word learning abilities finds that, at 17 months, infants have difficulties in recognizing a word in unfamiliar sentence contexts because of coarticulation with the adjacent sounds (Plunkett, 1997). Indeed, previous work from our laboratory suggests that even younger infants, at 9-months of age, show similar flexibility in word recognition by generalizing across speaker-specific attributes in word recognition, by recognizing the same word spoken by two different speakers in a word segmentation task. Taken together, these findings highlight infants' flexibility with phonological representations of words going from word segmentation (Schreiner et al., 2016) to word learning.

Register overlap does appear to have its benefits for word recognition, however. Thus, we note that infants of the ADS condition, who attended longer to the familiarized test words relative to the novel control words in the segmentation task, were also better at learning and recognizing the word-object association of this familiarized word, when assessed in ADS. This finding would suggest that – for those infants who were more able to learn from ADS – familiarity with a word in ADS positively and exclusively impacts recognition of this word in the same register later. Taking this finding further, it would appear that these infants might also have greater opportunities to acquire novel lexical items given that they show increased dexterity with different kinds of input in language acquisition. We note, however, that this finding must be treated with caution – given that we found neither successful segmentation from ADS nor word recognition when tested in ADS.

5.5.2. Word segmentation from IDS and ADS

Surprisingly, the 18-month-old German infants tested in the current study did not appear to differentiate between familiarized test and novel control words in the test phase of the segmentation task in both, the IDS and ADS condition. This could further imply that 18-month-olds are unable to segment words from fluent speech regardless of whether this speech is presented in the infant- or adult-directed register. However, we note that this stands in contrast to previous findings suggesting that even younger German infants are able to segment words from fluent IDS (at 9-months: Schreiner et al., 2016) and ADS (at 16-months: Mani & Paetzold, 2016). We attribute these differences to two factors. First, we note that the current study employed a reduced version of the standard segmentation task, presenting children with just one familiarized and one novel control word. This entailed that infants were familiarized with a single target word embedded in fluent speech during the entire 100 s of the familiarization phase – as opposed to two target words each presented for roughly half the time in earlier segmentation tasks. It is likely that this increased exposure to a single target word negatively impacted segmentation performance due to children potentially being habituated to the target by the time they were presented with test trials. Additionally, we note that the children being tested in the current task were quite old and the task may, therefore, no longer be age-appropriate. Indeed, the presentation of a blinking checkerboard for the entire duration of the task may have bored the infants leading to a general disinterest in the task overall. Indeed, while these two factors may have separately influenced performance, it is also equally likely that the combined effect of these two factors resulted in the failure to find word segmentation at 18-months in the current task.

Nevertheless, we note two additional findings from the segmentation task that are of considerable interest. First, we found that infants listened longer to the familiarization stimuli in the IDS condition relative to the ADS condition. Thus, despite infants learning with equal ease from both IDS and ADS in the current study, we find that infants were more interested in IDS relative to ADS, supporting the notion of IDS as a tool to attract and maintain infants' attention in language (Saint-Georges et al., 2013; Soderstrom, 2007).

Second, as noted briefly above, difference scores in listening times to familiarized and control words in the ADS condition correlated with difference scores in target looking times in the pre- and post-naming phase, again in the ADS condition. This resembles a pattern of effects we have documented in earlier work (Schreiner, Altvater-Mackensen & Mani, 2016), where we found that infants who attend more to ADS (as indicated by parental ratings of infants' attention) were more likely to segment words from ADS as well. Here, we extend this finding to show that children who are more likely to segment words from ADS are more likely to learn word-object associations and demonstrate their knowledge of these word-object associations when tested in ADS. Thus, there appears to be a continued ADS advantage for some children, where those children who attend more to ADS segment words from this input better and thereby also learn word-object associations and recognize these newly learned word-object associations in ADS better. Further, we note that the fact that these correlations are consistently found only in ADS processing – and not in IDS processing –supports the notion of an IDS advantage in speech processing, since there does not appear to be such individual variation in learning from IDS. Further research is needed to identify the extent to which these different abilities in ADS processing correlate with one another and the extent to which such findings are limited to the processing of ADS.

5.5.3. Pre-exposure to phonological forms

The word segmentation task was employed not merely to examine children's segmentation of words from fluent IDS and ADS, but also to provide them with pre-exposure to the phonological forms of words before introducing them to the object referents of these words. There is some debate in the literature as to the impact of such pre-exposure on word learning, with some studies showing effects of pre-exposure on word learning per se, and others finding only effects of pre-exposure on children's sensitivity to changes to the phonological form of new words (Altvater-Mackensen & Mani, 2013; Swingley, 2007). Against this background, infants were first presented with the phonological form of a word in a segmentation task in either IDS or ADS. Following this pre-exposure, infants were exposed to two different objects in an interactive play phase which were both later used as referents in a word learning task. Importantly, the label for one of the referents in the word learning task was already familiar to the infant from the segmentation task whereas the label for the second referent of the word learning task was completely novel.

We did not, however, find any effects of pre-exposure to the phonological form of words on children's learning of object referents for these pre-exposed words. Thus, children showed similar effects of naming for words they had heard before in the word segmentation task relative to words they had not heard before and suggests that for children at 18 months, it is sufficient to hear the label for a word-object association during training for the first time.

One caveat to this finding is, obviously, the fact that we found no effect of children's sensitivity to the difference between familiarized and control novel words in the segmentation task. Therefore, it is likely that the absence of an effect of pre-exposure stems from children not paying any attention during the segmentation task, and consequently having little familiarity with the phonological form of the pre-exposed word during the word learning task. While we cannot conclusively argue against this possibility, we suggest it is unlikely that 18-month-olds paid no attention to the sounds presented in the segmentation task, given that they had 100 s of exposure to the critical word embedded in sentences and also heard this word in isolation at test at six times. Given this degree of exposure, it is likely that the children had some degree of familiarity with the words in the pre-exposure condition but that such pre-exposure minimally impacts word learning success (as in previous research, Kucker & Samuelson, 2012, Swingley, 2007).

Furthermore, we note that the current study does not systematically address the influence of pre-exposure to the objects of later learned word-object associations as infants were pre-exposed to both objects of the word-objects associations in the interactive play phase in order to maximize infants' interest in the task. Thus, our conclusions on the role of pre-exposure are limited to pre-exposure to the phonological form of the words alone.

5.6. CONCLUSION

Taken together, the current study suggests that infants at 18-months of age are not only able to learn words from IDS but also from the less engaging ADS register. Indeed, the current study unravels a critical confound in the literature to-date with regard to the register used at test and the register used in teaching children new words to suggest that children are able to learn from a greater range of input than has previously been suggested in some of the literature to-date. We have argued that such flexibility with different registers is more in keeping with research suggesting, for instance, that young children are even able to learn from overheard speech (Akhtar, Jipson & Callanan, 2001; Gampe, Liebal, & Tomasello, 2012).

Nevertheless, infants demonstrate successful learning – i.e., show their knowledge of a newly learned word-object associations – only if they are tested in IDS. This finding highlights, therefore, the role of IDS in facilitating language acquisition by attracting and maintaining infants' attention (Saint-Georges et al., 2013; Soderstrom, 2007;) and speaks to the notion of IDS as a means of engaging children's attention in language processing.

CHAPTER 6: SUMMARY OF EMPIRICAL FINDINGS

The current chapter will summarize each of the four studies conducted in this thesis. First, it will identify the empirical and theoretical gain in each individual study. Second, it will give a brief description of the methods used. Third, the results of each study will be presented and finally, the theoretical contribution will be described.

6.1. STUDY 1: EARLY WORD SEGMENTATION IN NATURALISTIC ENVIRONMENTS – LIMITED EFFECTS OF SPEECH REGISTER

The study presented in the paper by Schreiner, Altvater-Mackensen & Mani (2016) set out to further explore the following: a) infants' extraction and storage of words in long-term memory and b) their ability to use the variety of input available to them, namely IDS and ADS. While most studies to date have investigated infant word segmentation in the standard laboratory setting, the extended exposure at home employed in the first study of this thesis allows for conclusions on infants' learning in their natural environment. Moreover, a comparison of infants' segmentation abilities from fluent IDS and ADS provides more insight into which kinds of speech input, available in their natural environment, infants are able to learn from.

Using the modified version of the preferential-listening paradigm, we compared infants' segmentation abilities of IDS and ADS after an extended exposure in their own home. After listening to a pseudoword (hereafter referred to as extended-exposure word) embedded in stories over a 6-week period of time in their own home, infants were invited to the laboratory and presented with two different passages containing the extended-exposure word of the home-stories and another novel pseudoword (hereafter referred to as laboratory-familiarized word) which infants had not heard before. During the test phase that immediately followed the familiarization phase, infants were presented with isolated tokens of the extended-exposure word, the laboratory-familiarized word, and two novel control pseudowords, which infants had never heard before. We calculated the infants' mean listening times to all three kinds of words: The extended-exposure word, the laboratory-familiarized word, and the two novel control pseudowords.

The results of the study indicated that infants listened significantly longer to the extended-exposure words than to the novel control words and the laboratory-familiarized words, regardless of the speech register of the extended exposure at home. There was, however, no significant difference in listening times for the laboratory-familiarized and novel control words. These results suggest that 7.5- to 9-month-old infants are able to extract and store words presented to them during extended exposure to IDS and ADS at home. Importantly, infants already demonstrated a significant difference in listening times to the passages of the extended-exposure word and passages of the laboratory-familiarized word during the familiarization phase in the laboratory. This underlines the fact that the infants' extended exposure at home was sufficient for them to extract and store the words in long-term memory.

The finding of successful word segmentation from overheard IDS but also overheard ADS has important implications for our understanding of early language acquisition as it dramatically expands the language input that infants are able to learn from. Another important finding that adds to current models of language acquisition is that infants' abilities to segment the extended-exposure words correlated significantly with the parental reports on the amount of attention that their infants paid to the stories played in ADS at home. Hence, infants' overt attention to the ADS stories did impact their word segmentation success, whereas this was not the case for infants who listened to the stories in IDS. These findings underline the idea of IDS as an attention-driving tool without overt attention being required, whereas learning from ADS is shaped by infants' overt attention to the relevant speech stimuli.

6.2. STUDY 2: LISTEN UP! DEVELOPMENTAL DIFFERENCE IN THE IMPACT OF IDS ON INFANTS' SEGMENTATION

As the laboratory familiarization in Schreiner, Altvater-Mackensen and Mani (2016) and Altvater-Mackensen and Mani (2013) was not sufficient for German infants to segment words even from fluent IDS, the second study of this dissertation presented in the paper by Schreiner and Mani (2017) set out to examine whether the difference in IDS modifications across German and American English was a possible explanation for the cross-linguistic differences in infants' reported segmentation abilities (Jusczyk & Aslin, 1995). Successful word segmentation of exaggerated IDS by infants learning languages other than American English would, therefore, suggest that the different findings of the studies result from differences in the input they are commonly exposed to. If German learning infants were, however, not able to segment words from exaggerated infant-directed passages, this would suggest that there might be other cross-linguistic differences responsible for the different findings in German and American English infants' segmentation abilities. Exploring 7.5- and 9-month-old infants would also provide insights into potential developmental differences.

