Stress patterns and vowel quality in Dutch infant-directed speech

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Abstract

It has been well documented that infant-directed speech (IDS) differs in prosody from adult-directed speech (ADS) and is thought to facilitate language acquisition. This study focuses on word stress, because it is important for lexical representation and might therefore play a big role in language acquisition. This study aims to investigate the prosodic properties of stress in Dutch IDS compared to Dutch ADS to see if there are differences in the indicators of stress. Additionally, this study aims to investigate if there are differences in stress and vowel quality in IDS for gender of the addressee. The participants consisted of 22 mother-infant pairs, of which 11 were mother-son pairs, and 11 were mother-daughter pairs. The data were collected from video and audio recordings of picture book readings to both the infant and the experimenter. Results showed that the difference in mean pitch between unstressed and stressed syllables and vowels was higher in IDS than in ADS. Furthermore, pitch minimum and pitch maximum were both higher in vowels of stressed syllables in IDS than in vowels of stressed syllables in ADS. A trend was found that the different types of pitch measures (mean pitch, minimum pitch, maximum pitch and pitch range) are higher in stressed syllables (and vowels) in IDS than in stressed syllables (and vowels) in ADS. For IDS directed to girls a trend was found that the same pitch measures were higher in stressed syllables than in IDS directed to boys. Thus, IDS directed to girls seemed to show an exaggerated pattern of the one that was found for IDS in general. Further research with additional participants should indicate if the found trends are representative for stress in Dutch IDS. Furthermore, additional research should indicate what the role of duration and vowel quality might be as stress markers.

Keywords: Dutch, infant-directed speech, adult-directed speech, stress, vowel quality, gender, picture book

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1. Introduction

Infant-directed speech (IDS) is the speech register adults commonly use when speaking to infants and it has distinctive prosody compared with adult-directed speech (ADS) (Soderstrom, 2007). IDS is characterized by higher mean pitch, greater pitch range, as well as longer pauses and shorter total length of utterances compared to ADS (Fernald & Simon, 1984; Grieser & Kuhl, 1988; Papousek, Papousek, & Symmes, 1991). IDS has been claimed to be an important speech register for language acquisition (Fernald & Weisleder, 2011). Stress might play a big role in language acquisition. Listeners of Dutch only need a word's first syllable to determine if it is stressed or not (Van Heuven, 1984). Furthermore, an initial stressed or unstressed syllable effectively narrows down word candidates (Van Heuven & Hagman, 1988). Thus it seems that a word's stress pattern is crucial for lexical representation in Dutch. Therefore, it is important for children's word learning. Because of this importance, this study will focus on the important cues for word stress in Dutch IDS: pitch, pitch range, syllable duration and vowel quality. In Dutch ADS, a stressed syllable is marked by a higher pitch, bigger vowel space and longer duration than a unstressed syllable (Rietveld & Van Heuven, 2013). In this study it will be investigated whether these cues are exaggerated in Dutch IDS. Literature on English IDS indicates that pitch range might also be greater in stressed syllables than in unstressed syllables (Albin & Echols, 1996; Wang et al., 2015). Furthermore, because greater pitch range is found in general in IDS (Andruski & Kuhl, 1996; Lee et al., 2014), stressed syllables in IDS might have a greater pitch range than stressed syllables in ADS. Because maximum pitch is always placed on the stressed syllable in Dutch ADS (Van Heuven & Rietveld, 2013), it is likely that pitch range is greater in Dutch IDS. In addition, Lee et al. (2014) suggest in their study on English IDS that vowel quality and prominence values, such as duration might be important markers of stress in Dutch IDS. Vowel space has also been found to be an important marker for word stress in Dutch ADS (Van Bergem, 1993). Furthermore, Kuhl et al. (1997) pose that hyperarticulation of vowels in IDS could help infants to learn the different phonetic categories. A few studies indicate that expanded vowel space expansion might be a universal cue of IDS. While studies on word stress and vowel quality have been conducted, not much is known about the realization of word stress and vowel quality in novel words. It is important to know whether word stress and vowel quality are exaggerated in Dutch IDS, in order to establish whether these features might play a role in an infant's language acquisition. Furthermore, it is important to study Dutch IDS to find out if the

results from English literature on IDS are universal features for IDS. Gender differences are accounted for in this study as well, because several studies indicate that parents alter their speech to the gender of their child. However, there are few studies on gender differences for prosody. It is important to study gender differences for prosody to find out if prosodic differences can account for the differences in language acquisition and language outcome between boys and girls.

1.1. The representation of word stress in IDS

The term 'stress' is quite ambiguous in English. It can refer to a pitch accent on sentence level, characterized by a sudden rise or fall in the pitch contour ('t Hart et al., 1990). Van Bergem (1993) calls this type of stress a 'sentence accent'. The prosodic head of a word (which need not carry a sentence accent, although it holds the potential to do so) is referred to by him as 'word stress'. In this study, the realization of word stress will be discussed. Word stress is an important cue to how a string of syllables are structured. Both Dutch and English infants can use the predominant stress pattern of their language to segment words from the speech stream when they are nine months old (Houston, Jusczyk, Kuijpers & Coolen, 2000). Parents also tend to accentuate a novel word in a sentence, if they want to introduce it to their infant (Ratner, 1996). As a consequence, the word stress of that novel word will be exaggerated too. In Dutch ADS, word stress is marked by a higher pitch, a longer duration of the stressed syllable and expansion of vowel space (Rietveld & Van Heuven, 2013; Van Bergem, 1993). This thesis aims to investigate how word stress is realized in novel words in Dutch IDS. Because there currently is no literature on stress in Dutch IDS, the literature on English IDS will be discussed first. After that, stress markers in Dutch ADS will be discussed. Based on the literature from these two languages, it will be discussed what expectations there are for stress in Dutch IDS.

As mentioned earlier, IDS is characterized in general by a higher mean pitch and pitch range than in ADS. The literature on English suggests that mean pitch and pitch range is also higher in syllables and vowels. Mean pitch of vowels and syllables in English IDS is higher than in ADS, in vowels and syllables (Albin & Echols, 1996; Andruski & Kuhl, 1996; Lee et al., 2014; Wang et al., 2015). Albin and Echols (1996) have found mean pitch to be higher in English IDS for word-final, stressed syllables. They did not find a higher mean pitch for word-final, unstressed syllables. This suggests that a syllable is only higher pitched when it has word

stress. Wang et al. (2015) repeated Albin and Echols' findings on the vowel level. Wang et al. (2015) found vowels from stressed syllables to have a higher mean pitch than vowels from unstressed syllables in English IDS.

Pitch range is also greater in vowels and syllables in English IDS than in ADS (Andruski & Kuhl, 1996; Lee et al., 2014). However, data determining whether pitch range is greater in stressed syllables and vowels is currently lacking. Lee et al. (2014) have investigated the rhythmic differences between Australian-English IDS and ADS. They have found a higher pitch range for vowels in IDS in their study. However, they did not distinguish whether stressed and unstressed syllables differed in pitch range. Even though Wang et al. (2015) mention that expanded pitch range is expected for vowels in stressed syllables, they do not test this in their study. Albin and Echols (1996) included pitch maximum into their study. They found pitch maximum to be higher in word-final stressed syllables than in word-final unstressed syllables. They concluded that pitch range might be important to investigate in further research. While their findings indicate that pitch range might be higher in stressed syllables than in unstressed syllables, this conclusion cannot be drawn with certainty. In conclusion, even though previous studies expect a difference between unstressed and stressed syllables and vowels in pitch range, and have good reasons to believe so, true data confirming this are still lacking.

Furthermore, it is questioned in the literature whether duration is an indicator of stress in English IDS. Wang et al. (2015) showed less promising results for duration as a marker of stress. The authors conducted a study where they looked at durational differences between ADS and IDS for vowels in unstressed and stressed syllables. They could not find a difference in duration between IDS and ADS, for both unstressed and stressed vowels. However, the durations of stressed and unstressed vowels were not directly compared within the same register. It is important to know these measures, in order to know the proportions in durations between stressed and unstressed vowels and syllables. Only in this way it is possible to conclude what role duration plays in the realization of stress in IDS. Furthermore, other studies do indicate a difference in duration between syllables. A different study, that provides important information on stress, investigated the rhythmic differences between Australian-English IDS and ADS (Lee, Kitamura, Burnham, & Todd, 2014). Measures of prominence on vowels (or sonorant segments) were used to assess these differences. A prominence value is a combined measure determined by factors such as intensity, pitch, spectral balance, and duration. Higher measures on these factors

can all be indicators of stress. The authors found the variability of the prominence values of vowels to be reduced in IDS. Meaning that there was not a big variability in duration between vowels. Together, these studies all suggest that there is not a significant role for duration as a marker of stress in IDS.

