The impact of the quality of maternal speech on infants' segmentation abilities

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Abstract

Across cultures, infants are typically addressed using a special speech register, called infant-directed speech (IDS). Infants appear to benefit from being addressed in this register, although there seem to be some cross-linguistic differences in their learning from IDS. One possible explanation for these differences is that children from different backgrounds are addressed in a less exaggerated register than standard American English IDS. Against this background, we examined whether German 7.5-month-olds are able to segment words from exaggerated IDS and standard German IDS. Furthermore, in order to evaluate the potential long-term consequences of continued exposure to less or more exaggerated IDS, we also examined the impact of individual differences in maternal IDS on early speech segmentation. We found that 7.5-month-old infants were able to segment words from exaggerated, but not from standard German IDS. A potential explanation for this result comes from our finding that infants whose mothers used more exaggerated IDS were able to also segment words from standard German IDS. Taken together, the current study a) underlines the importance of IDS in early language acquisition, b) demonstrates successful exaggerated IDS segmentation abilities, and c) presents a possible explanation for cross-linguistic differences in infants' segmentation abilities reported in the literature.

Keywords

Word segmentation, maternal input, infant-directed speech, mother-child interaction, social factors

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 register of speech is called infant-directed speech (hereafter, IDS), differs from the language typically used by adults when addressing each other, called adult-directed speech (hereafter, ADS), and has been identified in caregivers from a large number of languages (Ferguson, 1964; Fernald et al., 1989; Soderstrom, 2007). The use of this modified speech register when communicating with infants appears to be beneficial to early 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 their parents (Greenwood et al., 2011; Hart & Risley, 1995) and the increased use of IDS in communication with infants predicts improved language outcomes later in life (Shneidman & Goldin-Meadow, 2012; Weisleder & Fernald, 2013). There do, however, appear to be numerous cross-linguistic differences in the extent to which infants are able to learn from IDS and the reasons underlying these differences are, as yet, unclear. One potential reason may be that the speech that infants from different language backgrounds are exposed to may be less infant-directed, i.e., less exaggerated, relative to American English IDS. Against this background, the current study investigated whether 7.5-month-old German infants are able to segment words from exaggerated and standard German IDS using a more sensitive measure of infants' speech segmentation, namely the event-related potential measure. Furthermore,

against the background that extended exposure to less exaggerated IDS may have consequences for infants' segmentation of speech from even exaggerated IDS, we examined whether individual variation in the properties of maternal IDS influences early speech segmentation.

Word segmentation from standard 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 with them (in isolation) later. In particular, infants were familiarized with 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 their 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 isolated tokens of familiarized words or sentences containing the familiarized words – relative to control words – were interpreted as infants' preference for the familiarized words. Such a preference could only develop through infants' prior exposure to these words in sentences, suggesting that infants were able to segment words from fluent speech.

Since then, a number of studies have examined the factors that bolster infants' segmentation of words from fluent speech. Many of these suggest that infants are better able to segment words from fluent speech when this speech is in the infant-directed register relative to the adult-directed register (Schreiner & Mani, 2017; Singh, Nestor, Parikh, & Yull, 2009; Thiessen, Hill, & Saffran, 2005), although infants are able to segment words from ADS as well (Mani & Pätzold, 2016).

However, studies with infants learning languages other than American English have 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-months 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 to 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 (Altwater-Mackensen & Mani, 2013), been provided with extended exposure to these words in stories at home (Schreiner, Altwater-Mackensen, & Mani, 2016), or are exposed to the words in isolation first before hearing these words embedded in sentences (Höhle & Weissenborn, 2003).

Studies with Dutch infants similarly find that 7.5-month-old Dutch infants do not show successful segmentation of words with an initial strong syllable in either Dutch or English stimuli (Kuijpers, Coolen, Houston, & Cutler, 1998), and that – like German infants – it is only at 9 months that Dutch infants demonstrate the ability to extract familiarized words out of fluent speech.