Infants were again presented with a modified version of the preferential listening paradigm. During the laboratory-familiarization phase, infants heard two different pseudowords, hereafter referred to as familiarized words, embedded in two passages of six different sentences recorded in an exaggerated IDS register. During the test phase, we measured infants' mean listening time towards isolated tokens of the two familiarized words and towards isolated tokens of two novel pseudowords, hereafter referred to as control words.

The results of the study indicated that 9-month-old infants were successfully able to segment words from the exaggerated IDS register. However, 7.5-month-old infants did not show a significant difference in listening time between familiarized and novel control words.

These findings suggest that, similar to 10.5-month-old British English infants (Floccia et al., 2016), German infants at an age even younger than 10.5 months benefit from an exaggerated IDS familiarization. Hence, at least for the 9-month-old age group, the differences in performance between German and American English infants lie in the difference of their IDS modifications. The results of the 7.5-month-old infants however demonstrate that the presentation of exaggerated IDS alone may not be adequate for all German infants across development and suggest that there must be other cross-linguistic and cross-cultural factors influencing younger infants' segmentation success. Nevertheless, the results of the 9-month-old infants of the current study support models of IDS as an attention-grabbing spotlight (Kuhl, 2007) and underline the idea that prosody severely impacts infants' early language processing (Morgan, 1996).

6.3. STUDY 3: THE IMPACT OF THE QUALITY OF MOTHER'S SPEECH ON INFANTS' SEGMENTATION ABILITIES

To further examine 7.5-month-old German infants' speech segmentation abilities, the third study of this dissertation, presented in the paper by Schreiner, Hildenbrand, and Mani (in prep), employed an ERP-task. As there seems to be considerable variation in the IDS of mothers, we also explored whether the properties of maternal input might impact on infants' segmentation success. The examination of

German infants' speech segmentation abilities is critical for the following two reasons. First, it further investigates a potential explanation for the cross-linguistic differences between German and American English. Secondly, it also allows for further exploration of individual variation in infants' segmentation abilities in relation to their IDS input. Therefore, the third study further adds to the discussion of the role of IDS in early language acquisition.

In the familiarization phase, infants were presented with sentences containing novel pseudowords, hereafter referred to as familiarized words. In the test phase, we measured infants' neural responses to isolated tokens of the familiarized words and novel control words that infants had never heard before. Importantly, half of the sentences were presented in typical German IDS whereas the other half were presented in an exaggerated IDS register that resembled American English IDS.

Infants demonstrated a more negative neural response to familiarized words that had been embedded in exaggerated infant-directed sentences than to novel control words. This effect was already present 200 to 300 ms after the onset of the words. Neural responses to words that had been familiarized in typical German IDS, however, were identical to the neural responses to novel control words. This indicates that infants were able to segment words from fluent exaggerated IDS but not from typical German IDS. Furthermore, there were significant correlations of the difference between neural responses to words familiarized with exaggerated IDS and typical German IDS and the duration of mothers' utterances. This difference score also correlated significantly with the mothers' pitch range. Hence, infants whose mothers used longer utterances with wider pitch range demonstrated better segmentation abilities of typical German IDS.

Contrary to the behavioral findings of 7.5-month-old German-learning infants' failure to demonstrate successful word segmentation from exaggerated IDS

(Schreiner & Mani, 2017), the third study of this dissertation suggests that German-learning infants are able to segment words from fluent speech. Differences in neural responses to familiarized and novel control words indicated infants' segmentation success. This finding has several implications for our understanding of word segmentation in German-learning infants. First, it supports the idea that differences in IDS styles across different languages may be a possible explanation for the cross-linguistic differences in infants' ability to segment. Secondly, there seem to be methodological sensitivities yielding different results across different paradigms. Finally, exaggerated IDS may be an important tool in German infants' segmentation abilities, guiding infants' attention to the relevant speech stimuli (Kuhl, 2007). Another important discovery of this study is that the quality of maternal input influences infants' abilities to segment fluent speech. That is, infants whose mothers' use longer utterances and wider pitch ranges find it easier to segment fluent IDS thus highlighting the importance of IDS in early language acquisition.

6.4. STUDY 4: THE IMPACT OF TEST REGISTER – 18-MONTH-OLD INFANTS LEARN WORDS FROM FLUENT ADULT-DIRECTED SPEECH

The final study of this dissertation reported in the paper by Schreiner and Mani (in revision) explored infants' word segmentation and subsequent word learning abilities in order to assess the effect of pre-exposure on word learning. If infants benefit from an extended exposure in segmenting words from fluent IDS and ADS, a pre-exposure to the phonological form of a word might similarly impact infants' abilities to add meaning to these previously segmented words, especially in regard to the ADS that infants start learning from relatively late. This again would considerably change our understanding of which kinds of language input infants are able to learn from.

Eighteen-month-old infants of the study were presented with the modified version of the preferential-listening task including a familiarization of a pseudoword, hereafter referred to as familiarized word, embedded in sentences. In the test phase, infants' listening times to isolated tokens of the familiarized word and isolated tokens of a novel control word were measured. After a 5-minute interactive play phase with two different novel objects, infants participated in a word learning task. They were trained on two different word-object associations of which one label consisted of the familiarized word from the familiarization phase of the preferential-listening task and the other label consisted of a novel pseudoword that infants had never heard before. Critically, infants were either trained in IDS or ADS. In the test phase, infants were presented with both objects from the training phase, side by side, and tested on their recognition of the previously learned word-object associations. Importantly, infants were tested in both IDS and ADS registers, regardless of the register of the training phase. The reason for using this method was to explore whether infants are unable to learn from speech samples presented in ADS in general or whether infants rather have difficulties in demonstrating their achievements when tested in the ADS register.

The results of this study suggest that infants were able to learn words regardless of the register they were trained in. That is, infants trained in IDS as well as infants trained in ADS had significantly higher PTLs towards the named object in the post-naming phase compared to the pre-naming phase, however, only if tested in the IDS register. Pre-exposure to the phonological word form in the preferential listening task did not seem to have an impact on infants' word learning success.

In line with the findings from successful word learning from overheard ADS (Akhtar, Jipson, & Callanan, 2001; Gampe, Liebal, & Tomasello, 2012), the results of the fourth study of this dissertation also suggest that infants are able to learn from a much greater variety of input available to them than previously suggested, extending the findings from word segmentation (Schreiner, Altvater-Mackensen, & Mani, 2016) to word learning (Schreiner & Mani, in revision). This study provides additional evidence that infants need to be attracted to language stimuli in order to learn. The fact that the register at test was critical to infants' demonstration of their learning success underlines the importance of IDS in early language acquisition. Moreover, the longer times spent listening to IDS rather than ADS stimuli during the familiarization time of the preferential listening task support the idea of IDS as an attention-grabbing spotlight (Saint-Georges et al., 2013).

CHAPTER 7: DISCUSSION

Infants are exposed to language even before birth (DeCasper & Spence, 1986) and demonstrate remarkable language skills from very early on. However, most of the research to date has focused on language learning from a limited portion of the input available to infants. Against this background, the current thesis examined the range of possible inputs that infants are able to learn from and the extent to which language learning is impacted by both the type of exposure and the factors related to infants and mothers. Empirical investigations were conducted to investigate infants' word segmentation and word learning abilities from different kinds of input. Critically, German-learning infants of the different studies were exposed to IDS, ADS, and exaggerated IDS that resembled the IDS style of American English.

There are two main conclusions that can be drawn from the studies presented in this dissertation. Firstly, infants are able to learn from ADS when exposed to this register of speech over an extended period of time. This suggests that infants are able to learn from a much larger repertoire of language input than previously assumed: Infants do not only learn from the small proportion of IDS directly addressed at the child but they may also learn from overheard input in the ADS register. This finding has important implications for our understanding of early language acquisition. In learning their first language, infants may be able to make use of all input. Even in the presence of adult conversations that are not directed at the infant, infants may overhear and use these adult-directed conversations for language learning. Secondly, young German infants don't seem to be able to segment words from typical German IDS given short-term laboratory familiarization. In the course of two studies, the difference in IDS modifications in German compared to American English was identified as a possible explanation for German infants' failure to segment words from typical German IDS in short-term laboratory familiarization contexts. The magnitude of the differences between IDS and ADS in the two languages is identified as potential explanation for the cross-linguistic differences between German and American English infants' segmentation abilities.

The first section of the discussion will explore the role of input in segmenting and learning new words. The second section will consider implications of the findings on current models of early language acquisition. Thirdly, the results will be examined in terms of infants' generalization abilities, that is the flexibility with which infants recognize words despite variation within the speech signal. The fourth section will discuss the different methodological implications of neurophysiological measures and extended naturalistic home exposure that can be taken from this dissertation. Finally, suggestions for future research on early word segmentation and word learning from different kinds of input will be presented.

7.1. WORD SEGMENTATION AND WORD LEARNING FROM DIFFERENT KINDS OF INPUT

7.1.1. ADS

The human brain consists of approximately 85 billion neuron cells (Williams & Herrup, 1988). The importance of neurons is reflected by the fact that the discipline of brain research, *neuroscience*, is named after them. Until recently, researchers assumed that the entire information transmitting process of the brain is conducted by these cells alone and directed their scientific attention towards neurons. However, there are other cell types in the brain as well. Remarkably, glial cells are represented in equal numbers in the brain as neurons (Azevedo et al., 2009). Despite their equal presence, research has focused on neurons for many years, missing the opportunity to learn about the importance of glial cells for the brain (Allen & Barres, 2009).

ADS can similarly be seen as the glial cells of infant language research: Studies focus mostly on IDS (Mani & Plunkett, 2008), even though, more than half of the input that infants hear consists of adult conversations (Soderstrom, 2008; van de Weijer, 1998). Indeed, even research on prenatal exposure indicate that before birth, the fetus is able to perceive language through the mother's womb, which is most likely to be comprised of ADS (DeCasper & Spence, 1986). As most of the research investigating early language acquisition is based only on IDS input (e.g., word segmentation: Singh, Reznick, & Xuehua, 2012; Pelucchi, Hay, & Saffran, 2009; word learning: Rost, & McMurray, 2009; Swingley & Aslin, 2000), we have vastly neglected to explore the role ADS might play in early language learning. Therefore, in a series of empirical studies, the current dissertation examined infants' word segmentation and word learning abilities from different kinds of input, importantly, including ADS.

The results of the study by Schreiner et al. (2016), which investigated word segmentation of IDS and ADS given extended exposure in infants' naturalistic environment at home but also short-term familiarization in the laboratory (see Chapter 2.1.), and by Schreiner and Mani (in revision), which examined infants' word learning abilities from IDS and ADS within a laboratory setting but critically tested infants in both register (see Chapter 2.3.), demonstrated that infants as young as 7.5-month-of age are able to learn from speech input presented in IDS but, critically, also in the ADS register. Specifically, the first study on word segmentation by Schreiner et al. (2016) suggests that German-learning infants segment words from fluent IDS and ADS provided they are exposed to the words embedded in stories over an extended period of time in their naturalistic environment at home. Importantly, this finding presents the earliest evidence of ADS word segmentation in the literature to date.

One potential reason for the previous failure in finding successful word segmentation from ADS (Singh et al., 2009; Thiessen et al., 2005) may be attributed to the fact that in previous studies, infants had only been familiarized short-term in the laboratory. Infants of the current study, however, were exposed to the ADS stimuli over an extended period of time. In addition, the familiarization was conducted in infants' naturalistic environment at their own home. Therefore, one potential explanation for infants' failure to demonstrate successful word learning from ADS in these previous studies could be the fact that they were not exposed to the familiarized words in their naturalistic home environment. A second potential explanation could be the fact that words were not familiarized over an extended period of time. Hence, future research is needed in order to disentangle the individual influence of naturalistic exposure at home and familiarization over an extended period of time.