However, Monaghan, White and Merx (2013) acknowledge the occurrence of vowel lengthening in lexically stressed syllables. They note that vowel lengthening can also occur in word-final syllables. They propose that both types of vowel lengthening can assist in word segmentation. In their study they questioned whether the different lengthening cues are conflicting for word segmentation in case of initial stress. One theory, the receiver-work hypothesis predicted that the lengthening cues can only be disambiguated due to the co-occurrence with other prosodic cues, such as pitch and pitch variability. The listener must then draw conclusions from combining different sources of information. Another theory, the transmitter-work hypothesis, predicted that the distribution of lengthening within a word could potentially be discriminatory in itself. This means that additional prosodic features are not needed to determine the type of lengthening. In their study, corpus analysis of English IDS provided evidence for the transmitter work hypothesis. This means that stressed syllables are lengthened and that this lengthening is distinct from word-final lengthening.

Lee et al. (2014) suggest that vowel quality, instead of prominence factors, such as duration, may be the main indicator of stress. They come to this conclusion because of the reduced prominence values in their study. They also base their opinion on previous studies that have found vowel quality to be a more reliable and important indicator of stress (Cutler, 2009; Tyler & Cutler, 2009). However, they mention that in previous research it was found that in Dutch these prominence factors do play a critically important role (Cutler, 2009; Tyler & Cutler, 2009). They go on to suggest that if Dutch-learning infants use both prominence contrasts and vowel quality as a cue to determine if a syllable is stressed, they will start to use a stress-based strategy later into their development. This is suggested, because prominence contrasts are more salient in IDS when the infants are older. In both their study the infants do not surpass the age of 12 months. In this research paper, Dutch IDS directed towards 18 months old infants is studied. Therefore, it might be that prominence factors, such as duration are more apparent in the sample from this study. Lengthening of stressed syllables could thus be a marker of stress in Dutch.

The literature on Dutch ADS specifies three properties as important for words stress. The mean pitch of a syllable is seen as a first acoustic correlate of stress. When stress is placed on the first syllable, a rise in F0 is started before the end of the preceding word. After the stressed vowel is reached, an immediate fall in F0 is apparent. If the second syllable is stressed, the maximum F0 is reached at the start of the stressed syllable. (Rietveld & Van Heuven, 2013). The maximum F0 is therefore always in the stressed syllable (Sluijter, 1995). This might play a role in the pitch range of a stressed syllable. After all, a higher maximum pitch contributes to a greater pitch range.

Van Heuven en Rietveld (2013) note that duration is longer in stressed syllables than in unstressed syllables. According to them, duration is reliable cue of stress outside of word-final position. Duration is lengthened more in word-final position, regardless of stress. Van Bergem (1993) found vowels in a stressed syllable to be longer than vowels in a unstressed syllable. The type of syllable in which a vowel occurred, had a larger influence on the duration than a sentence accent. Perceptually, a difference in duration on the vocalic part of a syllable is the biggest determiner for stress (Van Heuven & Rietveld, 2013; van Leyden & Van Heuven, 1996).

Lastly, vowel quality is an important cue for stress. Vowel space is bigger in stressed syllables than in unstressed syllables (Van Bergem, 1993). However, on its own, vowel quality is not a great determiner of stress acoustically (Sluijter, 1995). It is also a very weak perceptual cue of stress (Van Heuven & Rietveld, 2013).

Summarizing, pitch has been found to be an indicator of stress in multiple studies on English IDS. In Dutch ADS, mean pitch is also an important cue for stress, so it is expected that this will also the case for Dutch IDS. In multiple studies on English IDS it was expected that stressed syllables will have a higher pitch range than unstressed syllables, but it has never truly been tested. In Dutch ADS the stressed syllable always contains the maximum pitch, therefore it is expected that pitch range will be bigger as well. Considering that IDS contains a lot of exaggerated features, it is expected that pitch range is exaggerated in Dutch IDS. A lot of studies on Egnlish IDS do not find stressed syllables to differ in duration from unstressed syllables (or vowels). However, Merx et al. (2013) suggested that duration can be an indicator of stress. Lee et al. (2014) suggest that in Dutch both prominence contrasts, such as duration, as well as vowel quality could be used as an indicator of stress. In Dutch ADS, duration is a perceptually strong cue for stress, especially for the vowels in stress. In light of these findings , it would be

interesting to study the characteristics of stress in Dutch IDS to find out to what extent duration, a prominence factor, is an indicator of stress for Dutch infants. It would be interesting to see if stress can be derived mostly through vowel quality, or that the combination of vowel quality and prominence features, such as duration and pitch, is necessary to derive stress. Because little is known about pitch range in both literature on English IDS and Dutch ADS, it would be interesting to test whether pitch range is a cue for stress. It is important to know whether word stress and vowel quality are exaggerated in Dutch IDS, in order to establish whether these features might play a role in an infant's language acquisition. Furthermore, it is important to study Dutch IDS to find out if the features that have been found in English literature on IDS are universal features for IDS.

1.2. Vowel quality in IDS

Previous studies have established that in English vowel space is exaggerated in IDS compared to ADS, which supports phonetic categorization (Kuhl et al., 1997) and is important to mark word stress (Lee et al., 2014). In ADS, vowel and consonant formants often undershoot their targets (Lindblom, 1963). Due to this, it is harder for infants to map a phonetic unit into a specific phonetic category, because its acoustic cues often overlap multiple categories (Hillenbrand, Getty, Clark & Wheeler 1995). If vowel formants are exaggerated more in IDS, vowels could be mapped into different categories more effectively. The theory that speaks in favor for this vowel exaggeration in IDS is called the hyperarticulation hypothesis (Cristia & Seidl, 2014).

Several studies on English IDS have found evidence in favor of the hyperarticulation hypothesis. The study by Kuhl and colleagues (1997) is a landmark study in this category. In their study they examined the acoustic properties of vowels in three languages: American English, Swedish and Russian. They measured the first three formants of three vowels: /a/, /i/ and /u/. In all three languages, it was found that vowel formants were exaggerated, indicating that vowel triangles were expanded in IDS in comparison to ADS. The authors propose that the stretching of the vowel space is beneficial to infants, because the vowels are more distinct from each other. Thus they can be categorized easier. Andruski and Kuhl (1996) showed a similar pattern in American English IDS. In their study the acoustic structure of vowels in the words 'sheep' and 'shoes' was measured. In these words they measured the first two formants. They found F2, but not F1, of both words to be more exaggerated in IDS than in ADS.

An important argument in favor of the hyperarticulation hypothesis is that vowel space expansion would serve a didactic role. This didactic role is shown in Burnham, Kitamura and Vollmer-Conna (2002). In their research they compared English IDS to pet-directed speech. While they found similarities in heightened pitch and affect, hyperarticulation was only present in IDS. This suggests that heightened pitch and affect play a role in gaining attention from the infant or pet, while hyperarticulation is the aspect of IDS that has a didactic role. Kangatharan (2015) has found further evidence for this didactic role. Her study depicted that vowel space expansion was apparent in both English IDS and speech directed to foreigners. She also showed that it was this aspect of both speech registers that made it clear to native and non-native speakers. Because vowel space expansion is only used when speaking to specific groups that can benefit from the clarity of speech, its shows that vowel space expansion has a clear didactic role.

Cristia and Seidl (2014) are a bit more hesitant to accept the hyperarticulation hypothesis. In their research on English, the authors not only looked at the contrasts in point vowels (/a/-/i/-/u/) but also in phonemically contrastive vowels (/i/-/ɪ/) and allophones of a phoneme (/ɛ/). They measured vowel space by extracting F1 and F2 of the vowels. While hyperarticulation was found for the point vowels, this effect could not be found for the other vowel contrasts. However, the authors do not completely reject the hyperarticulation hypothesis. They state that only the strongest version of the hyperarticulation hypothesis seems incorrect. Their sample suggests that not all phonemic contrasts are enhanced in IDS. They suggest that weaker versions of the hyperarticulation hypothesis could be suggested. It could be possible that parents only exaggerate the point vowels to promote language acquisition, but they do not exaggerate other contrasts.

