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Listen up! Developmental differences in the impact of IDS on speech segmentation

Melanie S. Schreiner and Nivedita Mani

Research Group Psychology of Language, Georg-August-University Göttingen, Goßlerstr.14, 37073 Germany

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.

Keywords

Infant language acquisition, speech perception, word segmentation, exaggerated infant-directed speech

Highlights

- German infants can segment exaggerated infant-directed speech
- Exaggerated IDS as a tool to guide attention and facilitate language learning
- Developmental differences in the role of IDS as an attentional spotlight in speech processing

Author Note

Correspondence regarding this article should be addressed to Melanie S. Schreiner, Georg-Elias-Müller Institute for Psychology, Research Group *Psychology of Language*, Georg-August-University Göttingen, Goßlerstr. 14, 37073 Göttingen, Germany. E-mail: melanie.schreiner@psych.uni-goettingen.de

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, 2016). 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 the 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? Or to put it differently, 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[1]. 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

[1] 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.

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 the one hand, 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 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 heard by American English infants.

METHOD

Participants

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

Material and Design

Four passages with one of four phonotactically legal German monosyllabic pseudowords, *Jopp [ˈjɔp]*, *Riel [ri:l]*, *Mauf [mauf]*, and *Lenn [lɛn]*, were recorded in an exaggerated speech register resembling American English IDS (Table 1; APPENDIX B). 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 1).

Table 1 **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)

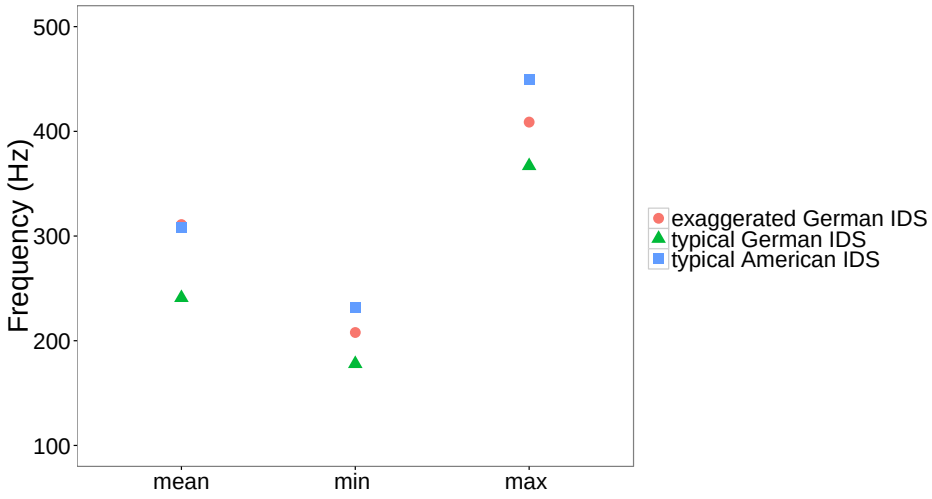

Figure 1 **Mean, minimum and maximum fundamental frequency for typical German IDS, typical English IDS (taken from Fernald et al., 1989), and the exaggerated German IDS stimuli used in the current study.**

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, in press, for an identical procedure). The experimenter was blind to the experimental condition as no information

on the stimuli being presented 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.

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 ($F(1, 42)=4.11$, $p=0.049$, $\eta_p^2=0.09$) and a significant main effect of age ($F(1, 42)=4.70$, $p=0.036$, $\eta_p^2=0.10$). There was no significant main effect of familiarity ($F(1, 42)=1.13$, $p=0.293$, $\eta_p^2=0.03$). 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 ($t(43)=-0.93$, $p=0.357$, $d=-0.14$). However, 9-month-olds listened significantly longer to the familiarized relative to the control words ($t(43)=2.99$, $p=0.005$, $d=0.45$) indicating successful word segmentation (Figure 2; APPENDIX C). 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.

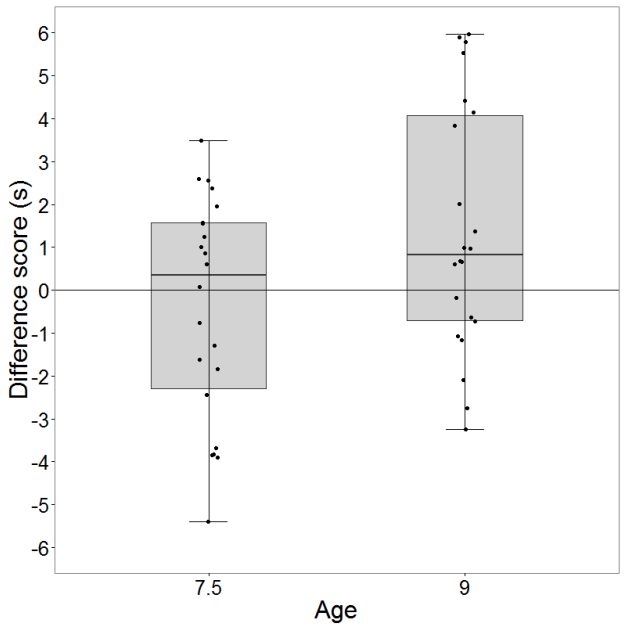

Figure 2 Difference scores for the mean listening times of the familiarized and the novel control words for the 7.5- and 9-month-old infants.

Familiarization Phase. Comparing infants' mean listening times to the familiarization trials (Table 2), an independent-samples t-test revealed a significant difference between 7.5- and 9-month-olds ($t(42)=3.67$, $p=0.001$, $d=1.11$). 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 2 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 (2.17)
9	18.41 (6.67)	6.77 (2.72)

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 infants already show segmentation abilities around 6-months of age: 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., 2016). 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 the one hand, 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 a six-week period 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 learned the relationship between their look-aways and stimulus presentation. 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. We note that the effect size reported for the 7.5-month-old age group is close to the meta-analytic effect size by Bergmann and Cristia (2016). Indeed, as we can see from Figure 2, a proportion of the 7.5-month-olds show a similar pattern as 9-month-olds, with increased listening times to familiarized relative to novel control words. Furthermore, previous results from our lab suggest that even younger German infants are able to segment words from fluent speech provided they have additional cues. Taken together, this suggests that our findings can only be taken to conclude that German infants may require different kinds of/increased exposure to speech relative to American English infants to show successful segmentation in this task. Against this background, ongoing studies in our lab are currently employing an ERP-task to examine speech segmentation in younger infants in greater detail.

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. (2016), 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.

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APPENDIX A. Participants of the study.

	age (days)	range (days)	female	additional infants[2]
7.5-month-old group	230	214–241	10	9
9-month-old group	271	255–291	11	4

APPENDIX B. 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.

[2] 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)).

APPENDIX C. 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 (4.89)	12.41 (5.43)
9	10.00 (3.70)	8.74 (4.00)