The study on learning word-object associations from fluent IDS and ADS by Schreiner & Mani (in revision) also indicated that infants as young as 18 months are able to learn word-objects associations not only from IDS but, importantly, also from ADS. This finding also presents the earliest evidence of learning word-object associations from fluent ADS. However, infants were only able to demonstrate their learning if they were tested in the IDS register. This finding might suggest that the reason for previous studies' failure in finding successful learning from ADS may lie in confounding the register at training with the register at test (Graf Estes & Hurley, 2013; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011). In these studies, infants have always been tested in the same register as the word-object association had been trained in. ADS might provide useful input from which infants can learn with relative ease. But, without any additional contextual cues, test trials containing ADS might fail in informing the child that she is being talked to, making ADS an unsuitable register for testing word learning until at least 18 months. In contrary, IDS may evoke the child's attention, as she knows that IDS input represents language that is directly addressed to herself. This assumption will be discussed in more detail later in the discussion of current theories and models (see Chapter 3.2.2.).

The finding of successful word learning from IDS and ADS suggests that infants are able to learn from all the language input that they are presented with. Furthermore, it implies that previous research has most certainly underestimated the role of ADS in early language acquisition. Earlier research failing to find successful word learning from ADS may be attributed to the fact that infants have only been tested in the ADS register (Graf Estes & Hurley, 2013; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011).

In summary, the empirical investigations of word segmentation and word learning from different kind of speech registers demonstrate that learning from ADS is already possible starting as young as 7.5 months of age. This is of enormous importance as it suggests infants are not just learning from the small proportion of IDS input that is directly addressed towards them but, instead, ADS may also provide a valuable source of input, which they can learn from. Hence, the empirical findings of this dissertation suggest that infants may learn from *all* the language input that they are exposed to. The role of ADS has been underestimated at large in previous research. Accordingly, it is important to also include ADS in future research and to further explore the role of ADS in early language acquisition.

7.1.2. Exaggerated IDS

As described in the introduction, the age at which infants demonstrate successful word segmentation abilities varies across languages. Whereas American infants around 7.5-months of age and Spanish and French infants around 6-months of age have been able to successfully segment words from fluent speech without the presence of additional cues (Bosch, Teixidó, & Ramon-Casas; Jusczyk & Aslin, 1995; Nishibayashi & Nazzi, 2016), Dutch, British English and German infants seem to have difficulties in showing evidence of successful word segmentation at similar ages (Floccia et al., 2016; Kuijpers, Coolen, Houston, & Cutler, 2008; Höhle & Weißenborn, 2003). The current dissertation also tested the hypothesis of whether these cross-linguistic differences in infants' segmentation abilities are due to a difference in the languages' IDS modifications (Englund & Behne, 2006; Fernald et al., 1989; Farran, Lee, Yoo, & Oller, 2016; Newman, 2003) by exploring infants' segmentation abilities from an exaggerated IDS register. Similar to the finding on British English-learning infants by Floccia et al. (2016), German-learning infants also benefited from an exaggerated IDS input resembling the IDS style of American English. Importantly, the results of this ERP study suggest that German-learning infants are able to segment words as early as 7.5-months of age given they are exposed to an equally modified IDS similar to that of American English (Schreiner, Hildenbrand, & Mani, in prep, see Chapter 3.2.3.). This finding supports the hypothesis that the cross-linguistic difference between German-learning and American English-learning infants may be attributed to these languages' differences in IDS style. Therefore, it also seems to be worth exploring whether infants of other language backgrounds, such as Dutch and British English who have previously failed in demonstrating segmentation abilities at a similar age as American infants, may also demonstrate comparable segmentation abilities provided they are exposed to an exaggerated IDS input.

In line with earlier findings, the results of successful segmentation abilities after an extended exposure at home and successful segmentation of exaggerated IDS suggest that German-learning infants may need additional cues in order to successfully segment fluent speech. In addition to prior familiarization with a similar sounding word (Altvater-Mackensen & Mani, 2013), extended exposure in their natural environment at home and the use of exaggerated IDS have proved successful in facilitating infants' word segmentation abilities. Importantly, exaggerated IDS may provide an important cue that guides German infants' attention in speech segmentation during short-term laboratory familiarizations. These findings support the idea of IDS as an attentional spotlight attracting and maintaining infants' attention to the relevant language stimuli (Kuhl, 2007) which will be further discussed in the section on the implications on current theories and models of early language acquisition (Chapter 3.2.2).

7.1.3. Typical German IDS

In line with previous research findings on German infants' segmentation abilities (Altvater-Mackensen & Mani, 2013), the empirical findings of the current dissertation indicated that German infants seem to have difficulties in segmenting words from fluent IDS after short-term laboratory familiarizations (Schreiner, Altvater-Mackensen & Mani, 2016). Even with the more sensitive measure of ERPs (Schreiner, Hildenbrand, & Mani, in prep), German infants were unable to demonstrate that they are capable of segmenting words from typical German IDS after a short-term laboratory familiarization. This provides further support for the assumption that German infants may require additional cues for successful segmentation. Importantly, these findings contrast with research on infants' speech segmentation of American English (e.g., Jusczyk & Aslin, 1995) and suggest that these cross-linguistic differences may be driven by differences in IDS style across German and American English. Given prior extended exposure at home, German-learning infants were able to recognize the extended-exposure words embedded in sentences and as isolated tokens in the laboratory. Hence, German-learning infants starting at 7.5-months of age may require additional cues in order to successfully segment typical fluent IDS. Our findings clearly suggest that German infants are able to segment words from fluent speech, however, they require more exposure. That is, German infants may need either more naturalistic exposure at home or extended exposure in order to successfully demonstrate their speech segmentation abilities.

The fact that 7.5-month-olds have been unable to show successful word segmentation from typical IDS, even given more sensitive neurophysiological measures, stands in contrast with the finding that infants starting around 7.5-months did segment words from ADS after an extended naturalistic exposure at home. This again suggests that more naturalistic exposure at home and extended exposure largely impacts infants' segmentation success. In addition, German 7.5-month-olds failure to provide evidence of successful segmentation further supports the idea that infants' segmentation success may be influenced by the magnitude of the difference between IDS and ADS in their mother tongue. That is, the cross-linguistic difference may come down to the fact that infants are exposed to differently modified IDS and ADS input in their respective languages.

Furthermore, the recordings of mother-child interactions provided evidence for individual variation in maternal IDS. The correlations between higher segmentation from IDS in 7.5-month-old infants and mothers' utterance length as well as pitch range may suggest that these prosodic modifications, which represent properties associated with IDS, may in fact modulate infants' IDS segmentation success given short-term laboratory familiarization. This suggests that the properties of IDS may play an important role in infants' word segmentation given short-term laboratory familiarization.

With regard to word learning, the study presented by Schreiner and Mani (in revision) proposed that German infants are able to learn word-object associations from fluent IDS and confirms previous findings of successful IDS word learning (Graf

Estes & Hurley, 2013; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011). The finding that infants, however, were only able to demonstrate their learning if the register at test was in IDS highlights that infants may see IDS as the register they are being spoken to. This goes in line with Csibra's (2010) assumption of IDS as an ostensive cue, which will be further discussed in the following section.

7.2. IMPLICATIONS OF THE FINDINGS ON CURRENT MODELS OF EARLY LANGUAGE ACQUISITION

The findings of the empirical studies conducted for this dissertation have important implications for the different theories and models of early language acquisition. The current section will discuss these in light of the findings presented in this dissertation. As the assumptions of the hyperarticulation account of IDS (e.g., Fernald, 2000; Fisher & Tokura, 1996; Morgan, Meier, & Newport, 1987; Steedman, 1996; Venditti, Jun, & Beckman, 1996) have largely been argued to be invalid, this account will only be addressed very briefly. Whilst the empirical findings of the conducted studies speak in favor of attention-driven learning, a large proportion of this section will be devoted to the implications for accounts of attention-driven learning (e.g., Dominey & Dodane, 2003; Gottlieb, Oudeyer, Lopes, & Baranes, 2013; Kuhl, 2007; Oudeyer & Smith, 2016).

7.2.1. Hyperarticulation account

Within the hyperarticulation account of IDS, it is suggested that IDS, as a form of hyperarticulated speech, facilitates infants' language acquisition (Fernald, 2000; Fisher & Tokura, 1996; Morgan, Meier, & Newport, 1987; Steedman, 1996; Venditti, Jun, & Beckman, 1996). Infants benefit from IDS as it is much more clearly articulated than ADS and is, hence, more intelligible. That is, through exaggerated prosody and contextual cues, IDS is suggested to provide maximized predictability of the occurrence of novel words.

The current findings of successful learning from both IDS and ADS language input challenges the idea that the facilitation effect of IDS on learning comes through hyperarticulation. We can eliminate the proposed beneficial impact of contextual cues, such as repetitions, the use of carrier phrases, etc., as these cues were held constant in the studies by Schreiner and colleagues (2016) and Schreiner and Mani (in revision) and were shown to have no impact. However, the prosody of the input in these two studies was modulated. Under the hyperarticulation account, the exaggerated and hyperarticulated prosody of IDS is proposed to make word boundaries more transparent. The fact that infants showed learning from ADS casts suspicion on the role of hyperarticulatory cues provided in IDS - at least to the extent that infants do not appear to rely exclusively on such hyperarticulation. The study by Martin and colleagues (2015), which provided important evidence against the assumption of an enhanced IDS in terms of better intelligibility, demonstrated that, indeed, ADS is clearer than IDS. Thus, the fact that ADS is more clearly articulated than IDS may be one possible explanation why infants have been able to learn words from ADS as well. Hence, ADS may present speech input with clarity in its articulation, which enables infants to also acquire words from this register.

One factor that may have driven successful word segmentation from ADS in the study by Schreiner et al. (2016) is that infants were exposed to the stimuli over an extended period of time in their naturalistic environment at home. The continuous repetitions of stories each day may have impacted infants' segmentation success as it demonstrated a feature commonly attributed with IDS. However, the results on infants' word learning abilities from ADS presented in the study by Schreiner and Mani (in revision) only included a laboratory exposure. These findings seem to suggest that the beneficial role of IDS through its enhancement in articulation and structure is too farfetched in the hyperarticulation account. Instead, ADS may provide an equally intelligible source of input that may be parsed into its constituent units and used for the subsequent assignment of word meaning.

7.2.2. Attention-driven learning

The empirical findings of this dissertation may speak in favor of models which see IDS as a promoter of attention. As the role of IDS has been identified as attention-grabbing spotlight (e.g., Kuhl, 2007), attention seems to take over a central role in infants' early language acquisition. The findings by Schreiner et al. (2016) support this idea. In particular, parental reports on infants' attention towards the source of the stories presented at home revealed a positive correlation with infants' segmentation success from ADS stimuli. This highlights the fact that overt attention may be a valuable tool guiding infants' learning from ADS. Hence, infants may learn from a much larger range of input, including overheard adult conversations provided they overtly attend to it. Similarly, the findings by Schreiner and Mani (in revision) suggest that infants who are able to segment words from fluent ADS stimuli demonstrated higher success in adding meaning to these segmented word forms[3]. Consequently, infants who attend to ADS are also able to segment and learn words from this register.