In conclusion, the literature on English mostly suggests that vowel space is exaggerated and that the hyperarticulation hypothesis, therefore, is supported. However, a universal vowel space expansion in IDS can of course not be derived from English literature. The results from Kuhl et al. (1997) do suggest a universal effect of vowel space expansion in IDS. In their study, the exaggeration of vowel formants was found for Swedish and Russian as well. Another study that provides evidence for a universal vowel space expansion in IDS is a ERP study by Zhang et al (2011). They studied how formant-exaggerated speech is coded in the brains of infants by means of an event-related potential (ERP) study. In their study two synthetic /i/ vowels were presented to the infants, of which one had exaggerated formants. The ERP wave form analysis

showed a higher activity (enhanced N250 peak) for formant exaggeration. Time-frequency analysis showed that neural synchronization was higher for formant-exaggerated vowels. Together, these results provide evidence that exaggerated vowel space in IDS enhances neural activities for phonetic encoding and language learning. This shows that vowel space expansion is beneficial for infants and could therefore be a universal property of IDS. Vowel quality has been studied in Dutch IDS as well. Van de Weijer (2009) has shown that vowel formants are exaggerated in Dutch IDS. In his study he measured F1 and F2 of the vowels /a/, /i/ and /u/ in both content and function words. In both ADS and IDS vowel space was the biggest for content words. However, vowel space was bigger in IDS than in ADS for content words, whereas for function words, vowel space was bigger in ADS than in IDS. Benders (2013) provided a different outlook on Dutch. She found vowel space of the point vowels to be smaller in IDS. Furthermore, she found F2 and F3 of the point vowels to be raised more in IDS. Thus, it is still uncertain how vowel quality is realized in Dutch IDS.

Summarizing the literature, vowel space expansion is suggested to support phonetic categorization in infants, because vowels are phonemically more contrastive when vowel space is exaggerated. This is called the hyperarticulation hypothesis. Furthermore, exaggerated vowel quality is suggested to be a marker of stress in IDS. Most of the studies on English find vowel quality to be exaggerated in IDS, thus providing evidence in favor of the hyperarticulation hypothesis. Even studies that do not find all vowel contrasts to be exaggerated, do not completely reject the hyperarticulation hypothesis. Further evidence in favor of the hyperarticulation hypothesis is the clear didactic role of vowel space expansion. Exaggerated vowel quality is apparent in English IDS and foreigner-directed speech, but not in pet-directed speech, even though this speech register is similar to IDS in other prosodic aspects. While there is extensive literature on exaggeration of vowel space in English, it is not yet known whether this is a universal property of IDS. This study on Dutch could therefore contribute to the current literature there is on this topic. This is especially important, because in the literature on Dutch there still is not a consensus on whether vowel space expansion is a property of Dutch IDS. In this study, vowel quality will be studied in novel words, because the didactic role of hyperarticulation can be established this way. It is likely that vowel space is more expanded when parents teach their infants novel words, because of the supposedly didactic role of vowel space expansion. Furthermore, as earlier mentioned, exaggerated vowel quality is a marker of

word stress. Because of that, vowel space expansion should be biggest for vowels in the stressed syllables.

1.3. Gender

Besides investigating the differences between IDS and ADS in stress and vowel quality, this study will also look at the effect of the gender of the addressee on IDS. Many studies show that boys and girls have different developmental trajectories in language acquisition, especially in vocabulary development, and girls are usually further ahead of their male peers. For example, girls across cultures and languages consistently develop greater vocabularies, which they also develop sooner (Bauer, Goldfield & Resnick, 2002; Berglund & Westerlund, 2005; Zhang et al., 2008). They also tend to engage in verbal communication more than boys (Bauer, Goldfield & Resnick, 2002; Murray, Johnson, & Peters, 1990; Roulstone, Loader, Northstone, & Beveridge, 2002).

In previous studies it has been shown that parents alter their speech to fit to the need of their infant (Smith & Trainor, 2008; Werker et al., 2007). Parents may also accommodate their speech to different genders. In a study by Johnson and colleagues (2014) it was found that in the first months after birth parents responded preferentially to infants of their own gender. Also, parents used more emotion words and a greater variety of emotion words with girls than with boys (Adams, Kuebli, Boyle & Fivush, 1995). Cervantes and Callanan (1998) showed that mothers used more explanations than labels in talk about emotions with boys. With girls they used equal amounts. In both the study by Adams et al. (1995) and the study by Cervantes and Callanan (1998) different outcomes in language production were found for boys and girls. In other studies, input cannot be directly linked to the different outcomes for gender. Huttenlocher et al. (1991) could not find a correlation between the amount of vocabulary input from parents and the bigger growth in vocabulary for girls. The same holds for a study by Hadley et al. (2011) in which there was a variance in morphosyntactic growth for the gender of the child, but this could not be explained by the number of utterances produced by the parents, their variation in words, or the informativeness of their input. However, only these morphosyntactic input measurements were accounted for. It could be possible that other aspects of input, for instance prosody, could account for the different outcomes of language production.

A few studies have investigated the role of gender of the addressees in IDS prosody. For example, Gratier et al. (2015) found vocalizations from mothers of boys to be of longer duration

than vocalizations to girls, while Cherry and Lewis (1976) showed that mothers of girls talked more to their child, measured in the total of utterances. Their utterances to girls also had a higher mean length of utterance. Albin and Echols (1996) found a main effect of gender on the lengthening of the word-final syllables. In both ADS and IDS, mothers of girls lengthened their word-final syllables more than mothers of boys did. Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin (2001) asked whether modifications in pitch are made for age and gender throughout the first year of the infant's life. The mothers all spoke Australian English to their children. Results showed that mothers did modify their speech according to the gender of the child. A higher mean pitch and pitch variability was used by mothers when talking to daughters. There seemed to be an interaction effect of gender with age. The pitch differences in IDS directed to boys and girls were biggest at 12 months old, the oldest age they were tested at in that study. The study by Kitamura and Burnham (2003) found similar effects for gender. In their study, pitch and pitch variability was higher in IDS directed to girls than to boys and this difference increases from birth to when the infants are 12 months old. Burnham et al. (1998) looked at differences between genders in pitch, pitch range, and duration on the vowel level. In their study they looked at the point vowel /a/, /i/ and /u/. The results showed that for the point vowels /u/ and /a/ the pitch range measures are higher when directed to girls. However, the /i/ vowel has a higher pitch range when it is directed to boys. They also found differences for gender in the duration of these vowels. The point vowels /a/ and /u/ were particularly lengthened more in IDS directed to girls than to boys.

Overall, it seems that IDS directed towards girls is more exaggerated than IDS directed towards boys. Specifically, pitch and pitch variability is higher in IDS directed to girls. It has also been found that duration of vowels is higher in IDS directed to girls and that word-final syllables are lengthened more in IDS directed to girls. While these findings suggest an exaggeration of IDS stress markers and vowel quality when addressing girls, this has not been studied yet. It is important to study gender differences for prosody to find out if prosodic differences can account for the differences in language acquisition and language outcome between boys and girls. Stress and vowel quality are important in particular, because they might help in making words more salient in a speech stream, therefore facilitating word learning.

1.4. Research questions and hypotheses

Summarizing, a discussion of the literature on stress differences between IDS and ADS concluded that pitch is higher in English IDS for stressed syllables than in English ADS. In Dutch ADS, pitch is higher in stressed syllables as well. It is expected that pitch range is greater for stressed syllables in IDS, because the literature on English IDS suggests that pitch range might be greater in stressed syllables. Furthermore, in Dutch ADS maximum pitch is always apparent in the stressed syllable. It is less clear what role duration might play as a marker for stress. Duration is an important marker of stress in Dutch ADS. Some studies on English IDS cannot find duration as a marker of stress. However, another study on English IDS suggests that duration is a marker of stress, and that listeners can distinguish between lengthening due to stress and word-final lengthening. The literature also suggests that vowel quality is an important indicator of stress, in addition to pitch, pitch range and duration. For this reason it is interesting to investigate the role of these individual factors as indicators of stress in Dutch IDS. Furthermore, vowel space expansion is suggested to enhance phonetic categorization, because of the bigger contrasts between vowels. Therefore, vowel space expansion seems to serve a didactic role. It also seems to be a universal feature of IDS. Lastly, some literature on gender differences in IDS has been discussed. Throughout literature it has been found that parents differently address children according to their gender. Overall, it seems that parent exaggerate their speech when talking to girls. They use a higher pitch, greater pitch range and longer duration of vowels when talking to girls. Vowel quality and stress markers have not been studied yet for gender of the addressee.

This study aims to investigate the prosodic properties of stress in Dutch IDS compared to ADS to see if there are differences in the indicators of stress. This examination of stress will be focused on duration, pitch, pitch range and vowel quality, considering that the literature suggests that these are the most important markers of stress in Dutch ADS. Furthermore, we investigated if vowel space is expanded more when parents teach their children novel words. This is expected, considering that exaggerated vowel quality is suggested to enhance vowel phonetic categorization and therefore has a clear didactic role. We examined these questions by looking at the stress measurements in novel words. In addition, we ask if stress and vowel quality are exaggerated more when parents speak to a girl instead of a boy.