Studies with British English infants, similarly, 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. Furthermore, Schreiner and 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 with American English infants.

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., the 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. Nevertheless, infants from a number of different language backgrounds, e.g., German, may not be able to segment words from even fluent exaggerated IDS at the same age as American English infants, i.e., at 7.5-months of age. Against this background, the current study set out to examine German infants' segmentation of exaggerated IDS using a more sensitive measure of early speech segmentation, namely by tapping into electrophysiological measures of speech segmentation.

Using electrophysiological measures to tap into infant's segmentation abilities

Aside from the two-stage behavioral familiarization-test method described above, EEG paradigms have also been used to assess infants' segmentation of words from fluent speech. For instance, while it has been difficult to find evidence for successful segmentation of words from fluent speech in Dutch infants using the behavioral paradigm described above (Kuijpers, Coolen, Houston, & Cutler, 1998), studies using electrophysiological measures report that Dutch infants at 10-months 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 using behavioral paradigms could be that infants are unable to show the overt behavioral response required by this paradigm. This might be especially problematic for younger infants who are less able to support their head by themselves as yet. Alternatively, we note that the preferential listening 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 listening behavior between the 7.5- and 9-month-old infants tested, with 7.5-month-olds listening longer during familiarization trials and showing fewer lookaways from the visual stimulus during familiarization and test. The authors interpreted this difference as possibly suggesting that the younger infants were not on task, i.e., that they potentially had not learned that lookaways triggered the end of the trial and that the preferential listening design may not be appropriate across different kinds of stimuli and age groups.

Against this background, we will reinvestigate word segmentation in German 7.5-month-olds using a more sensitive electrophysiological measure that does not require an overt response from the infant and may provide a more reliable estimate

of the onset of speech segmentation in German infants and potential differences in infants' segmentation of exaggerated and language typical IDS at early ages.

In particular, we will examine infants' segmentation of words from both exaggerated and standard German IDS in an ERP task. It is possible that the use of a more sensitive measure will provide us a more reliable estimate of infants' segmentation of words from standard German IDS. This not being the case, the comparison to exaggerated IDS will also allow us to investigate whether we find segmentation of at least exaggerated speech (similar to American English IDS) in children from different language backgrounds at a younger age, i.e., 7.5-months of age, than has been reported to-date (c.f. Floccia et al., 2016; Schreiner & Mani, 2017) using a more sensitive paradigm. Such a finding is of considerable importance, since if we do not find segmentation of even exaggerated speech at this younger age then this suggests important differences in the segmentation abilities of young American-English infants and infants from other language backgrounds. For instance, this might suggest that continued exposure to less exaggerated IDS has potentially long-term effects on infants' speech segmentation such that infants typically exposed to less exaggerated IDS lag behind in their segmentation abilities even given more exaggerated IDS.

Individual variation in maternal input

With particular regard to the possibility of long-term effects on speech segmentation due to continued exposure to less exaggerated IDS, we will also obtain recordings of the mothers' IDS to her infant to examine the extent to which infants' segmentation of speech (from either exaggerated or standard German IDS) is influenced by the quality of IDS that the child has typically been exposed to. Analysis of mother-child dyads of 12- to 30-month-old infants reveals considerable individual

variation 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, Seidl, Cristia, Reimchen, & Soderstrom, 2015). In particular, this study finds that duration, speaking rate, mean pitch, minimum pitch, and maximum pitch – but not pitch range – of the mother correlates significantly with those of the infant. Another longitudinal study of mothers' speech to their infants reveals 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 (Narayan & McDermott, 2016, 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 those infants who are less exposed to such exaggerated input, similarly easily able to acquire their mother tongue?

Against this background, we will investigate the extent to which there is individual variation in the properties of mothers' speech to their infants 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 the impact of the quality of mothers' speech on infants' ability to segment words from fluent exaggerated and standard German IDS.