According to the social-gating model introduced by Kuhl (2007), social interaction takes over a central role in infants' language acquisition. Infants are attracted by IDS and, therefore, they attend to and learn from this input. As infants were not only able to learn from IDS but also demonstrated successful learning from

[3] Note, that infants seem only able to demonstrate this successful learning of ADS word-object associations given they are tested in IDS. The implication of this finding will be discussed in more detail later in the discussion.

ADS, the findings of the studies by Schreiner et al. (2016) and Schreiner and Mani (in revision) may at first glance seem to counter Kuhl's proposal. Yet, closer inspection reveals that these findings may even extend this model in the extent to which infants' attention and arousal to speech, in general, impacts learning. As attention to the ADS stories at home seemed to modulate infants' later word recognition abilities, overt attention may demonstrate an important tool in learning from ADS stimuli. Thus, infants are not just able to learn from IDS but, instead, they are able to learn from *all* language input, that is IDS and ADS, provided they are interested in this input. The fact that infants' own interest is a prerequisite for successful learning may have driven infants' response in the test phase of the word learning study (Schreiner & Mani, in revision).

In her model, Kuhl (2007) identifies social agents as a necessary factor in order for infants to learn in natural language learning contexts by providing referential information that facilitate language learning. Importantly, she bases her assumptions on the findings of phonetic learning after foreign language exposure (Tsao, Kuhl, & Lui, 2003). In this study, infants only demonstrated successful learning if they were exposed to the language stimuli during live exposure with an experimenter but not if they were presented with the language stimuli through television or audio recordings. Contrary to this, the findings of Schreiner et al. (2016) and Schreiner and Mani (in revision) suggest that live interaction of a social agent may not be necessary in order to segment and learn new words. Infants in the study by Schreiner et al. (2016) were able to recognize the words from the stories of the extended exposure at home phase, even though, there was no agent interacting with the infants when the pre-recorded stories were played, thus, overhearing the speech stimuli without any additional contextual support being available. Similarly, the word learning study by Schreiner and Mani (in revision) did not involve a live teaching session nor was a social agent present in the training videos. This may suggest that while the presence of a social agent is not necessary, interest in speech signals – which is in itself a social factor – does drive learning. However, the child and an experimenter played with both objects prior to watching the training videos in the laboratory. Therefore, it remains open, whether infants' interest in learning the names of the objects might have been impacted by the prior exposure to the objects in the interactive play phase.

While Schreiner et al. (2016) and Tsao, Kuhl, and Lui, (2003) equally employed an extended exposure, the first study familiarized infants with their language stimuli at home whereas the latter study was performed in the laboratory only. From this, we may assume that the success of word segmentation without social interaction may have been impacted by the naturalistic exposure at infants' own home. Counter to this are, however, the findings of the word learning study from IDS and ADS by Schreiner and Mani (in revision), which suggest that infants may even learn in laboratory situations without a social agent present. Accordingly, the difference in findings on the necessity of social agents may not be driven by the fact that these studies employed different kinds of exposure.

Nevertheless, it is crucial to note that the studies by Schreiner et al. (2016) and Schreiner and Mani (in revision) investigate first language acquisition, whereas Tsao, Kuhl, and Lui (2003) have investigated infants' phonetic discrimination abilities of a foreign language. This may suggest that, contrary to Kuhl's (2007) proposal, first language acquisition may, under certain situations, e.g., extended exposure at home, not require a social agent for successful learning. Therefore, the findings of the current thesis raise the question whether social agents are as crucial for early language acquisition as proposed in the social-gating model by Kuhl (2007).

In summary, the social-gating model (Kuhl, 2007) may overemphasize the role of social agents in early language acquisition, however, the fact that infants' interest in speech drives learning may be support for the sociality of language learning. In addition, in order to account for language learning from ADS, the model needs to be adapted from attention driving language learning from IDS to attention driving language learning from *all* kinds of input, namely IDS and ADS.

The emergentist coalition model (Hollich et al., 2000) suggests that in the process of acquiring a language, infants use multiple cues, which are weighted differently and that the weighting of these cues changes over time. Importantly, the model argues that language acquisition happens in two phases. In the first phase, the immature infant may rely heavily on attentional cues, whereas with the start of the second phase, social and linguistic cues become available to the child. The fact that attention has been identified as cue available right from the start is supported by the findings of the current dissertation. Infants starting at 7.5-months of age were able to segment words from both IDS and ADS, with attention being a primary modulator of infants' segmentation success. The model defines perceptual salience and temporal contiguity as the early cues shaping successful word learning. In terms of the findings of this dissertation, exaggerated IDS may, therefore, be perceptually salient to infants driving their attention to this artificial register, which is not part of the range of input German infants are exposed to. Also, ADS may be perceptually salient from relatively early on because parents don't speak to their children that much using ADS but later on, they may use more ADS with their children resulting in ADS becoming less salient to the child. Moreover, it is important to note that perceptional salience is not objective. Rather, it is bound to vary across individuals: What may be salient for one child may not be salient for another. And this individual variation may be the reason for some infants attending to ADS while others don't.

According to the model, exaggerated prosody as provided by IDS reveals a linguistic cue that may only be accessible to the infant as it moves to a more mature state. But the large amount of research on infants' register preferences suggests that this exaggerated prosody of IDS is accessible right after birth with infants preferring IDS over ADS (Cooper & Aslin, 1990; Pegg et al., 1992*)*. In line with this, the empirical findings of the current dissertation provide evidence that exaggerated IDS and typical IDS[4], may be accessible from relatively early onwards despite the absence of any social cues.

As infants were equally able to segment words from IDS and ADS, this model underestimates the role of language input other than IDS. Note that successful ADS segmentation was found even without the presence of social cues. Similarly, the findings of 18-month-old infants' successful word learning from IDS and ADS suggest that both registers are equally accessible, again despite the absence of social cues. Therefore, the emergentist-coalition may not entirely grasp the early accessibility of different kinds of language input. At the same time, the estimations about the developmental course of the accessibility of such cues may be inadequate. According to the findings of this dissertation, unlike the assumptions of the emergentist coalition model, we propose that all cues may be accessible from early on. As suggested by emergentist coalition, these cues may be weighted differently in the course of development but they may also be dependent on the specific language learning situations.

In terms of curiosity-driven learning, the empirical findings of this dissertation demonstrate evidence that IDS may offer extrinsic motivation that guides infants' attention to the relevant aspects within the speech signal (Dominey & Dodane, 2003; Gottlieb, Oudeyer, Lopes, & Baranes, 2013). The fact that infants are extrinsically

[4] Note that infants did not demonstrate successful segmentation of fluent typical IDS after short-term exposure but seems to be dependent upon extended exposure at home

motivated to attend to IDS may also be revealed by the large number of studies demonstrating preferential listening of IDS over ADS (Cooper & Aslin 1990; Cooper et al., 1997; Fernald, 1985; Pegg et al., 1992). On the one hand, German-learning infants as young as 7.5-months are extrinsically motivated by IDS. This register attracts and maintains their attention in a way that they successfully extract phonological word forms from fluent speech. On the other hand, if infants are intrinsically motivated, they may also overtly shift their attention to input of the ADS register and successfully learn from this comparatively monotone register (see Figure 16). The study by Schreiner et al. (2016) suggests that infants between 7.5- and 9-months are able to extract words from ADS they just overhear. According to their parental reports, infants who attended more to the ADS stimuli played at home were later better able to recognize the familiarized words in the laboratory. Thus, infants are active participants whose intrinsic but also extrinsic motivation helps them in seeking the situations they wish to learn from (Oudeyer & Smith, 2016).

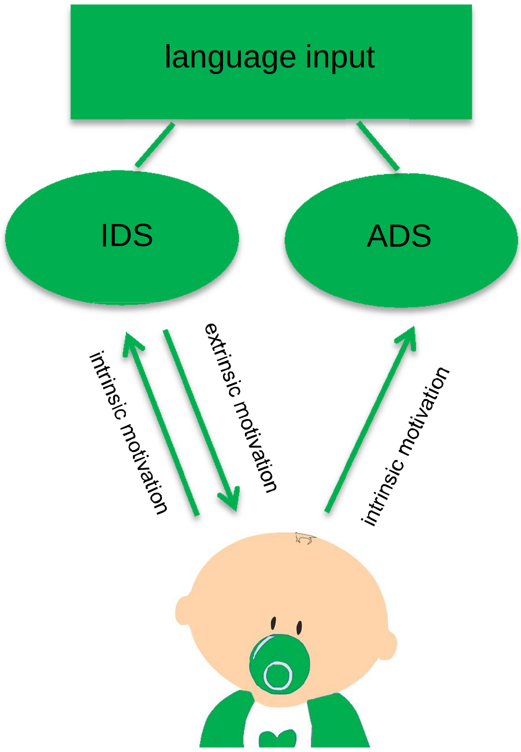


Figure 16 Schematic of curiosity-driven learning from IDS and ADS input.

Contrary to curiosity-driven learning which envisages the infant as an active participant, Csibra (2010) pictures the infant as a passive participant whose attention is attracted by ostensive cues. He assumes that IDS may provide such an ostensive cue attracting infants' attention by informing them that they are being talked to. In line with this, 18-month-old German infants of the study by Schreiner and Mani (in revision) were only able to demonstrate their word learning abilities from ADS if they were tested in IDS. Infants at this age may assume that a question is directed at them only if it is articulated with IDS properties. Hence, if asked over a loudspeaker without additional information of a social agent present (e.g., eye contact, gaze, pointing, joint attention), they might simply just not feel addressed and, consequently, don't respond to the task. This underlines that IDS may be an important ostensive cue that tells infants that they are being talked to and guides their attention to the infant-directed language uttered by the speaker.

In conclusion, the empirical findings of this dissertation suggest that attention does not only play an important role in early language acquisition from IDS but also from ADS. While IDS clearly seems to have a facilitatory role drawing infants' attention to the relevant speech stimuli supporting current attention-driven theories, ADS may also be exploited by the infants given they are able to overtly shift their attention to it. Hence, extending Kuhl's (2007) social-gating model, infants may learn from *all* language input provided they attend to it. The role of ADS input may, therefore, be largely underestimated and is mostly not directly addressed in current theories of early language acquisition. Curiosity-driven learning, which does not directly address learning from different kinds of input, may provide a fundamental basis, which may be easily extended to account for IDS and ADS input. In particular, infants are active participants who are extrinsically attracted by IDS and may be intrinsically motivated to shift their attention towards ADS, thus, seeking the situations they are willing to learn from. Still, future research is needed to further explore the particular roles of IDS and ADS in early language acquisition and to further adapt and fine-tune the existing models thereof.

7.3. INFANTS' GENERALIZATION ABILITIES

Another finding of the current dissertation that is worth highlighting is the remarkable flexibility infants have demonstrated in learning new words. As described earlier, infants did this by overcoming variation within the speech signal. The empirical findings presented in the study by Schreiner et al. (2016) and Schreiner and Mani (in revision) provide evidence of these generalization abilities in infants. The first study by Schreiner et al. (2016) demonstrated that infants are able to generalize across different speakers and different speech registers. Even though the new words were embedded in fluent IDS or ADS during the extended exposure at home, infants managed to recognize these words in a moderate IDS later in the laboratory phase.