Thus, on basis of the literature on Dutch, the following research questions and hypotheses that complement each other were formed:

1. What differences are there between IDS and ADS in the way in which stress and vowel quality are marked?
→ Vowel space expansion is bigger in IDS than in ADS.
→ Stressed syllables will be longer in duration than unstressed syllables
→ A higher mean pitch and pitch range will be found in stressed syllables for IDS in comparison to ADS.

2. What role does the gender of the infant play in the way parents mark stress and vowel quality to their infants?
→ In IDS directed to girls a higher mean pitch and pitch range will be found in general, but especially for stressed syllables.
→ Vowel space expansion of IDS directed to girls will be bigger in comparison to boys, especially for stressed syllables.
→ In IDS directed to girls, duration of stressed syllables will be longer than in IDS directed to boys.

For this study the dependent measures are duration, mean pitch (F0), mean maximum pitch, mean minimum pitch and pitch range. These dependent measures are on the syllable and vowel level. The means of the first three formants (F1, F2 and F3) are only measured on the vowel level. The independent factors in this research are gender of the infant and the condition of the reading, which is either ADS or IDS.

2. Methods

2.1. Participants

The participants of this study were 11 mother–son pairs and 11 mother-daughter pairs. These 22 mother-child dyads were part of a larger sample of a longitudinal study. All of the participating children were 18 months old (Mean=18;16). The mean age per gender is presented in Table 1. The recruited families all were native speakers of Dutch and the children were raised monolingually. When recruiting the children, it was checked if they were at family risk for dyslexia. The sample of mother-child dyads was chosen to reflect IDS directed towards typically developing infants. The families all lived in or near Utrecht, a city in the center of the Netherlands.

Table 1

The Number of Participants, the Mean Age of the Infant Measured in Months and Days and the Standard Deviation of the Mean Age Measured in Days for both Gender Conditions

Gender	N	M	SD
Male	11	18;16	8.77
Female	11	18;15	9.81

2.2. Material

The material for this study was a children's picture book. The book was called *Konijntje heeft geluk* ('Little Rabbit is lucky'). This picture book tells the story of a rabbit and the adventures she has throughout the day. Each picture is accompanied with a word on the left page. In total there are 12 pictures with their corresponding words. In figure 1, an example of a picture in the book is shown. In the book there are seven filler words that the infant is presumed to know. The filler and target words were chosen on basis of the N-CDI (Dutch CDI questionnaire). At eighteen months most infants are marked to know the chosen filler words. The five chosen target words were presumed to be words that the infant could not know yet. Out of these 12 words, five words - five targets - were chosen for analysis. The words that were analyzed for this study, all novel target words, were all disyllabic words, of which two words were iambic. All of the words, both targets and fillers can be seen in table 2.

Figure 1: *Example of a Picture in the Book representing the Word 'Pompoen' (Pumpkin)*

Table 2

The Words in the Picture Book, their English Translation and the Categories of Words they are

Word	Target/ Filler	Familiar/ Novel	Iamb/ Trochee	Gloss
zon	Filler	Familiar	N/A	'sun'
markt	Filler	Familiar	N/A	'market'
appel	Target	Familiar	Trochee	'apple'
walnoot	Target	Novel	Trochee	'walnut'
bos	Filler	Familiar	N/A	'forest'
eland	Target	Novel	Trochee	'moose'
bever	Target	Novel	Trochee	'beaver'
kasteel	Target	Novel	Iamb	'castle'
(naar) huis	Filler	Familiar	N/A	'(go) home'
opa	Target	Familiar	Trochee	'grandpa'
pompoen	Target	Novel	Iamb	'pumpkin'
slapen	Filler	Familiar	Trochee	'(go to) sleep'

2.3. Procedure

Prior to their appointment, the mothers were sent a questionnaire to assess the vocabulary of their child. Soon after the infants turned 18 months old, the mother-child pairs came to the UiL-OTS Baby Lab in Utrecht. Upon arrival at the UiL-OTS Labs they were brought to a room where the mothers would read a picture book to their child. The picture book was instructed to be read twice, the first time to the experimenter (ADS condition) and the second time to the infant (IDS condition), or vice versa. In the ADS condition the mother would be instructed to read the story, keeping in mind that they had to read it to an adult. In the IDS condition, infants sat on their mother's laps. The mothers were instructed to read to their child just like they would do at home. These instructions were given to ensure similarity between the readings of the different mothers. The main pointer the mothers got, was to always include the word on the left. When the mother read the story to the researcher, the child would play with the toys in the room. Both readings were recorded with a Canon HF11 camcorder and a Zoom H1 audio recorder (with 16-bit resolution and a sampling rate of 44.1 kHz). Afterwards, the mothers filled in a questionnaire on the words used in the picture book. They had to note whether their child knew or said these words prior to reading the book. This was done to make sure the target words were not familiar to the infants. The appointments usually lasted 30 minutes. At the end of the appointment the infants were gifted a picture book.

2.4. Annotation

The two audio recordings of each participant (44 audio recordings in total, Mean ADS= 1:59 minutes, Mean IDS boys= 02:58 minutes, Mean IDS girls=03:15 minutes) were used for annotation in the speech analysis program 'Praat'. For all of these audio recordings particular parts of the speech stream - containing one of the five target words - were segmented out of it. Segmentation of the speech stream happened on several levels, in a top down manner. First, all of the utterances containing a target word were segmented out of the speech stream. The utterances were then all marked with a number of the target word that it contained. After that, all of the target words were filtered out. Each of these words was marked with a number, in the order in which they appear in the book. Then, the syllables of each word were segmented out, including any pauses between the syllables. However, only the syllables of each first mentioned target word were segmented. If there were more mentions of a target word, these were not

analyzed further. The syllables were marked with two numbers, one for the word they were a part of, and one depicting whether the syllable contains primary or secondary stress. Primary stress was indicated with the number '1' and secondary stress with the number '2'. Lastly, the vowels of each segmented syllable were sectioned out. The vowels were each marked with two numbers, depicting word and syllable number, and the IPA notation of their sound. The minimum and maximum pitch of the first mentioned words, their syllables and vowels, were manually marked by making use of a point tier. These pitch markings were tagged with 'min' or 'max'. All of these specific name markings were important in order to have clear tags that a script could run on. Two individual scripts were eventually run on the audio files along with their segmentations. Beforehand, the words that were not suitable for analysis, i.e. due to noise, were marked in the Praat file. This was done in order to easily filter out non-usable data in further stages of analysis. The first script analyzed all of the segmented vowels and extracted the mean pitch, duration and first three formants of each vowel. F1 and F2 are most relevant to distinguish vowels in Dutch (Mens et al., 2005). However, F3 does play a role in for example the difference between the Dutch vowels /y/ and /u/. The second script analyzed the point tiers with the minimum and maximum pitch markings, along with the corresponding segmentation level these markings belonged to. This was done on two levels, at the syllable level and at the vowel level. This script also measured duration of each segmentation and mean pitch. The outcomes of the script were saved and then further analyzed in SPSS.

3. Data analysis and results

As mentioned earlier in the introduction, the current study will report on an analysis on both syllable and vowel measures. For this analysis the role of the independent measures gender of the infant, condition and stress on the several dependent measures will be reported. These dependent variables consist of duration, mean pitch (F0), mean minimum pitch, mean maximum pitch, pitch range and the means of the first three formants (F1, F2 and F3). The first three formants are only measured on the vowel level. Five Dutch words from the book were chosen for analysis: 'walnoot', 'eland', 'bever', 'kasteel' and 'pompoen'. As mentioned in the methods part, these are all disyllabic words. The measures from the (vowels in the) stressed syllables were all added up and averaged to represent the mean for one speaker. Thus, the stressed condition represents the (vowels in the) stressed syllables from all words. The same holds for the unstressed condition. In almost all of the analyses in the next sections, (the vowels in) the stressed syllables will be compared to (the vowels in) the unstressed syllables. Only in the first analysis the change in measures from unstressed to stressed syllables was computed. In this analysis the amount of change in measures in compared between ADS and IDS.

3.1. Conditions: IDS versus ADS

3.1.1. Syllables: difference in exaggeration in IDS and ADS

For this analysis the differences between stressed and unstressed syllables were computed by subtracting the mean values of the unstressed syllables from the stressed syllables. This was done for both conditions. These delta measures of IDS and ADS were then compared to each other. The goal of this analysis was to give information on whether stress is exaggerated more in IDS or not. In table 3 the difference in exaggeration is noted for both ADS and IDS. As can be seen in this table, the exaggeration is greater in IDS for most of the measures. To check the significance of the found effects, pairwise t-tests were performed.