Current Study

The current study investigated whether 7.5-month-old German infants are able to segment words from exaggerated and standard German IDS using a more sensitive measure of infants' speech segmentation, namely the event-related potential measure. Furthermore, against the background that extended exposure to less exaggerated IDS may have consequences for infants' segmentation of speech from even exaggerated IDS, we examined whether individual variation in the properties of maternal IDS influences early speech segmentation. 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 might show segmentation of the less exaggerated register relative to the more exaggerated register. Nevertheless, if the main function of IDS is to attract infants' attention to language (c.f., McMurray, 2016), 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 improved segmentation of words in the exaggerated register.

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, Hagoort, & Cutler, 2009; Männel & Friederici, 2013). This effect is typically interpreted as indexing the increased ease of processing of 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, Plunkett, Prat, & Schafer, 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.

METHOD

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 ($n=4$), 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 in the study. Infants were given a t-shirt, a book, and a certificate as appreciation for their participation in the study.

Material and Design

Forty different monosyllabic words, which were likely to be novel to 7.5-month-old infants, were selected for the study. 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 1 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 standard German IDS and the exaggerated IDS register.

Table 1 Prosodic characteristics in Hz and duration in s for the stimuli of the familiarization and test phase.

	mean pitch		duration	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
standard German IDS familiarization	236.54	20.18	3.87	0.92
exaggerated IDS familiarization	314.67	26.75	4.19	0.97
isolated tokens at test	277.28	25.84	0.70	0.11

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 loudspeaker located above where the infant was sat in the room.

The study consisted of a familiarization and a test phase (see Figure 1). 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). Sentences in each passage were

separated by 1000 ms of silence. Each familiarization passage was directly followed by a test phase. During the test phase, infants were presented with four trials, where each trial presented either one isolated token of the word embedded in sentences in the familiarization phase or a novel control word that infants had not heard before. The interstimulus interval between the test trials was 2000 ms.

Each infant was presented with a total of 40 familiarization-test blocks as described above. Half of the blocks contained familiarization phases presented in exaggerated IDS and the other half in standard IDS. The test stimuli were presented in a register between standard German and exaggerated IDS.

Phase	Auditory stimuli
<i>Familiarization Phase</i>	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 .
<i>Test Phase</i>	Zink Nut Nut Zink

Figure 1 Schematic of the experimental procedure.

Across infants, we counterbalanced which words were presented embedded in sentences 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 are unlikely to be a result of a preference for the sounds of one word relative to the other, but rather due to infants' prior exposure to the words alone.

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 k Ω . 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 μ V 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 (200-300 ms), and a late time window (600-700 ms) in each condition. For analyses, we combined four electrodes of three different regions: Fronto-central (F3, F4, FC1, FC2), Centro-parietal (C3, C4, CP1, CP2), and Parieto-occipital electrodes (P3, P4, PO3, PO4). Data from these regions were included in a 3x2x2x2 repeated-measures ANOVA with the within-subject factors *region* (fronto-central, centro-parietal, parieto-occipital), *hemisphere* (left, right), *register* (exaggerated IDS, standard IDS), and *word familiarization* (familiarized, novel control) for each of the two time-windows.

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 4 minutes, mothers were asked to read aloud a children's picture book to their child. During the last 4 minutes, mothers were given toy cubes with which they were asked to play with their infant (see Figure 2). Importantly, mothers were not told the purpose of the recording, i.e., to record the quality of the speech they directed towards their infant.

Figure 2 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, summed utterance duration, and speaking rate. 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.

Vocabulary Assessment

Parents were also asked to complete the ELFRA (Grimm & Doil, 2006), a German vocabulary checklist for infants aged 12 to 24 months at three time-points, i.e., when infants turned 12, 18, and 24 months. The questionnaire provides an estimate of infants' receptive and productive vocabulary at these ages respectively.