Furthermore, infants of this study managed to recognize the phonological word forms even though there was variation caused by a difference in speaker. Critically, the stories at home were recorded by a different speaker than the language stimuli recorded for the familiarization and test phase conducted in the laboratory. Despite this change in speaker, infants successfully recognized the words produced by another speaker during the extended exposure at home managing to overcome variation in the speech signal.

The fourth paper of this dissertation by Schreiner and Mani (in revision) further adds to the finding that infants' phonological representations of words have become more flexible. Infants who had learned a word-object association in ADS were also able to demonstrate successful learning if they were tested in IDS. This extends the finding of generalization across registers from word segmentation to word learning. Importantly, at 18-months of age, this generalization ability has only been identified in one direction: Learning from ADS and successful demonstration of recognition in IDS but not the other way around.

In summary, these findings underline that by approximately 9-months of age, the representation of phonological word forms in infants' mental lexicon are more or less unaffected by the variation in the speech signal. In line with previous research findings, infants manage the task of generalizing across different kinds of input and different kinds of speakers becoming mature listeners of their native language (Johnson, Westreck, Nazzi, & Cutler, 2011; Johnson, Seidl, & Tyler, 2014; Schmale, Cristia, Seidl, & Johnson, 2010; Van Heugten & Johnson, 2012).

7.4. METHODOLOGICAL CONSIDERATIONS

Whereas most of the research up until now has focused on examining infants' language learning abilities in the laboratory with familiarization and test phase immediately following one another, the study by Schreiner et al. (2016) went one step further by exposing infants to the language stimuli at their own home. This approach not only allows us to investigate infants' retention of words in long-term memory, it also enables us to learn about infants' early language acquisition outside of the lab in their naturalistic environment. The finding that infants benefited from this extended exposure at home in comparison to a short-term laboratory familiarization suggests that we also need to shift our focus on what is happening outside of the laboratory.

Using behavioral measures, German 7.5-month-olds seem to be unable to demonstrate successful segmentation of exaggerated IDS. With neurophysiological measures, however, we were able to tap into 7.5-month-olds exaggerated IDS segmentation abilities. This has important implications for the interpretation of behavioral results. The absence of a difference in listening times towards familiarized and control words may not necessarily be an indication of infants' failure to segment. For this reason, ERPs may provide a more sensitive measure to tap into infants' segmentation abilities. While the co-registration of eye movements and EEG, that is the simultaneous collection of preferential listening and ERP data, may reveal more insights for the interpretation of obtained results, the simultaneous collection may not always be feasible. Hence, when designing new infant research, differences across the various paradigms should be carefully evaluated before settling on a method to be employed.

7.5. SUGGESTIONS FOR FUTURE RESEARCH

7.5.1. The development of learning from different kinds of input

Further empirical research is required to investigate the influence of different kinds of input across infants' development. Whereas the current studies have suggested that word segmentation from ADS after extended exposure develops between 7.5- and 9-months of age, further research is needed to explore the onset of IDS and ADS segmentation after a standard lab-familiarization.

Similarly, the failure to demonstrate successful IDS word learning if tested in ADS requires further attention. When does the ability to demonstrate successful word learning from IDS and ADS if tested in ADS develop? At what age do children start to assume they are being talked to, even though the prosodic modulations correspond to ADS? This may be of importance as the IDS input an infant receives is comprised of large individual variations in its modification compared to ADS extending to an IDS that may almost entirely lack a modulation of IDS properties. Hence, a series of studies is needed in order to investigate the developmental pattern of learning from IDS and ADS input and to validate or adapt the different existing models of early language acquisition.

7.5.2. Exploring the role of attention

In order to further evaluate the role attention in learning from different kinds of input, new research may be conducted by manipulating attention during different learning tasks. Particularly, in a segmentation task, varying infants' attention towards IDS and ADS language input may reveal further answers to the specific role of overt attention and extrinsic motivation in learning from IDS and ADS.

Another possibility to explore the role of attention and motivation in early language acquisition from different kinds of input may be through the investigation infants' theta activity. Theta oscillations have been identified to be associated with infants information encoding and their expectation of information (Begus, Gliga & Soutchgate, 2016; Begus, Southgate, & Gliga, 2015). Hence, infants' theta activity may be used to explore infants' intrinsic motivation to learn and their subsequent ability to segment and learn words from IDS and ADS.

7.5.3. Cross-linguistic investigations of infants' word segmentation and word learning

The modifications of IDS compared to ADS differ across languages (Ferguson, 1964; Fernald et al., 1989). American English reveals the most drastic modifications from ADS to IDS making the prosodic characteristics of these two registers diverge a lot more than in other languages. Therefore, it would be of special interest whether American English infants would be equally able to segment words after an extended ADS exposure at home as it has been demonstrated with German-learning infants. If we were to find that American English infants are not able to segment ADS after an extended exposure it home, it might be attributed to the fact that the ADS style is too different from the IDS style American English speakers typically employ. However, if American English infants were able to learn from ADS after extended exposure, it is crucial to also examine infants' attention. If overt attention similarly impacted infants' ADS segmentation success as found in German-learning infants, this would further support the idea of infants' curiosity and attention being the main contributors to early language learning.

In addition, it seems to be worth exploring whether American English infants may also demonstrate successful word learning from ADS around 18-months of age if tested in IDS. If American English infants were able to demonstrated successful ADS word learning during an IDS test phase, the previous failure in finding successful ADS word learning (Graf Estes & Hurley, 2013; Ma, Golinkoff, Houston &

Hirsh-Pasek, 2011) may be brought down to the differences in the speech register at test. If, however, American English infants would not show similar ADS word learning abilities, this would again speak for cross-linguistic differences caused by differences in the input that infants are typically exposed to.

Along these lines, investigating the impact of exaggerated IDS on word segmentation abilities of infants of other language backgrounds would further explore the hypothesis whether the cross-linguistic differences in infants' word segmentation are a result of the difference in these languages' modifications of IDS. If, for instance, Dutch and British English infants, who have previously failed in demonstrating segmentation abilities at a similar age as American English infants (Floccia et al., 2016; Kuijpers, Coolen, Houston, & Cutler, 2008), were able to demonstrate similar segmentation abilities given an exaggerated IDS input, this would further support the idea of differences in IDS style being a possible explanation for the cross-linguistic findings of infants' word segmentation.

CHAPTER 8: CONCLUSION

The current dissertation explored the role of input on early word segmentation and word learning. It has provided new and useful insights on whether infants may use the information provided by different speech registers when acquiring their first language. One major finding of this dissertation is that infants may use a much larger range of input at a much earlier age than previously assumed. Analogous to the fact that even if infants prefer to attend to red colors (Teller, Civan, & Bronson-Castain, 2004) this does not necessarily imply that they are unable to perceive other colors, the empirical findings of this dissertation suggest that just because infants preferentially attend to IDS does not imply that they do not listen to ADS and are unable to learn from stimuli presented in the adult-directed manner. As a matter of fact, infants showed evidence of word segmentation and word learning not just from IDS but also from ADS, thus, presenting the earliest evidence of ADS word segmentation and of ADS word learning in the literature up to this date.

In summary, infants' language learning is driven by a set of complex attentional mechanisms. IDS by means of its prosodic modifications provides extrinsic motivation that attracts and maintains infants' attention to language input. On the other hand, infants' intrinsic motivation may also shift their attention to language stimuli presented in the ADS register. The set of studies presented in this thesis demonstrate the importance of the variety of input in early language acquisition. Hence, this thesis concludes that infants are capable of learning from *all* language input. This brings us one step further in understanding the complexity of infants' language acquisition and highlights further directions for future research.

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APPENDIX A

Stories of the extended-exposure at home phase.

Story 1: Der 1 NOVELWORD und das Pferd
[NOVELWORD 1: 477 words, 14 NOVELWORD tokens, ratio 1:34]

1 Es hatte ein Bauer ein treues Pferd, das war alt geworden und konnte keine Dienste mehr tun; da wollte ihm sein Herr nichts mehr zu fressen geben und sprach: "Brauchen kann ich dich freilich nicht mehr, indes mein' ich es gut mit dir, zeigst du dich noch so stark, dass du mir einen Löwen hierher bringst, so will ich dich behalten; jetzt aber mach dich fort aus meinem Stall", und er jagte es damit ins weite Feld.
2 Das Pferd war traurig und ging auf den Wald zu, um dort ein wenig Schutz vor dem Wetter zu suchen.
3 Da begegnete ihm der 2 NOVELWORD und sprach: "Was hängst du so den Kopf und gehst so einsam herum?" -
4 "Ach", antwortete das Pferd dem 3 NOVELWORD, "Geiz und Treue wohnen nicht beisammen in einem Haus, mein Herr hat vergessen, was ich ihm für Dienste in so vielen Jahren geleistet habe, und weil ich nicht recht mehr ackern kann, will er mir kein Futter mehr geben und hat mich fortgejagt." -
5 "Ohne allen Trost?" fragte der 4 NOVELWORD.
6 "Der Trost war schlecht.
7 Er hat gesagt, wenn ich noch so stark wäre, dass ich ihm einen Löwen brächte, wollt' er mich behalten, aber er weiß wohl, dass ich das nicht vermag." antwortete das Pferd dem 5 NOVELWORD.
8 Und der 6 NOVELWORD sprach: "Da will ich dir helfen, leg dich nur hin, strecke dich aus und rege dich nicht, als wärest du tot."
9 Das Pferd tat, was der 7 NOVELWORD verlangte.
10 Der 8 NOVELWORD aber ging zum Löwen, der seine Höhle nicht weit davon hatte und sprach: "Da draußen liegt ein totes Pferd, komm doch mit hinaus, da kannst du eine fette Mahlzeit halten."
11 Der Löwe ging mit dem 9 NOVELWORD, und wie sie bei dem Pferd standen, sprach der 10 NOVELWORD: "Hier hast du's doch nicht nach deiner Gemächlichkeit, weißt du was?
12 Ich will's mit dem Schweif an dich binden, so kannst du's in deine Höhle ziehen und in aller Ruhe verzehren."
13 Dem Löwen gefiel der Rat des 11 NOVELWORDes.
14 Er stellte sich hin, und damit ihm der 12 NOVELWORD das Pferd festknüpfen könnte, hielt er ganz still.
15 Der 13 NOVELWORD aber band mit des Pferdes Schweif dem Löwen die Beine zusammen und drehte und schnürte alles so wohl und stark, dass es mit keiner Kraft zu zerreißen war.
16 Als der 14 NOVELWORD nun sein Werk vollendet hatte, klopfte er dem Pferd auf die Schulter und sprach: "Zieh, Schimmel, zieh."
17 Da sprang das Pferd mit einmal auf und zog den Löwen mit sich fort.
18 Der Löwe fing an zu brüllen, dass die Vögel in dem ganzen Wald vor Schrecken aufflogen, aber das Pferd ließ ihn brüllen, zog und schleppte ihn über das Feld vor seines Herrn Tür.
19 Wie der Herr das sah, besann er sich eines besseren und sprach zu dem Pferd: "Du sollst bei mir bleiben und es gut haben", und gab ihm satt zu fressen, bis es starb.