A first test was executed to compare the change in duration from unstressed to stressed syllables between ADS and IDS. The change in duration of syllables in ADS was slightly bigger compared to the IDS condition. This difference in duration of stressed and unstressed syllables between ADS (M= -.03, SD=.04) and IDS (M= -.01, SD=.04) did not prove to be significant; $t(21)=-1.28$, $p = .214$. These results show that duration differences between stressed and unstressed syllables are not bigger for one of the speech styles. For pitch several measures were

executed. Firstly, the change in mean pitch was compared between ADS and IDS. A stressed syllable was marked more by pitch in IDS than in ADS. This difference between ADS (M= 8.64, SD= 41.09) and IDS (M= 44.04, SD= 48.83) was significant; t(21)=-2.88, p = .009. The change in mean pitch from unstressed to stressed syllables in the conditions ADS and IDS can be seen in figure 2. Secondly, the change in pitch range was compared. The change in pitch range from unstressed to stressed syllables was slightly higher in IDS (M= 51.69, SD= 60.14) than in ADS (M= 45.20, SD= 45.67). However, this effect was not found to be significant; t(21)= -.42, p = .682. For minimum pitch, similar effects were found. There was a bigger change in pitch minimum between stressed and unstressed syllables in IDS (M= 63.51, SD= 64.50), compared to ADS (M= 33.01, SD= 51.82) . However, the difference between ADS and IDS was not significant; t(21)= -1.96, p= .089. Lastly, the change in maximum pitch between ADS and IDS was compared. Maximum pitch unexpectedly was lower in stressed syllables in ADS than in unstressed syllables (M= -12.19, SD= 45.39). In IDS maximum pitch was higher in stressed syllables than in unstressed syllables (M= 11.81, SD= 54.21). However, maximum pitch differences between ADS and IDS were not significant; t(21)= -1.96, p= .063.

Table 3

Mean Change and Standard Deviation (SD) from Unstressed (US) to Stressed (S) Syllables in ADS and IDS, measured for Duration, Mean Pitch, Pitch Range, Pitch Minimum, Pitch Maximum (N=22)

		M	SD
Δ Duration	ADS	-.03[a]	.04[a]
	IDS	-.01[a]	.04[a]
Δ Mean Pitch	ADS	8.64[b]	41.09[b]
	IDS	44.04[b]	48.83[b]
Δ Pitch Range	ADS	45.20[b]	45.67[b]
	IDS	51.69[b]	60.14[b]
Δ Pitch Minimum	ADS	33.01[b]	51.82[b]
	IDS	63.51[b]	64.50[b]
Δ Pitch Maximum	ADS	-12.19[b]	45.39[b]
	IDS	11.81[b]	54.21[b]

[a] Duration measured in seconds (s), [b] Pitch measured in Hertz (Hz)

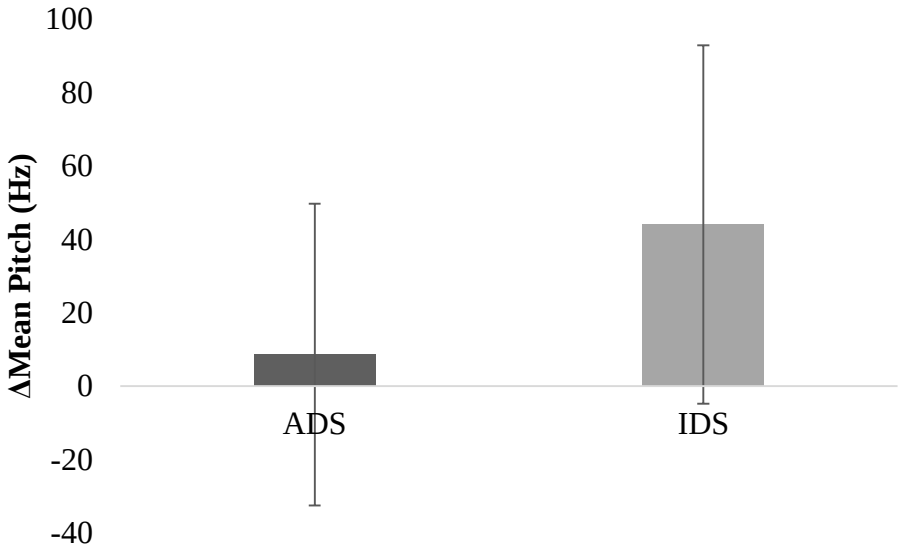

Figure 2. *Change (Δ) in Mean Pitch (in Hertz, Hz) from Unstressed to Stressed Syllables in both the Adult-directed Speech (ADS) and Infant-directed Speech (IDS) conditions. Error bars denote one Standard Deviation around the Mean.*

3.1.2. Syllables: direct comparison between stressed and unstressed syllables in ADS and IDS

In the previous analysis, it was tested if stress was exaggerated more in IDS than in ADS by looking at the differences in measures between stressed and unstressed syllables. In this analysis, the measures of stressed and unstressed syllables in IDS and ADS are directly compared. In table 4, the duration, mean pitch, pitch range, pitch maximum and pitch minimum of stressed and unstressed syllables are presented, for both IDS and ADS. As can be seen in the table, the values for stressed syllables are exaggerated in comparison to unstressed syllables. The same holds for the conditions. The values for IDS are exaggerated in comparison to ADS. A two-way repeated measures ANOVA was conducted multiple times, to check for main effects of condition and stress, as well as interaction effects of condition with stress. All of the two-way repeated measures ANOVAs are corrected for sphericity by means of the Greenhouse-Geisser correction.

The duration of syllables was slightly higher in the IDS condition than in the ADS condition. This effect proved to be significant ($F(1.00, 21.00) = 24.08$, $p < .001$). Furthermore, the duration differed significantly between stressed and unstressed syllables ($F(1.00, 21.00) = 6.96$, $p = .015$). However, there was no interaction effect of stress with condition for duration ($F(1.00, 21.00) = 1.64$, $p = .214$).

The mean pitch was higher in stressed syllables than in unstressed syllables. Moreover, the mean pitch of syllables was higher in the IDS condition than in the ADS condition. A repeated measures ANOVA with a Greenhouse-Geisser correction showed that mean pitch was significantly higher in IDS ($F(1.00,21.00) = 9.30$, $p = .006$). Mean pitch was also significantly higher in stressed syllables than in unstressed syllables ($F(1.00, 21.00) = 12.67$, $p = .002$). Lastly there was an interaction effect of stress with condition for mean pitch ($F(1.00, 21.00) = 8.29$, $p = .009$). Pairwise t-tests were performed to indicate which pairs in the repeated measures ANOVA differed significantly from each other. The tests showed that mean pitch in stressed syllables ($M= 269.35$, $SD=44.12$) of IDS is significantly higher than in unstressed syllables ($M= 225.31$, $SD= 39.28$); $t(21)= 4.23$, $p < .005$. Mean pitch was also higher in stressed syllables of IDS ($M= 269.35$, $SD= 44.12$) than of ADS (222.01, $SD= 27.91$); $t(21)= -4.35$, $p < .005$. No significant differences in mean pitch were found between stressed ($M= 222.01$, $SD= 27.91$) and unstressed syllables ($M= 213.37$, $SD= 42.52$) in ADS; $t(21)= .986$, $p = .335$. Neither was there a significant difference between unstressed syllables of IDS ($M= 225.31$, $SD= 39.28$) and ADS ($M= 213.37$,

SD= 42.52); t(21)= -.987, p = .335. The mean pitch of syllables in all conditions can be seen in figure 3.

After that, the repeated measures ANOVA was performed on pitch range. The mean pitch range in IDS was found to be significantly higher for syllables in IDS than in ADS (F=1.00, 21.00) = 9.13, p = .006). Pitch range was also found to be higher for stressed syllables than for unstressed syllables (F(1.00, 21.00) = 34.27, p < .001). However there was no interaction effect between stress and condition for pitch range (F(1.00, 21.00) = .173, p = .682).

After that, pitch minimum was compared between IDS and ADS and between stressed and unstressed syllables. Unlike our expectations, pitch minimum was consequently found to be higher in the IDS condition (F(1.00, 21.00) = 5.65, p = .027). Pitch minimum did not differ significantly in stressed and unstressed syllables (F(1.00,21.00 < .001, p = .983). The also was no interaction effect found between stress and condition for pitch minimum (F(1.00, 21.00) = 3.85, p = .063).