RESULTS

Based on previous studies examining infant speech segmentation (Junge, Kooijman, Hagoort, & Cutler, 2012; Männel & Friederici, 2013), we analyzed ERP responses during an early (200-300 ms), and a late time window (600-700 ms).

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, centro-parietal, parieto-occipital), *hemisphere* (left, right), *register* (exaggerated IDS, standard 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*, $F(2,40)=5.47$; $p=.008$; $\eta_p^2=0.215$. 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, centro-parietal, parieto-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 (see Figure 3). 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 standard IDS register, a 3x2x2 repeated-measures ANOVA with the within-subject factors *region* (fronto-central, centro-parietal, parieto-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 standard German IDS sentences.

Further planned comparisons examined ERPs to the test and control words in the exaggerated IDS register and the standard IDS register, to ensure that the difference between registers stems from a difference in ERPs to the test words and not the control words. There was a significant difference in ERPs to the test words in the exaggerated IDS register and the standard IDS register, $t(20)=-2.46$; $p=0.023$; $d=0.621$. However, ERPs to the control words did not differ between the two registers, $t(20)=0.50$; $p=0.621$; $d=-0.146$. This suggests that infants processed the test words previously familiarized in exaggerated IDS differently to test words previously familiarized in the standard IDS register, while there was no such difference in responses to the control words.

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-parieto, parieto-occipital), *hemisphere* (left, right), *register* (exaggerated IDS, standard 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 to the familiarized words and the novel control words in either the exaggerated and the standard IDS register in this late window (see Figure 3).

Figure 3 Grand average waveforms for the familiarized and novel control words in the standard German IDS and exaggerated IDS at the fronto-central, the centro-parietal, and parieto-occipital regions; negativity is plotted downwards; 0 ms indicates word onset. Windows of analyses are shaded in grey.

Relationship between quality of maternal input and infants' speech segmentation

A principle component analysis (hereafter, PCA) was conducted on six features of maternal IDS including minimum pitch, maximum pitch, mean pitch, pitch range, summed duration of utterances, and speaking rate. The Kaiser-Meyer-Olkin measure ($KMO=0.58$) and the Bartlett's test of sphericity ($X^2(15)=199.38$, $p<0.001$) confirmed that a PCA was justified (see Table A.1 for correlation matrix). The resulting PCA extracted two principal factors, which explained 89.43% of the variance (see Figure A.1 for scree plot). The features retained in each of the two factors suggested that factor 1 captured the exaggeration of maternal IDS, including the length of her utterances, speed of her speech, maximum pitch and pitch range, whereas factor 2 captured the pitch of maternal input (see Table A.2 for factor loadings).

We ran bivariate correlations between the difference in ERPs to familiarized words in the exaggerated IDS register and the standard IDS register and the two extracted factors from the PCA that represented the physical 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. Our measure of infants' speech segmentation ability was the difference in ERPs to familiarized words in the exaggerated IDS register and familiarized words in the standard IDS register averaged across all electrodes in the 200-300ms time window. The more negative this value is, the more infants are able to segment words from exaggerated IDS as opposed to standard German IDS. The more positive this value is, the more infants are able to segment words from the standard German register relative to the exaggerated IDS register. Thus, the correlation between the factors identified by PCA and this measure allows us to examine the extent to which infants' segmentation of

exaggerated and standard German IDS is influenced by the quality of their mothers' IDS.

There was a significant positive correlation between infants' speech segmentation and factor 1 of the PCA of mothers' utterances, $r(21)=0.49$, $p=.024$. Thus, infants, whose mothers tended to exaggerate their speech by using wider pitch ranges, higher maximum pitch, a slower speaking rate, and more utterances, were better at segmenting standard German IDS (see Figure 4).