Story 2: Der 1 NOVELWORD und die Katze
[NOVELWORD 2: 280 words, 14 NOVELWORD tokens, ratio 1:20]

1 Es trug sich zu, dass die Katze in einem Walde dem Herrn 2 NOVELWORD begegnete, und weil sie dachte: Der 3 NOVELWORD ist gescheit und wohl erfahren und gilt viel in der Welt, sprach sie ihm freundlich zu.
2 "Guten Tag, lieber Herr 4 NOVELWORD, wie geht's? wie steht's?
3 wie schlagt Ihr Euch durch in dieser teuren Zeit?"
4 Der 5 NOVELWORD, alles Hochmutes voll, betrachtete die Katze von Kopf bis zu Fuß und wusste lange nicht, ob er eine Antwort geben sollte.

5 Endlich sprach der 6 NOVELWORD: "Du armseliger Bartputzer, du buntscheckiger Narr, Hungerleider und Mäusejäger, was kommt dir in den Sinn?
6 Du unterstehst dich zu fragen, wie mir's gehe, dem 7 NOVELWORD?
7 Was hast du gelernt?
8 Wie viel Künste verstehst du?" –
9 "Ich verstehe nur eine einzige", antwortete die Katze dem 8 NOVELWORD bescheiden.
10 "Was ist das für eine Kunst?" fragte der 9 NOVELWORD.
11 "Wenn die Hunde hinter mir her sind, kann ich auf einen Baum springen und mich retten." antwortete die Katze dem 10 NOVELWORD.
12 "Ist das alles?" sagte der 11 NOVELWORD,
13 "ich bin Herr über hundert Künste und habe überdies noch einen Sack voll Listen.
14 Du jammerst mich, komm mit mir, ich will dich lehren, wie man den Hunden entgeht."
15 Da kam ein Jäger mit vier Hunden daher.
16 Die Katze sprang behend auf einen Baum und setzte sich in den Gipfel, wo Äste und Laubwerk sie völlig verbargen.
17 "Bindet den Sack auf, Herr 12 NOVELWORD, bindet den Sack auf", rief ihm die Katze zu, aber die Hunde hatten den 13 NOVELWORD schon gepackt und hielten ihn fest.
18 "Ei, Herr 14 NOVELWORD", rief die Katze, "Ihr bleibt mit Euern hundert Künsten stecken.
19 Hättet Ihr heraufkriechen können wie ich, so wär's nicht um Euer Leben geschehen."

Story 3: Der 1 NOVELWORD und der Ziegenbock
[NOVELWORD 3: 294 words, 14 NOVELWORD tokens, ratio 1:21]
1 Der 2 NOVELWORD ging an einem heißen Sommertag mit seinem Freund, dem Ziegenbock, spazieren.
2 Der 3 NOVELWORD und der Bock kamen an einem Brunnen vorbei, der nicht sehr tief war.
3 Der muntere Bock kletterte sofort auf den Brunnenrand, blickte neugierig hinunter und sprang, ohne zu zögern, in das kühle Nass.
4 Der 4 NOVELWORD hörte ihn herumplatschen und genüsslich schlurfen.
5 Da der 5 NOVELWORD selber sehr durstig war, folgte er dem Ziegenbock und trank sich satt.
6 Dann sagte der 6 NOVELWORD zu seinem Freund: "Der Trunk war erquickend, ich fühle mich wie neugeboren.
7 Doch nun rate mir, wie kommen wir aus diesem feuchten Gefängnis wieder heraus?"
8 "Dir wird schon etwas einfallen, 7 NOVELWORD", blökte der Bock zuversichtlich und rieb seine Hörner an der Brunnenwand.
9 Das brachte den 8 NOVELWORD auf eine Idee.
10 "Stell dich auf deine Hinterbeine, und stemme deine Vorderhufe fest gegen die Mauer", forderte der 9 NOVELWORD den Ziegenbock auf, "ich werde versuchen, über deinen Rücken hinaufzugelangen."
11 "Du bist wirklich schlau, 10 NOVELWORD", staunte der ahnungslose Bock, "das wäre mir niemals eingefallen."
12 Er kletterte mit seinen Vorderfüßen die Brunnenwand empor, streckte seinen Körper, so gut er konnte, und erreichte so fast den Rand des Brunnens.
13 "Kopf runter!" rief der 11 NOVELWORD ihm zu, und schwupps war der 12 NOVELWORD auch schon über den Rücken des Ziegenbocks ins Freie gelangt.
14 "Bravo, 13 NOVELWORD!" lobte der Bock seinen Freund, "du bist nicht nur gescheit, sondern auch verteufelt geschickt."
15 Doch plötzlich stutzte der Ziegenbock.
16 "Und wie ziehst du mich nun heraus?"
17 Der 14 NOVELWORD kicherte.
18 "Hättest du nur halb soviel Verstand wie Haare in deinem Bart, du wärest nicht in den Brunnen gesprungen, ohne vorher zu bedenken, wie du wieder herauskommst.
19 Jetzt hast du sicher Zeit genug dazu.
20 Lebe wohl!
21 Ich kann dir leider keine Gesellschaft leisten, denn auf mich warten wichtige Geschäfte."

Story 4: Der 1 NOVELWORD und der Hahn
[NOVELWORD 4: 350 words, 18 NOVELWORD tokens, ratio 1:19]
1 Ein Hahn saß auf einem hohen Gartenzaun und kündete mit lautem Krähen den neuen Tag an.
2 Ein 2 NOVELWORD schlich um den Zaun herum und blickte verlangend zu dem fetten Hahn empor.

3 "Einen schönen guten Morgen", grüßte der 3 NOVELWORD freundlich, "welch ein herrlicher Tag ist heute!"
4 Der Hahn erschrak, als er den 4 NOVELWORD erblickte, und klammerte sich ängstlich fest.
5 "Brüderchen, warum bist du böse mit mir?
6 lass uns doch endlich Frieden schließen und unseren Streit begraben." sagte der 5 NOVELWORD.
7 Der Hahn schwieg noch immer.
8 "Weißt du denn nicht", säuselte der 6 NOVELWORD mit sanfter Stimme, "dass der König der Tiere den Frieden ausgerufen hat?
9 Er hat mich als seinen Boten ins Land geschickt.
10 Komm schnell zu mir herunter, wir wollen unsere Versöhnung mit einem Bruderkuss besiegeln.
11 Aber beeile dich, ich habe noch vielen anderen diese freudige Nachricht zu bringen."
12 Der Hahn schluckte seine Furcht vor dem 7 NOVELWORD hinunter und sagte sich: "Diesem verlogenen 8 NOVELWORD komme ich nur mit seinen eigenen Waffen bei."
13 Und mit gespielter Freude rief er: "Mein lieber 9 NOVELWORD, ich bin tief gerührt, dass auch du des Königs Friedensbotschaft verbreitest.
14 Ja, lass uns Frieden schließen.
15 Es trifft sich gut, denn gerade sehe ich zwei andere Boten auf uns zueilen.
16 Wir wollen auf sie warten und gemeinsam das glückliche Fest feiern.
17 Du kennst sie recht gut, 10 NOVELWORD, es sind die Wachhunde des Gutsherrn."
18 Kaum hatte der 11 NOVELWORD diese Kunde vernommen, war er aufgesprungen und eiligst davongerannt.
19 "He 12 NOVELWORD, warte doch!" krähte der Hahn hinter dem 13 NOVELWORD her.
20 "Ich habe noch sehr viel zu tun", keuchte der 14 NOVELWORD aus der Ferne, "ich hole mir den Friedenskuss ein andermal von dir.
21 Du kannst dich darauf verlassen."
22 Der Hahn freute sich, dass ihm die List gelungen war.
23 Der 15 NOVELWORD aber war verärgert.
24 Er hatte alles so klug eingefädelt, und just in diesem Augenblick mussten seine ärgsten Feinde auftauchen und alles verderben.
25 Aber, wo blieben sie denn?
26 Der 16 NOVELWORD verlangsamte seine Schritte und blickte sich um.
27 Niemand folgte dem 17 NOVELWORD, auch hatte er kein Bellen gehört.
28 Sollte dieser alte Hahn den 18 NOVELWORD reingelegt haben?
29 Ausgerechnet so ein aufgeplusterter, dummer Hahn?

Story 5: Wie der Bär den 1 NOVELWORD teilen lehrte
[NOVELWORD 5: 331 words, 12 NOVELWORD tokens, ratio 1:28]
1 Einst begegneten sich ein Bär, ein Wildschwein und ein 2 NOVELWORD.
2 Sie grüßten einander und klagten sich ihr Leid - wie das Leben doch so schwer sei, vor allem, wie schlimm es sei, oft tagelang mit knurrendem Magen herumzulaufen.
3 Der Bär, das Wildschwein und der 3 NOVELWORD beweinten gemeinsam ihr Los und schlossen dann Brüderschaft.
4 Sie schworen sich, von nun an alles brüderlich zu teilen, was sie in Zukunft auch erbeuten sollten.
5 Gemeinsam zogen der Bär, das Wildschwein und der 4 NOVELWORD auf Fang aus und schnüffelten überall herum, ob es nicht irgendwas zu fressen gäbe.
6 Nach langem Suchen fanden sie ein krankes Reh, das sie leicht erbeuten konnten.
7 Im Schatten wollten der Bär, das Wildschwein und der 5 NOVELWORD nun die Beute brüderlich teilen.
8 Dem Wildschwein knirschten vor Hunger schon die Zähne.
9 "Teile du!" sagte der Bär zum Wildschwein.
10 "Den Kopf kriegst du", sagte da das Wildschwein zum Bären, "denn du bist unser Herr und Meister, den Rumpf nehme ich mir, und die Beine kriegt der 6 NOVELWORD, der so viel auf den Beinen ist."
11 Das Wildschwein kam mit diesem Satz gar nicht zu Ende, denn der Bär hieb ihm mit der Tatze derart auf den Kopf, dass es von den Bergen widerhallte.
12 Das Wildschwein brüllte auf und sprang mit einem Riesensatz in die Büsche.
13 Da drehte sich der Bär zum 7 NOVELWORD um und sagte: "So, lieber 8 NOVELWORD, jetzt darfst du einmal teilen."

14 Der schlaue 9 NOVELWORD tänzelte heran und begann die Teilung mit schmeichelnder Stimme: "Unser Herr und Meister bekommt den Kopf und den Rumpf dazu, weil er immer so väterlich und gütig zu uns ist - und die Beine soll er auch haben, weil er auf allen Wegen stets um unser Wohl besorgt ist" sagte der 10 NOVELWORD.
15 Gerührt fragte da der Bär: "Ach, mein gescheiter 11 NOVELWORD, von wem hast du nur so klug und so gerecht zu teilen gelernt?"
16 "Von dir, Herr und Meister", flüsterte der 12 NOVELWORD ihm ins Ohr, "als ich sah, wie du das Wildschwein belehrtest."