Lastly, pitch maximum was tested. As expected, maximum pitch was found to be higher in the IDS condition (F(1.00, 21.00) = 15.81, p = .001). Furthermore, maximum pitch is also higher in stressed syllables than in unstressed syllables (F(1.00, 21.00) = 28.30, p < .001). However, there was no interaction effect of stress with condition for maximum pitch (F(1.00, 21.00) = 3.17, p = .089).

Table 4

Duration, Mean Pitch, Pitch Range, Pitch Minimum and Pitch Maximum of Stressed (S) and Unstressed Syllables (US) in ADS and IDS (N=22)

		ADS		IDS	
		M	SD	M	SD
Duration	S	.22[a]	.04[a]	.27[a]	.04[a]
	US	.25[a]	.04[a]	.28[a]	.05[a]
Mean Pitch	S	222.01[b]	27.91[b]	269.35[b]	44.12[b]
	US	213.37[b]	42.51[b]	225.31[b]	39.28[b]
Pitch Range	S	94.66[b]	39.24[b]	124.33[b]	49.42[b]
	US	49.46[b]	27.49[b]	72.64[b]	38.29[b]
Pitch Minimum	S	169.13[b]	29.66[b]	204.16[b]	46.81[b]
	US	181.32[b]	45.60[b]	192.34[b]	51.35[b]
Pitch Maximum	S	263.79[b]	29.80[b]	328.49[b]	70.35[b]
	US	230.78[b]	50.30[b]	264.98[b]	50.11[b]

[a] Duration measured in seconds (s), [b] Pitch measured in Hertz (Hz)

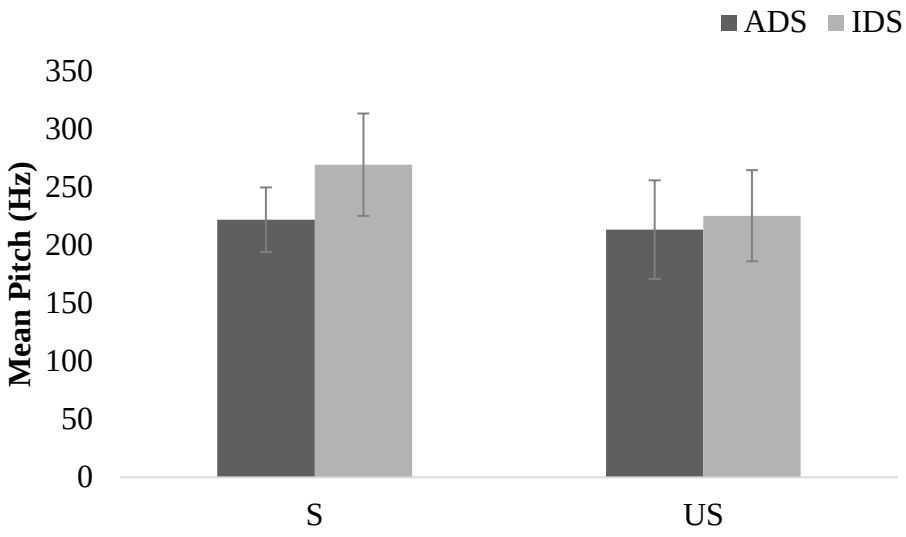

Figure 3. *Mean Pitch (in Hertz, Hz) for Stressed (S) and Unstressed (US) Syllables in both the Adult-directed Speech (ADS) and Infant-directed Speech (IDS) conditions. Error bars denote one Standard Deviation around the Mean.*

3.1.3. General vowel measures

In this section, similarly to the previous section, the measures of stressed and unstressed syllables in IDS and ADS are directly compared. In table 5, the duration, mean pitch, pitch range, pitch maximum and pitch minimum of vowels in stressed and unstressed syllables are presented, for both IDS and ADS. As can be seen in the table, the values for vowels in stressed syllables are exaggerated in comparison to vowels in unstressed syllables. The same holds for the conditions. The values for IDS are exaggerated in comparison to ADS. A two-way repeated measures ANOVA was conducted multiple times, to check for main effects of condition and stress, as well as interaction effects of condition with stress. All of the two-way repeated measures ANOVAs are corrected for sphericity by means of the Greenhouse-Geisser correction. Vowel quality, consisting of F1, F2 and F3, will be discussed in the next section.

The duration of vowels was found to be higher in the IDS condition, as had been expected ($F(1.00, 21.00) = 13.94$, $p = .001$). Vowels were also found to be of significantly longer duration in stressed than in unstressed syllables. While the data seem to show an interaction effect, this is not significant ($F(1.00, 21.00) = 2.74$, $p=.113$).

For mean pitch, as was the case for mean pitch in syllables, there are both significant main effects and a significant interaction effect ($F(1.00, 21.00) = 11.26$, $p = .003$). Thus, the mean pitch of vowels is higher in the IDS condition than in the ADS condition ($F(1.00, 21.00) = 8.99$, $p = .007$) and it is higher in stressed syllables than in unstressed syllables ($F(1.00, 21.00) = 10.99) = .003$). Pairwise t-tests were performed to indicate which pairs in the repeated measures ANOVA differed significantly from each other. The tests showed that mean pitch in vowels of stressed syllables ($M= 273.10$, $SD=42.18$) of IDS was significantly higher than in unstressed syllables ($M= 228.81$, $SD= 42.91$); $t(21)= 4.41$, $p < .005$. Mean pitch was also higher in vowels of stressed syllables in IDS ($M= 273.10$, $SD= 42.18$) than of ADS (218.83, $SD= 28.60$); $t(21)= -5.07$, $p < .005$. No significant differences in mean pitch were found between vowels in stressed ($M= 218.83$, $SD= 28.60$) and unstressed syllables ($M= 220.15$, $SD= 51.78$) in ADS; $t(21)= -.15$, $p = .880$. Neither was there a significant difference between vowels in unstressed syllables of IDS ($M= 228.81$, $SD= 42.91$) and ADS ($M= 220.15$, $SD= 51.78$); $t(21)= -.62$, $p = .545$. The mean pitch of vowels in all conditions can be seen in figure 4.

After that, the repeated measures ANOVA was performed on pitch range. Pitch range was found to be higher in vowels in IDS than in ADS ($F(1.00, 21.00) = 5.47$, $p = .029$). It was also found to be higher in vowels in stressed syllables than in unstressed syllables ($F(1.00, 21.00) = 57.11$, $p < .001$). While the data suggest an interaction effect between stress and condition for pitch range, this was not found to be significant ($F(1.00, 21.00) = 1.47$, $p = .238$).

Unlike our expectations, the minimum pitch of vowels is higher in IDS than in ADS ($F(1.00, 21.00) = 6.23$, $p = .021$). The data seem to show a predicted lower minimum pitch of vowels in stressed syllables, however this did not to be significant ($F(1.00, 21.00) = 1.41$, $p = .249$). However, a significant interaction effect was found ($F(1.00, 21.00) = 5.14$, $p = .034$). Pairwise t-tests were performed to indicate which pairs in the repeated measures ANOVA differed significantly from each other. The tests showed that minimum pitch of vowels in stressed syllables ($M= 227.26$, $SD=31.24$) in IDS did not differ significantly from unstressed syllables ($M= 220.40$, $SD= 38.76$); $t(21)= .72$, $p = .477$. Minimum pitch was higher in vowels of stressed syllables in IDS ($M= 227.26$, $SD= 31.24$) than in ADS (189.13, $SD= 27.95$); $t(21)= -5.68$, $p < .005$. Vowels in stressed ($M= 189.13$, $SD= 27.95$) syllables in ADS were found to be lower than unstressed syllables ($M= 212.99$, $SD= 54.21$) in ADS; $t(21)= -2.33$, $p = .030$. There was no significant difference between vowels of unstressed syllables in IDS ($M= 220.40$, $SD=$

38.76) and ADS (M= 212.99, SD= 54.21); t(21)= -.51, p = .617. The minimum pitch of vowels in all conditions can be seen in figure 5.