Figure 4 Correlation between the difference for ERPs of exaggerated and standard IDS test words and factor 1 of the principal component analysis representing exaggerated characteristics of maternal input

Relationship between speech segmentation and later vocabulary size

Based on the results of previous studies showing a relationship between early speech segmentation and later vocabulary size (Junge, Kooijman, Hagoort, & Cutler, 2012; Kooijman, Junge, Johnson, Hagoort, & Cutler, 2013; Newman, Ratner, Jusczyk, Jusczyk, & Dow, 2006), we also collected parental reports for receptive and productive vocabularies of their infants at 12, 18, and 24 months (see Table 2). We found a number of significant correlations between infants' vocabulary sizes at 12 months and their ability to segment words from exaggerated IDS, i.e., difference in ERPs to familiarized and novel control words. In particular, the difference in ERPs to familiarized and novel control words in the parieto-occipital area, $r(18)=0.54$, $p=.022$,

correlated significantly with both productive vocabulary size and overall vocabulary size at 12 months, ($r(18)=0.47$, $p=.047$). Since ERPs to familiarized words were more negative than to control words, the reported correlations suggest that infants who were better able to segment words from exaggerated IDS at 7.5 months had lower vocabulary sizes at 12 months.

Table 2 Receptive, productive and overall vocabulary scores reported by parents for their infants at 12-, 18-, and 24-months of age.

	12 ($n=19$)		18 ($n=18$)		24 ($n=17$)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Receptive vocabulary	45.21	36.13	77.17	29.39	27.71	32.77
Productive vocabulary	4.58	4.21	31.89	28.56	100.71	34.76
Overall vocabulary	49.79	38.23	109.06	20.18	128.41	8.07

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 3). Infants' productive vocabulary size at 12-months correlated positively with the number of isolated target words produced by the mother at 7 months, i.e., when her infant was 7-month-old, $r(19)=0.53$, $p=.019$. Furthermore, overall vocabulary size at 12 months correlated marginally significantly with the number of repetitions of target words produced by the mother at 7 months, $r(19)=0.45$, $p=.057$). Hence, infants, whose mothers presented them with more isolated target words and repetitions of words at 7 months, had higher vocabulary scores at 12 months.

At 18 months, infants' receptive vocabulary size correlated negatively with the number of isolated target words produced by the mother at 7 months, $r(18)=-0.61$,

$p=.008$. That is, the more target words the mother used in isolation at 7 months, the fewer words were reported to be understood by the child at 18 months of age. However, the number of isolated target words used by the mother at 7 months correlated significantly with productive vocabulary size at 18 months, $r(18)=0.47$, $p=.049$. Furthermore, productive vocabulary size at 18 months correlated significantly with the number of repetitions of target words produced by the mother at 7 months, $r(18)=0.53$, $p=.024$. Thus, infants' productive vocabulary size appears to be aided by increased structural content in mothers' IDS, although infants' receptive vocabulary size appears to be impeded by the same features of mothers' IDS.

Table 3 Mothers' use of target words in isolation and in sentences and repetition of these in isolation and in sentences.

	number of target words	
	<i>M</i>	<i>SD</i>
in isolation	4	2.63
in sentences	14.61	7.07
repeated in isolation	1.57	3.20
repeated in sentences	14.14	9.28

DISCUSSION

The current study set out to examine German infants' segmentation of words from exaggerated and language typical IDS. Previous studies suggest that infants from some language backgrounds, e.g., British English (Floccia et al., 2016), German (Schreiner & Mani, 2017) and Dutch (Kuijpers et al., 1998), have difficulties segmenting language typical IDS while succeeding in segmenting words from exaggerated IDS (similar to American English IDS) – albeit at an older age than has been reported in American English infants (Schreiner & Mani, 2017). Thus, while German infants only segment exaggerated IDS from around 9-months of age (similar to British English infants), American English infants segment words from fluent