Story 6: Der 1 NOVELWORD und die Gänse
[NOVELWORD 7: 213 words, 8 NOVELWORD tokens, ratio 1:30]
1 Der 2 NOVELWORD kam einmal auf eine Wiese, wo eine Herde schöner fetter Gänse saß.
2 Da lachte der 3 NOVELWORD und sprach 'ich komme ja wie gerufen, ihr sitzt hübsch beisammen, so kann ich eine nach der andern auffressen.'
3 Die Gänse gackerten vor Schrecken, sprangen auf, fingen an zu jammern und den 4 NOVELWORD kläglich um ihr Leben zu bitten.
4 Der 5 NOVELWORD aber wollte auf nichts hören und sprach 'da ist keine Gnade, ihr müßt sterben.'
5 Endlich nahm sich eine das Herz und sagte zum 6 NOVELWORD 'sollen wir armen Gänse doch einmal unser junges frisches Leben lassen, lieber 7 NOVELWORD, so erzeige uns die einzige Gnade und erlaub uns noch ein Gebet, damit wir nicht in unsern Sünden sterben.
6 Hernach wollen wir uns auch in eine Reihe stellen, damit du dir immer die fetteste aussuchen kannst.'
7 'Ja,' sagte der 8 NOVELWORD 'das ist billig, und eine fromme Bitte.
8 Betet, ich will so lange warten.'
9 Also fing die erste ein recht langes Gebet an, immer 'ga! ga!' und weil sie gar nicht aufhören wollte, wartete die zweite nicht, bis die Reihe an sie kam, sondern fing auch an 'ga! ga!'
10 Die dritte und vierte folgte ihr, und bald gackerten sie alle zusammen.
11 Und wenn sie nicht gestorben sind, dann gackern sie noch heute.

APPENDIX B

Table B.1 Participants of the study.

	age (days)	range (days)	female	additional infants[5]
7.5-month-old group	230	214–241	10	9
9-month-old group	271	255–291	11	4

Passages of the familiarization phase.

1 Das **Jopp** schmeckt sehr lecker.
2 Ein **Jopp** schmilzt in der Sonne.
3 Von dem köstlichen **Jopp** gibt es viele Sorten.
4 Das rote **Jopp** riecht nach Erdbeere.
5 Am Imbiss kauft Tom Gabi ein großes **Jopp**.
6 Mit Sahne wird das **Jopp** cremig.

1 Der **Riel** dient als Schutz.
2 Ein **Riel** ist ein eckiges Holz.
3 Wenn Mona den **Riel** bewegt, wird es lustig.
4 Ein Stück **Riel** schützt den Tisch.
5 Auf dem Boden liegt der schöne braune **Riel**.
6 Im Laden kann man **Riel** kaufen.

1 Der **Mauf** liest eine Geschichte.
2 Ein **Mauf** steigt die Treppe hinab.
3 Sobald er den **Mauf** hört, freut er sich.
4 Der tolle **Mauf** ist sehr mutig.
5 Im Dunkeln leuchten die grünen Augen des **Mauf**.
6 Dort draußen wohnt der **Mauf** allein.

1 Das **Lenn** ist eine Pflanze.
2 Ein **Lenn** hat eine große Blüte.
3 Da Pia das **Lenn** vergaß, ist es eingegangen.
4 Das pinke **Lenn** hat keine Blätter.
5 In der Erde stecken die Zwiebeln des **Lenn**.
6 Der Topf passt dem **Lenn** gut.

[5] An additional 13 infants were tested but had to be removed from the analysis for different reasons (unsteadiness (n=4), inability to finish the experiment (n=3), disturbance through toys (n=2), bilingualism (n=2), and technical problems (n=1), looking times during the test phase more than two SDs away from mean (n=1)).

Table B.2 Mean listening times in s for the familiarized and the control words for the 7.5- and 9-month-old age group. Standard deviations are provided in brackets.

age group	familiarized word	control word
7.5	12.02 (4.92)	12.41 (5.43)
9	10.15 (3.75)	8.74 (4.00)

APPENDIX C

Passages of the speech segmentation task.

Das **Gen** ist Ursache für die Erkrankung.
Ein **Gen** kodiert ein Merkmal.
Das männliche **Gen** sieht aus wie ein Y.
Biologen können ein **Gen** ohne Probleme kopieren.
Der Arzt will das **Gen** wissen.
In der Mitose teilt sich das **Gen** mehrere Male.
Eine Frau hat ein weibliches **Gen**.
Die DNA enthält ein **Gen**.

Der **Smog** bildet sich über der Region.
Durch **Smog** wird Luft verschmutzt.
Der giftige **Smog** steigt aus der Fabrik auf.
Hinter dem dunklen **Smog** liegt das Tal.
Die Sicht ist durch **Smog** behindert.
Vor allem in großen Städten tritt **Smog** verstärkt auf.
Über der Stadt sieht man **Smog**.
Viele Emissionen führen zu **Smog**.

Einen **Eid** legt man vor Gericht ab.
Ein **Eid** ist ein Versprechen.
Den langen **Eid** kann sich kein Mensch merken.
Nur auf einen **Eid** ist wirklich Verlass.
Im Gericht wird ein **Eid** gesprochen.
Der Zeuge lernt am Abend den **Eid** fleißig auswendig.
Vor der Aussage kommt der **Eid**.
Alle Polizisten sprechen den **Eid**.

Eine **Maut** muss jedes Mal gezahlt werden.
Die **Maut** ist manchmal teuer.
Die neue **Maut** wurde nach einem Jahr abgeschafft.
Er zahlt die **Maut** jeden Tag.
Neulich wurde nochmal die **Maut** erhöht.
Hier steht wieder, dass die aktuelle **Maut** erhöht wird.
Autos zahlen im Tunnel keine **Maut**.
Der Beamte kassiert eine **Maut**.

Die **Werft** steht neben dem großen Hafen.
Die **Werft** liegt am Fluss.
Die neue **Werft** wurde neben der alten gebaut.
Schau, über der **Werft** fliegt ein Ballon.
Schiffe werden in einer **Werft** gebaut.
Schon von weitem kann man die **Werft** gut sehen.
Der Besitzer zeigt uns seine **Werft**.
Sie besichtigen eine alte **Werft**.

Der **Bug** ist das Vorderteil des Schiffs.
Ein **Bug** wurde gestern gebaut.
Auf dem **Bug** saß ein Hund und bellte.
Das Loch im **Bug** war zu groß.
Lass uns bis zum **Bug** laufen.
Er lief zum Steg, um den **Bug** zu sehen.
Er rannte voraus bis zum **Bug**.
Das Schiff hat ein **Bug**.

Das **Heck** wurde von der Flasche getroffen.
Das **Heck** ist leider zerbrochen.
Auf dem **Heck** steht der Name des Bootes.
Das rot gestrichene **Heck** ist sehr schön.
Sie spielten auf dem **Heck** verstecken.
Sie fanden die poröse Stelle im **Heck** des Schiffes.
Hinten am Schiff ist ein **Heck**.
Sie springt über das **Heck**.

Ein **Sen** ist sehr wenig Euro wert.
Der **Sen** ist eine Währung.
Ohne einen **Sen** ging er auf den Markt.
Er bekam vier **Sen** von ihm zurück.
Er soll mir fünf **Sen** geben.
Er verdiente trotz guter Arbeit keinen **Sen** für sich.
Sie zahlte die Rechnung in **Sen**.
Er verschenkte seinen letzten **Sen**.

Der **Mulch** ist ein unverrottetes organisches Material.
Den **Mulch** kann man herstellen.
Mit dem **Mulch** kann man schöne Beete anlegen.
Er schüttet den **Mulch** auf den Kompost.
Unter dem Schnee lag **Mulch** begraben.
Sie ärgert sich über den stinkenden **Mulch** im Garten.
Das ist aber ein stinkender **Mulch**.
Auf der Straße liegt **Mulch**.

Das **Perm** ist eine Epoche der Geochronologie.
Im **Perm** herrschte trockenes Klima.
Die Epoche **Perm** liegt weit in der Vergangenheit.
Sie las, dass **Perm** eine Epoche ist.
Der Schüler fragt, was **Perm** bedeutet.
Die Menschen lebten im Zeitalter des **Perm** noch nicht.
Das Trias folgt zeitlich dem **Perm**.
Er redete über das **Perm**.

Ein **Quant** ist ein winzig kleines Teilchen.
In **Quant** misst man Mengen.
Was mit **Quant** gemeint ist, bleibt noch unklar.
Der Lehrer schreibst **Quant** an die Tafel.
Die Einheit **Quant** wurde neu eingeführt.
Mit bloßem Auge kann man ein **Quant** nicht sehen.
Einen Zustandswechsel nennt der Physiker **Quant**.
Er liest das Wort **Quant**.

Aus **Mull** kann man einen Verband machen.
Der **Mull** ist ein Gewebe.
Neben dem **Mull** liegt ein kleines weißes Pflaster.
Der Arzt legte **Mull** auf die Wunde.
Im Regal wird der **Mull** gestapelt.
Sie ging in den Laden, um **Mull** zu kaufen.
Für den Pullover kaufte er **Mull**.
Das Kleid besteht aus **Mull**

Im **Gau** leben viele Familien mit Kindern.
Ein **Gau** ist ein Gebiet.
Das kleine **Gau** wird im nächsten Jahr aufgelöst.
Um unser schönes **Gau** ist ein Zaun.
Sie liefen durch das **Gau** hindurch.
Auf der Karte kann man sein **Gau** gut sehen.
Er lebt in einem neuen **Gau**.
Sie zieht in das **Gau**.

Das **Volt** ist eine Einheit der Physik.
Zehn **Volt** sind zu wenig.
Zu viel **Volt** kann unter Umständen gefährlich werden.
Der Lehrer schreibt **Volt** an die Tafel.
Sie versteht nicht, was **Volt** ist.
Mit einem speziellen Gerät kann man **Volt** gut messen.
Sie maß die Spannung in **Volt**.
Spannung misst man in **Volt**.

APPENDIX C

Das **Mol** ist eine Einheit der Chemie.
In **Mol** misst man Mengen.
Er sagte, **Mol** sei ein sehr wichtiges Wort.
Er fragte, wie viel **Mol** es waren.
Sie wusste nicht, was **Mol** bedeutet.
Der Professor fragte mich, ob ich **Mol** schon kenne.
Die Menge war angegeben in **Mol**.
Er benötigt die Einheit **Mol**.

Mit **Brom** kann man spannende Experimente machen.
Das **Brom** ist ein Halogen.
Neben dem **Brom** steht eine Flasche mit Chlor.
Sie ließ das **Brom** aus Versehen fallen.
Er wog das flüssige **Brom** ab.
Der Lehrer zeigt den Schülern das **Brom** im Unterricht.
Hier stinkt es fürchterlich nach **Brom**.
Auf dem Boden liegt **Brom**.

Das **Verb** steht in den meisten Sätzen.
Ein **Verb** ist ein Wort.
Neben dem **Verb** gibt es noch weitere Satzteile.
Er lernt das **Verb** in der Schule.
Das Kind liest das **Verb** vor.
Jede Handlung kann mit einem passenden **Verb** beschrieben werden.
In vielen Sätzen steht ein **Verb**.
Das Mädchen schrieb ein **Verb**.

In **Ohm** gibt man den Widerstand an.
Das **Ohm** ist eine Einheit.
Zusätzliche zehn **Ohm** waren während der Testung messbar.
Der Schüler schreibt **Ohm** in sein Heft.
Er wusste nicht, was **Ohm** bedeutet.
Wir lernen, wie man Widerstand in **Ohm** messen kann.
Hinter die Zahl schreibt man **Ohm**.
Widerstand misst man in **Ohm**.

Das **Zinn** steht in der fünften Hauptgruppe.
Mit **Zinn** macht man Versuche.
Er holte **Zinn** aus dem großen Schrank heraus.
Er wollte das **Zinn** im Glas erhitzen.
Er sah, wie das **Zinn** explodierte.
Die Studenten versuchen, kleine Münzen aus **Zinn** zu machen.
Zu den Schwermetallen zählt auch **Zinn**.
An ihren Händen war **Zinn**.