Lastly, a repeated- measures ANOVA was performed on maximum pitch. The data met our expectations, as it was found that maximum pitch of vowels was higher in IDS than in ADS (F(1.00, 21.00) = 10.47, p = .004). Furthermore, maximum pitch of vowels was higher in stressed syllables than in unstressed syllables (F(1.00, 21.00) = 27.25, p < .001). An interaction effect was also found (F(1.00, 21.00) = 5.09, p = .035). Pairwise t-tests were performed to indicate which pairs in the repeated measures ANOVA differed significantly from each other. The tests showed that maximum pitch of vowels in stressed syllables (M= 317.05, SD=65.68) in IDS is significantly higher than in unstressed syllables (M= 257.63, SD= 51.81); t(21)= 4.48, p < .005. Maximum pitch was also higher in vowels of stressed syllables in IDS (M= 317.05, SD= 65.68) than in ADS (253.47, SD= 32.63); t(21)= -3.96, p = .001. Maximum pitch of vowels in stressed syllables (M= 253.47, SD= 32.63) was found to be higher than of vowels in unstressed syllables (M= 233.51, SD= 56.66) in ADS; t(21)= 2.08, p = .050. There was no significant difference between vowels of unstressed syllables in IDS (M= 257.63, SD= 51.81) and ADS (M= 233.51, SD= 56.66); t(21)= -1.49, p = .152. The maximum pitch of vowels in all conditions can be seen in figure 6.

Table 5

Duration, Mean Pitch, Pitch Range, Pitch Minimum and Pitch Maximum of Vowels in Stressed (S) and Unstressed Syllables (US) in ADS and IDS (N=22)

		ADS		IDS	
		M	SD	M	SD
Duration	S	.15[a]	.02[a]	.18[a]	.03[a]
	US	.08[a]	.02[a]	.10[a]	.03[a]
Mean Pitch	S	218.83[b]	28.60[b]	273.10[b]	42.18[b]
	US	220.15[b]	51.78[b]	228.81[b]	42.91[b]
Pitch Range	S	68.29[b]	27.95[b]	93.44[b]	53.12[b]
	US	26.12[b]	14.91[b]	34.54[b]	21.58[b]
Pitch Minimum	S	189.13[b]	27.95[b]	227.26[b]	31.24[b]
	US	212.99[b]	54.21[b]	220.40[b]	38.76[b]
Pitch Maximum	S	253.47[b]	32.63[b]	317.05[b]	65.68[b]
	US	233.51[b]	56.66[b]	257.63[b]	51.81[b]

[a] Duration measured in seconds (s), [b] Pitch measured in Hertz (Hz)

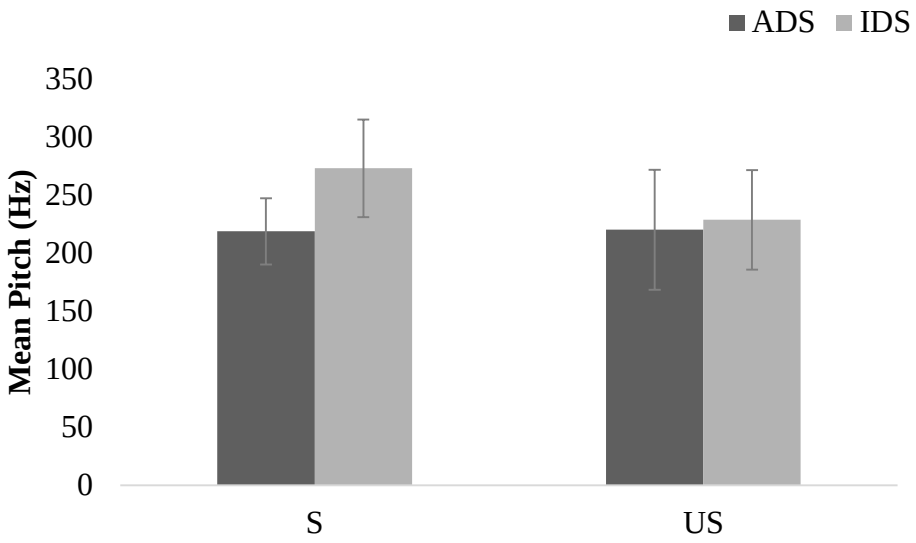

Figure 4. *Mean Pitch (in Hertz, Hz) for Vowels in Stressed (S) and Unstressed (US) Syllables in both the Adult-directed Speech (ADS) and Infant-directed Speech (IDS) conditions. Error bars denote one Standard Deviation around the Mean.*

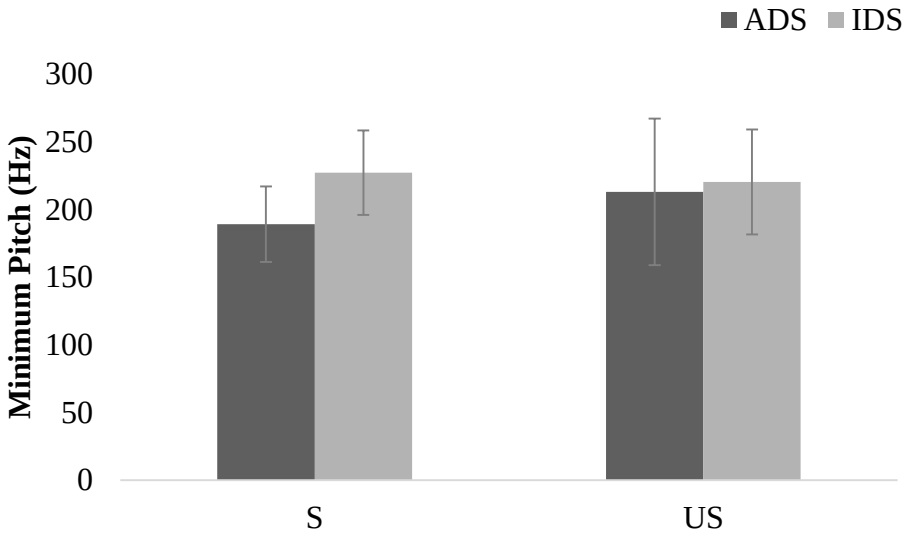

Figure 5. *Minimum Pitch (in Hertz, Hz) for Vowels in Stressed (S) and Unstressed (US) Syllables in both the Adult-directed Speech (ADS) and Infant-directed Speech (IDS) conditions. Error bars denote one Standard Deviation around the Mean.*

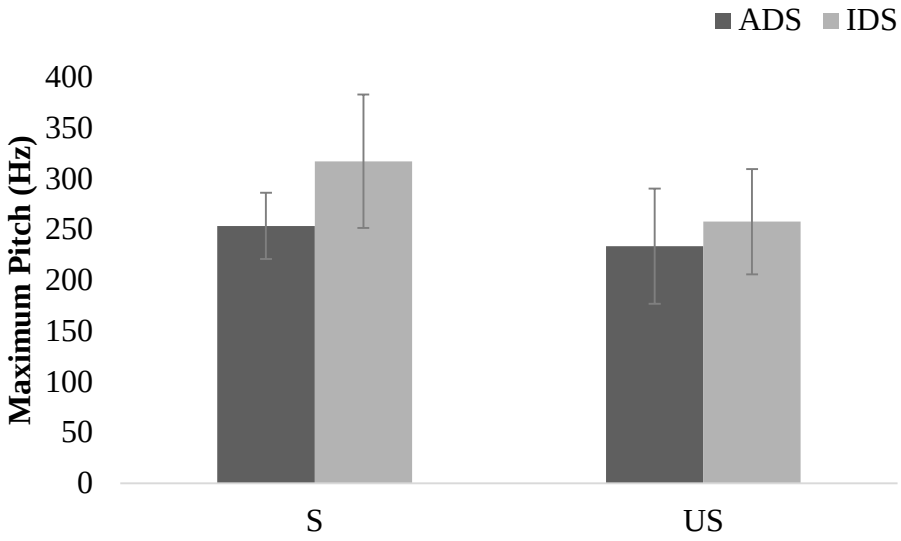

Figure 6. *Maximum Pitch (in Hertz, Hz) for Vowels in Stressed (S) and Unstressed (US) Syllables in both the Adult-directed Speech (ADS) and Infant-directed Speech (IDS) conditions. Error bars denote one Standard Deviation around the Mean.*

3.1.4. Vowel quality

In this section, vowel quality in IDS and ADS of vowels in both stressed and unstressed syllables is compared. This is done by looking at F1, F2 and F3. To compare vowel quality, a two-way repeated measures ANOVA was used. All of the two-way repeated measures ANOVAs on vowel quality are corrected for sphericity by means of the Greenhouse-Geisser correction. In table 6 the values of the formants are noted.

For F1, it was expected that the values would be lower for stressed syllables in order to have a larger vowel space. This effect was found in the data, but it was not significant ($F(1.00, 21.00) = 1.48$, $p = .237$). It was also expected that F1 would be lower in IDS in order to have a larger vowel space. However, the opposite effect was found ($F(1.00, 21.00) = 32.57$, $p < .001$). No significant interaction effect was found ($F(1.00, 21.00) = 2.51$, $p = .128$).