speech by at least 7.5-months of age, and potentially earlier. We asked whether this difference in the onset of successful segmentation was indicative of delayed speech segmentation in infants from some language backgrounds, or indicative of the reduced sensitivity of the previously used paradigms in these studies. We employed a more sensitive measure to test younger infants' ability to segment words from fluent speech in exaggerated and standard German IDS, namely infants' electrophysiological response to words previously familiarized in exaggerated and standard German IDS. We further hypothesized that reduced segmentation of words from fluent speech in infants from some language backgrounds might directly result from continued exposure to less exaggerated IDS. Consequently, we also examined the extent to which individual variation in the quality of mother's input impacted infants' segmentation of words from fluent speech. We reasoned that infants whose mothers used more exaggerated IDS may show improved segmentation of exaggerated IDS, while infants whose mothers used less exaggerated IDS may potentially show improved segmentation of standard German IDS.

Infants segment words from exaggerated German IDS

The critical finding of the current study was the difference in ERPs to words that infants had previously been familiarized with in exaggerated IDS relative to both novel control words and words they had previously been familiarized with in standard German IDS. This suggests that infants succeeded in recognizing the words previously presented to them in the familiarization phase, only when sentences in this phase were presented in the exaggerated IDS register. Thus, 7.5-month-old German infants are able to segment words from exaggerated IDS, similar to American English IDS. This compares to previous studies, showing that with American English infants at the same age are able to segment words from American English IDS. Thus, it does

not appear to be the case that extended exposure to less exaggerated IDS negatively impacts children's segmentation of words from at least the exaggerated speech presented to them in the current study. This finding is of considerable importance, since the results of previous studies (e.g., Floccia et al. 2016; Schreiner & Mani, 2017) left open the possibility that infants who are typically exposed to less exaggerated IDS do not develop the ability to segment words from fluent speech at the same pace as infants exposed to more exaggerated IDS, thereby failing to segment words from both exaggerated and standard German IDS at very early ages. The results of the current study veto this possibility by showing that there are few differences in the segmentation abilities of young German and American English infants, so long as these infants are presented with exaggerated IDS.

Our findings also suggest that German infants appear to be unable to segment words from standard German IDS even when segmentation is assessed using a more sensitive paradigm. This has serious consequences for early language learning in German infants, suggesting that these infants may be unable to segment words from standard German IDS until at least around 9-months of age or – at the very least – may require more input in order to be able to segment words from fluent speech. This finding is in keeping with previous studies showing that, for instance, infants were only able to demonstrate segmentation of words from fluent speech if they had been previously familiarized with similar sounding words (Altwater-Mackensen & Mani, 2013) or that even older infants at 9 months of age were only able to segment words from fluent speech when they had been familiarized with these words over a 6-week-period at home (Schreiner, Altwater-Mackensen, & Mani, 2016). Taken together, these current findings suggest that German infants may require more exposure to the words to be segmented before they are able to segment words from fluent speech. On the one hand, this would then suggest that

the characteristics of caregiver speech – and the extent to which caregiver speech provides them with this increased exposure – ought to play an important role in early language learning in these infants. On the other hand, this would suggest that there ought to be a strong correlation between early speech segmentation and later vocabulary size, since those infants who are more easily able to segment words from standard German IDS ought to have larger vocabularies later in life. We examine both of these possibilities in greater detail next.

Infant language development and the quality of maternal input

Considerable previous work highlights potential relationships between the quantity and the quality of the input to the child and their language outcomes (Greenwood et al., 2011; Hart & Risley, 1995; Shneidman & Goldin-Meadow, 2012; Song, Demuth & Morgan, 2010; Weisleder & Fernald, 2013). Against this background, we asked whether the quality of the mothers' input to her child impacts infants' ability to segment words from fluent speech. The results of the current study suggest that infants' early speech segmentation – and language development, in general – benefit from certain characteristics of maternal IDS.