Der **Schlick** schmilzt in der heißen Sonne.
Im **Schlick** liegt eine Muschel.
Der feuchte **Schlick** klebt an den nassen Füßen.
Der Junge schaufelt **Schlick** in den Eimer.
Die Mutter macht den **Schlick** ab.
Er geht ins Wasser, um den **Schlick** zu entfernen.
Die neuen Schuhe waren voller **Schlick**.
Die Kinder spielen im **Schlick**.

Der **Spind** steht neben dem kleinen Schrank.
Ein **Spind** ist meistens verschließbar.
Der blaue **Spind** steht gleich neben dem roten.
Auf dem anderen **Spind** klebt ein Sticker.
Es wurde ein zusätzlicher **Spind** gekauft.
Der neue Hausmeister repariert den kaputten **Spind** am Abend.
Er suchte seine Kleidung im **Spind**.
Der Mann baute den **Spind**.

Mit **Dur** bezeichnet man ein bestimmtes Tongeschlecht.
In **Dur** schreibt man Lieder.
Sie mochte **Dur** lieber als das traurige Moll.
Lieder können in **Dur** oder Moll sein.
Die Tonart wird als **Dur** bezeichnet.
Er überlegt, das Lied in hellem **Dur** zu schreiben.
Manche Pianisten **spielen** lieber in **Dur**.
Moll klingt dunkler als **Dur**.

Das **Öhr** befindet sich an der Nadel.
Ein **Öhr** ist eine Öffnung.
Das schmale **Öhr** frustriert die Näherin immer wieder.
Durch das schmale **Öhr** hängt ein Faden.
Sie will das kleine **Öhr** vergrößern.
Es gelang ihm, das Seil durchs **Öhr** zu ziehen.
Der Faden passt durch das **Öhr**.
Das Mädchen betrachtet das **Öhr**.

Ein **Patt** ist eine Endposition im Schach.
Das **Patt** bedeutet ein Unentschieden.
Bei einem **Patt** hat keiner der Spieler gewonnen.
Er sah das **Patt** und ärgerte sich.
Ein Remis wird als **Patt** bezeichnet.
Der Mann versuchte, wenigstens noch ein **Patt** zu erreichen.
Der Spieler sorgte für ein **Patt**.
Der Spieler registriert das **Patt**.

Ein **Reff** hat normalerweise eine schwarze Farbe.
Das **Reff** ist eine Spielkarte.
Mit dem **Reff** besiegte er den Gegner sofort.
Er hat kein **Reff** auf der Hand.
Auf der Karte ist **Reff** abgebildet.
Als Trumpf ist für diese Runde **Reff** festgelegt worden.
Die Frau spielte die Karte **Reff**.
Sie zog die Karte **Reff**.

Aus **Zink** stellt man dünnen Draht her.
Das **Zink** ist ein Element.
Er löffelte **Zink** in ein Gefäß aus Plastik.
Er stellte das **Zink** in das Regal.
Der Professor zündete das **Zink** an.
Manche Menschen nehmen viel zu wenig **Zink** zu sich.
Er füllte das Glas mit **Zink**.
Auf dem Tisch stand **Zink**.

Das **Chrom** ist ein selten vorkommender Stoff.
Das **Chrom** steht im Periodensystem.
Das glühende **Chrom** brodelte in dem heißen Topf.
Der Lehrer füllte **Chrom** in ein Glas.
Der Schüler wollte das **Chrom** benutzen.
Nach dem Erhitzen leuchtet das flüssige **Chrom** leicht rosa.
Der Chemiker arbeitet gerne mit **Chrom**.
Die Verbindung enthielt etwas **Chrom**.

Der **Ruß** bildet sich in dem Schornstein.
Etwas **Ruß** klebt am Fenster.
Der schwarze **Ruß** bedeckte den Boden des Zimmers.
Bei all dem **Ruß** sieht man nichts.
Er atmete zu viel **Ruß** ein.
Er holte einen Besen, um den **Ruß** zu entfernen.
Die Kleidung war schwarz vom **Ruß**.
Im Schornstein befindet sich **Ruß**.

Ein **Sumpf** bildet sich meist in Flussnähe.
Der **Sumpf** ist ein Feuchtgebiet.
In einem **Sumpf** kann man auch baden gehen.
Um den feuchten **Sumpf** herum wachsen Blumen.
Der Hund muss den **Sumpf** durchqueren.
Man sieht nicht, wie tief der **Sumpf** wohl ist.
Er suchte seinen Schuh im **Sumpf**.
Er versank in dem **Sumpf**.

Viel **Schutt** sammelt sich im Gebirge an.
Der **Schutt** besteht aus Gestein.
Den meisten **Schutt** haben wir gestern schon aufgeräumt.
Wir haben viel **Schutt** auf dem Hof.
Sie häufte im Garten **Schutt** auf.
Der Mann ist gekommen, um den **Schutt** zu holen.
Er baute einen Haufen aus **Schutt**.
Sie vergrub Steine im **Schutt**.

APPENDIX C

Die **Milz** sieht man im Bild nicht.
Eine **Milz** ist ein Organ.
Zum Thema **Milz** fällt dem Studenten nichts ein.
Sie untersucht die **Milz** der kranken Frau.
Sie wurde zum Thema **Milz** befragt.
Er nimmt Tabletten, um die kranke **Milz** zu heilen.
Der Arzt entfernte die kranke **Milz**.
Sie erkrankte an der **Milz**.

Mit **Teer** kann man Straßen gut ausbessern.
Der **Teer** kann komisch riechen.
Er glättet **Teer** mit einer großen, schweren Walze.
Im Baumarkt wird **Teer** oft nicht verkauft.
Die Straße wurde mit **Teer** bedeckt.
Der Arbeiter kommt heraus, um den **Teer** zu sehen.
Sie lief auf dem frischen **Teer**.
Zum Straßenbau benutzt man **Teer**.

Der **Schacht** ist an einigen Stellen beleuchtet.
Ein **Schacht** stürzte fast ein.
Im dunklen **Schacht** wird den ganzen Tag gearbeitet.
Er sperrte den **Schacht** übers Wochenende ab.
Er kam am hinteren **Schacht** an.
Die Gruppe kam, um den neuen **Schacht** zu sehen.
Die Männer gruben einen langen **Schacht**.
Die Kinder spielen im **Schacht**.

Ein **Speer** hat eine sehr scharfe Spitze.
Der **Speer** landete im Feld.
Der kaputte **Speer** ist nicht mehr zu gebrauchen.
Mit einem guten **Speer** kann man fischen.
Der Sportler muss den **Speer** tragen.
Sie geht ins Haus, um den **Speer** zu holen.
Er übte Werfen mit dem **Speer**.
Er traf mit dem **Speer**.

Bei **Gicht** kann man hohes Fieber bekommen.
Die **Gicht** ist eine Krankheit.
Durch seine **Gicht** hatte der Patient große Probleme.
Man lindert die **Gicht** mit einer Creme.
Der Mann war an **Gicht** erkrankt.
Sie fuhr auf Kur, um ihre **Gicht** zu therapieren.
Die Beschwerden kommen von der **Gicht**.
Sie starb aufgrund von **Gicht**.

In **Lot** gibt man die Masse an.
Das **Lot** ist eine Maßeinheit.
Das schiefe **Lot** wurde gestern vom Handwerker korrigiert.
Heute verwendet man **Lot** nur noch selten.
Der Kapitän zeichnet ein **Lot** auf.
Vor einigen Jahren noch wurde das **Lot** häufiger gebraucht.
Früher maß man öfter in **Lot**.
Sie erklärt ihm das **Lot**.

Die **Nut** kann man in Stein meißeln.
Eine **Nut** ist eine Vertiefung.
Die schmale **Nut** sieht doch sehr länglich aus.
Er sieht die **Nut** und ist zufrieden.
Sie zeichnete eine längliche **Nut** ab.
Er holt die Säge, um die **Nut** zu arbeiten.
Der Ring fiel in die **Nut**.
Am Boden ist eine **Nut**.

Vom **Tau** sind die Blätter ganz nass.
Der **Tau** besteht aus Wasser.
Von dem **Tau** kann der Käfer etwas trinken.
Sie wischte den **Tau** ganz vorsichtig weg.
Der Junge fasste den **Tau** an.
An diesem Morgen glitzert der frische **Tau** im Sonnenlicht.
Im Winter bildet sich der **Tau**.
Auf der Wiese war **Tau**.

Der **Rost** bildet sich besonders bei Regen.
Der **Rost** entsteht durch Oxidation.
Der rötliche **Rost** kann leicht das Getriebe zerstören.
Sie machten den **Rost** ganz vorsichtig ab.
Er hat den gesamten **Rost** entfernt.
Er lackierte das Fahrrad, um den **Rost** zu verdecken.
Sie ärgert sich über den **Rost**.
Er entdeckte am Metall **Rost**.

Ein **Priel** kann sich in Gewässern bilden.
Der **Priel** endet im Meer.
Im tiefen **Priel** kann es sehr gefährlich werden.
Sie suchten im **Priel** lange nach Steinen.
Sie gingen den schmalen **Priel** entlang.
Durch die heiße Sonne ist der **Priel** fast ausgetrocknet.
Im Fluss bildet sich ein **Priel**.
Die Kinder spielen im **Priel**.

APPENDIX D

Passages of the speech segmentation task.

Tork Block 1

Ein **Tork** springt in die Luft.
Der **Tork** spielt mit dem Mädchen.
Plötzlich sah der **Tork** einen riesigen Hund.
Die Pflanze findet der **Tork** sehr hübsch.
Franz ist ein Freund von **Tork**.
Laute Geräusche macht der **Tork** selten.

Melp Block 1
Ein **Melp** ist allein zu haus.
Der **Melp** findet eine rote Blume.
Danach setzte der **Melp** sich langsam hin.
Das Buch liest der **Melp** zu Ende.
Kinder singen ein Lied mit **Melp**.
Auf einmal jubelt der **Melp** begeistert.

Narf Block 1
Ein **Narf** hat eine tolle Idee.
Der **Narf** möchte auf den Stuhl.
Gespannt öffnete der **Narf** das bunte Geschenk.
Die Musik mag der **Narf** überhaupt nicht.
Viele Leute kennen den lieben **Narf**.
Das Spiel hat der **Narf** gewonnen.

Tork Block 2

Ein **Tork** kann sehr alt werden.
Der **Tork** hat ein weiches Fell.
Später traf der **Tork** eine langhaarige Frau.
Am Morgen putzt der **Tork** die Zähne.
Der Käfer versteckt sich vor **Tork**.
Am Abend ist der **Tork** müde.

Melp Block 2
Ein **Melp** möchte das Gedicht hören.
Der **Melp** holt Wasser vom Brunnen.
Leise schlich der **Melp** um das Haus.
Das Versteck hat der **Melp** schon entdeckt.
Einige Kinder träumen vom netten **Melp**.
Das Stroh hält den **Melp** warm.

Narf Block 2
Ein **Narf** ist ein guter Läufer.
Der **Narf** tanzt mit dem Affen.
Erwartungsvoll blickte der **Narf** auf die Tür.
Anna hat Tom den **Narf** sofort vorgestellt.
Die Tasse gehört dem großen **Narf**.
Die Uhr kennt der **Narf** schon.