With regard to early speech segmentation, we found that infants whose mothers used a higher pitch and, relatedly, a greater range of pitch as well as a slower speaking rate and longer utterance durations were better able to segment words from fluent standard German IDS. In particular, we found that infants who showed more negative ERPs to words previously familiarized in standard IDS relative to exaggerated IDS were exposed to more exaggerated IDS in their maternal language input, i.e., higher and more variable pitch. One explanation of these results targets the attentional salience of at least exaggerated IDS (Kuhl, 2007; McMurray, 2016), especially against the background of our finding that only 5 of 21 infants did

not show more negative ERPs to familiarized words relative to control words in the exaggerated IDS condition, while half of the infants did not show a similar effect in the standard IDS condition (10/21). Taken together, we suggest that the acoustic salience of exaggerated IDS leaves little room for variation in infants' ability to segment words from this kind of input. Thus, regardless of their language background, infants appear to be able to segment words from exaggerated IDS. Indeed, this finding receives some support from previous studies showing that British English and German infants are able to segment words from exaggerated IDS (Floccia et al. 2016; Schreiner & Mani, 2017). In contrast, infants' segmentation of standard German IDS appears to be susceptible to modulation by variation in the kind of input available to the child. In particular, infants of mothers who produce more exaggerated IDS are able to better segment words from standard German IDS. This suggests that there are, indeed, long-term consequences of exposure to IDS such that increased exposure to more exaggerated IDS boosts segmentation of words from even a less exaggerated input. This would further imply that exposure to more exaggerated IDS on a daily basis might lead to German infants being better able to segment words from standard German IDS. Thus, exposure to exaggerated IDS does appear to have long-term consequences for infants' language development. To what extent then do such long-term effects manifest in infants' general language development?

On the one hand, we found some evidence that infants' later vocabulary size (at 12 months) was influenced by infants' segmentation of words from exaggerated IDS. Thus, those infants who were better able to segment exaggerated IDS had a smaller vocabulary at 12 months. This might be taken to suggest that infants who need more exaggerated IDS in order to segment words from fluent speech may have smaller vocabularies later in life, given that their caregivers do not typically provide

them with such exaggerated input. Such a finding would then highlight the long-term consequences of the quality of maternal IDS on infant speech segmentation and infant language learning, in general.

However, there are at least two caveats to this conclusion. First, we note that the correlation between infants' segmentation of exaggerated speech and later language outcomes was only significant across parieto-occipital areas while the effect of familiarization was broadly distributed across the brain (with regards to exaggerated IDS). This warrants caution in interpreting this finding. Second, although there were some correlations between the characteristics of maternal input and later vocabulary size, there was no overlap between the characteristics of maternal input that appeared to influence speech segmentation (i.e., maximum pitch, pitch range, speaking rate, and summed utterance duration) and the characteristics of maternal input found to impact later vocabulary size (i.e., structural aspects of speech). In other words, there appears to be no straightforward relationship between specific characteristics of maternal input, early speech segmentation and later vocabulary size. While these factors interact in different ways along single dimensions, the current findings do not trace the developmental links between maternal input, speech segmentation and later language outcomes. Thus, while there do appear to be some long-term effects of maternal input on speech segmentation – such that infants whose mothers use more exaggerated IDS are better able to segment words from standard German IDS – this does not appear to impact later vocabulary size.

One possible explanation for the absence of a robust influence on vocabulary size may be the ages at which we examined language outcomes. At 12, 18 and 24 months, this is considerably lower than the ages at which language outcomes have been reported to correlate with early speech segmentation skills – thus suggesting that a later test at, for instance, three years of age, may highlight more

straightforward links between input, early segmentation and vocabulary size. Alternatively, the weak correlations between infants' segmentation abilities of fluent speech and later vocabulary outcomes (e.g., Junge, Kooijman, Hagoort, & Cutler, 2012) may also, in part, be due to the reliability of parents' reports on their infants' comprehension skills (Friedrich & Friederici, 2006, 2010; Mills et al., 2005; Rämä, Sirri, & Serres, 2013; Torkildsen et al., 2006, 2008, 2009).

We did find that the structural characteristics of mothers' speech to her infant correlated with 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. At 12 months, this effect was quite stable showing that mothers who produced more isolated tokens in speech and who repeated these tokens more had larger vocabularies (production and overall vocabulary size) at 12 months of age.

At 18 months, this effect was more variable with infants whose mothers produced more isolated tokens of target words and repeated target words more often showing smaller receptive vocabularies but larger productive vocabularies. The latter findings and the results with 12-month-olds are in keeping with the results of previous studies suggesting that exposure to isolated words boosts later vocabulary skills (Brent & Siskind, 2001, who also examined early production). 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. Nevertheless, the dissociation between the influence of these structural characteristics on receptive and productive vocabulary size necessitates more discussion. Given that Brent and Siskind (2001) also only analyzed production vocabulary, it is difficult to ascertain the extent to which this disassociation captures the pattern of early vocabulary development. On the one

hand, it is possible that hearing isolated forms of words boosts production of these words in ways that it may not similarly impact comprehension of words. Isolated forms of words present infants with less coarticulation and may, therefore, help children to correctly produce these forms. In contrast, hearing words presented in meaningful contexts may help infants to decipher the meanings of these words, thereby, aiding their understanding of the meaning of these words. This is not to suggest that hearing words in isolation does not boost receptive vocabulary size but rather that there may be developmental changes at play that require that children are presented with words in variable and meaningful contexts for them to more easily acquire the meanings of these words.

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. While it is undeniable that the input to the child has an impact on the child's acquisition of language, including the individual hurdles to acquiring a language, like speech segmentation, vocabulary learning, it is just as likely that the child has an influence on specific characteristics of maternal input. 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.

Taken together, the results of the current study highlight that infants from language backgrounds other than American English are able to segment words from fluent speech, as long as this input is sufficiently salient to the child, i.e., is presented in an exaggerated infant-directed register. Somewhat worryingly, we find that even

using a sensitive electrophysiological measure, we do not find segmentation of standard German IDS. This finding is in keeping with previous studies showing that infants from some language backgrounds may need more cues to speech segmentation at early ages, including the use of an exaggerated register, greater exposure to the words to be learned, or to similar-sounding words (Altwater-Mackensen & Mani, 2013; Floccia et al., 2016, Schreiner, Altwater-Mackensen & Mani, 2016; Schreiner & Mani, 2017).

The finding that even young German infants are able to segment words from exaggerated IDS highlights the attentional salience of exaggerated speech – thus, even given reduced exposure to such exaggerated speech, children were able to segment words from this register with little difficulty. However, the current study does more than merely demonstrate the attentional salience of exaggerated IDS and goes on to highlight the potential long-term consequences of exposure to less exaggerated IDS. Young infants who had more continued exposure to more exaggerated IDS were better able to segment words from standard German IDS – suggesting that one reason why German infants may struggle to segment words from fluent speech is the kind of IDS that they are exposed to at home, and not just the kind of IDS that they are tested on.

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APPENDIX A

Table A.1 Correlation matrix of the six different items of the PCA.

	pitch range	speaking rate	maximum pitch	minimum pitch	mean pitch	summed duration
pitch range	1.000	-.216	.635	-.778	-.100	.793
speaking rate	-.216	1.000	-.643	-.219	-.669	-.331
maximum pitch	.635	-.643	1.000	-.014	.697	.475
minimum pitch	-.778	-.219	-.014	1.000	.693	-.652
mean pitch	-.100	-.669	.697	.693	1.000	-.117
summed duration	.793	-.331	.475	-.652	-.117	1.000

Figure A.1 Scree plot of the PCA.**Table A.2** Factor loadings of factor 1 and 2 extracted from the PCA.

	factor	
	1	2
pitch range	.930	-.278
speaking rate	-.518	-.692
maximum pitch	.779	.547
minimum pitch	-.581	.798
mean pitch	.156	.972
summed duration	.877	-.244

APPENDIX B

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 schreibt **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**.

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 versuchten, 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**.

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**.