F2 was expected to be higher in stressed syllables and in IDS, because the contrast with F1 would then be biggest, therefore creating a bigger vowel space. This effect was found for stress ($F(1.00, 21.00) = 10.45$, $p = .004$). However, a significant opposite effect for condition was found ($F(1.00, 21.00) = 109.04$, $p < .001$). No significant interaction effect was found ($F(1.00, 21.00) = .10$, $p = .754$).

Lastly, F3 was expected to be higher in IDS and stressed syllables, because the contrast with F2 and F1 would be bigger that way, therefore creating a bigger vowel space. The results found this effect for both condition ($F(1.00, 21.00) = 7.13$, $p = .014$) and stress ($F(1.00, 21.00) = 56.90$, $p < .001$). However, no significant interaction effect was found ($F(1.00, 21.00) = .01$, $p = .936$).

Table 6

F1, F2 and F3 Measured in Hertz (Hz) of Vowels in Stressed (S) and Unstressed Syllables (US) in ADS and IDS (N=22)

		ADS		IDS	
		M	SD	M	SD
F1	S	479.49	40.23	483.35	44.44
	US	578.14	67.34	549.25	72.67
F2	S	1921.99	247.55	1818.90	199.93
	US	1451.70	184.62	1326.69	140.44
F3	S	2879.49	179.17	2968.07	143.93
	US	2594.27	200.27	2676.63	234.73

3.2. Gender

3.2.1. Syllable level

This section considers possible gender differences in the way stress is realized. This is done by comparing the stressed syllables spoken to the different genders with each other and the unstressed syllables. In table 7 the duration, mean pitch, pitch range, pitch minimum and pitch maximum of unstressed and stressed syllables in IDS to the different genders is noted. A one-way MANOVA was performed on the stressed syllables, to see if there was a difference in the way stress is realized in IDS for the different genders. No main effect of gender could be found ($F(4, 17) = 1.09$, $p = .393$; Wilk's $\Lambda = 0.796$). However, there seem to be some trends, such as a higher mean pitch and maximum pitch in IDS to female infants. Some of seeming trends in the data, are more unexpected. Pitch range is higher in IDS to male infants and pitch minimum is lower in IDS to male infants.

A one-way MANOVA was also performed on the unstressed syllables, which also was not found to be significant ($F(4, 17) = .24$, $p = .914$; Wilk's $\Lambda = 0.947$). Some of the same trends that are apparent for the stressed syllables, are apparent for the unstressed syllables as well. Mean pitch and pitch maximum are higher in syllables directed to female infants, while minimum pitch is lower in IDS directed to male infants.

Table 7

Duration, Mean Pitch, Pitch Range, Pitch Minimum and Pitch Maximum of Stressed (S) and Unstressed Syllables (US) in IDS to Males and Females

		Male (N=11)		Female (N=11)	
		M	SD	M	SD
Duration	S	.27[a]	.04[a]	.27[a]	.04[a]
	US	.29[a]	.05[a]	.28[a]	.05[a]
Mean Pitch	S	258.70[b]	45.04[b]	280.00[b]	42.54[b]
	US	220.30[b]	33.79[b]	230.32[b]	45.20[b]
Pitch Range	S	128.64[b]	51.93[b]	120.03[b]	48.90[b]
	US	72.14[b]	45.81[b]	73.14[b]	31.29[b]
Pitch Minimum	S	191.18[b]	54.49[b]	217.12[b]	35.54[b]
	US	185.93[b]	30.42[b]	198.75[b]	67.25[b]
Pitch Maximum	S	319.83[b]	74.48[b]	337.15[b]	68.42[b]
	US	258.08[b]	44.18[b]	271.89[b]	56.72[b]

[a] Duration measured in seconds (s), [b] Pitch measured in Hertz (Hz)

3.2.2. Vowel level

In the previous section, the gender analysis was done on the syllable level. In this section, the gender analysis on the vowel level is discussed. Table 8 shows the values of these vowel measures in both IDS directed to boys and girls for vowels in stressed and unstressed syllables. A one-way MANOVA was performed to determine if there was a main effect of gender for

vowels in stressed syllables, which could not be found ($F(8, 13) = .87$, $p = .565$; Wilks' $\Lambda = 0.652$). Table 8 shows that there are some trends in the data. Mean pitch and maximum pitch are higher in IDS directed to girls, similarly to what was found in the data on the syllable level. Minimum pitch was also found to be lower in IDS directed to male infants. A difference between the results of the syllable analysis and the vowel analysis is that pitch range is higher in the vowel analysis.

A second one-way MANOVA was performed on the vowels in unstressed syllables. No main effect of gender was found ($F(8, 13) = 1.04$, $p = .457$, Wilks' $\Lambda = .610$). The data of the vowels in the unstressed syllables only show one trend: mean pitch is higher in IDS directed to girls.

It was also tested if vowel quality differed for IDS directed to the two different genders. In table 9 shows the vowel quality measures for both genders in stressed and unstressed syllables. No main effect of gender was found for both the analysis of stressed vowels found ($F(8, 13) = .87$, $p = .565$; Wilks' $\Lambda = 0.652$), and unstressed vowels ($F(8, 13) = 1.04$, $p = .457$, Wilks' $\Lambda = .610$). Even though a main effect cannot be found, an effect of gender could be found for F3 for both the stressed ($F(1, 20) = 6.29$, $p = .021$) and unstressed vowels ($F(1, 20) = 5.79$, $p = .026$). The found effect was unexpected, but because F1 and F2 are mostly important to derive vowel space, it is not exactly clear how this should be interpreted. For both the unstressed and stressed vowels the trend is found that F2 is higher in IDS directed to males, which had also not been expected. It had been expected that F2 would be higher in IDS directed to girls, as a part of an exaggerated vowel space. Lastly, for F1 the trend was found that F1 was lower in stressed syllables directed to boys. For unstressed syllables the opposite pattern can be recognized. While the findings for the unstressed syllables fall in the line of expectations, the findings for the stressed syllables do not. It had been expected that F1 would be lower in IDS directed to girls, in order to create a bigger vowel space in combination with a higher value for F2.

Table 8

Duration, Mean Pitch, Pitch Range, Pitch Minimum and Pitch Maximum of Vowels in Stressed (S) and Unstressed Syllables (US) in IDS to Males and Females

		Male (N=11)		Female (N=11)	
		M	SD	M	SD
Duration	S	.18[a]	.04[a]	.17[a]	.02[a]
	US	.10[a]	.03[a]	.10[a]	.02[a]
Mean Pitch	S	266.42[b]	43.26[b]	279.78[b]	42.18[b]
	US	225.96[b]	40.08[b]	231.67[b]	47.35[b]
Pitch Range	S	84.28[b]	52.40[b]	102.61[b]	54.73[b]
	US	33.70[b]	27.46[b]	35.38[b]	14.91[b]
Pitch Minimum	S	225.09[b]	31.72[b]	229.42[b]	32.15[b]
	US	219.98[b]	33.26[b]	220.82[b]	45.26[b]
Pitch Maximum	S	305.70[b]	67.04[b]	328.39[b]	65.44[b]
	US	258.98[b]	58.70[b]	256.26[b]	46.76[b]

[a] Duration measured in seconds (s), [b] Pitch measured in Hertz (Hz)

Table 9

F1, F2 and F3 Measured in Hertz (Hz) of Vowels in Stressed (S) and Unstressed Syllables (US) in IDS to Males and Females

		Male (N=11)		Female (N=11)	
		M	SD	M	SD
F1	S	472.28	41.02	494.42	46.84
	US	568.92	71.92	529.57	71.18
F2	S	1869.49	195.24	1768.30	200.49
	US	1362.70	145.10	1291.20	132.66
F3	S	3036.86	92.80	2899.27	156.46
	US	2785.32	191.99	2567.93	229.90

4. Discussion

In earlier studies the characteristics of stress in English IDS and Dutch ADS have been set out. Based on the findings in those studies, the expectations for the characteristics of Dutch IDS were formed for this study. The most important cues for stress in these studies for both languages were mean pitch, duration and vowel quality. It was also suggested that pitch range might play a big role. In the studies on English IDS, these characteristics were mostly found to be exaggerated. Therefore, we expected that mean pitch and pitch range would be higher in stressed syllables in ADS than in IDS. We also expected that stressed syllables would be longer in duration in IDS than in ADS. Lastly, we expected vowel space expansion to be bigger in IDS than in ADS. Furthermore, this study studied possible gender differences for stress and vowel quality. The literature on gender differences suggest that girls' language acquisition and outcome differs from that of boys. Literature on prosody suggests that IDS directed to girls is characterized by exaggerated characteristics of IDS compared to IDS directed to boys. Based on the findings for prosody, the expectations for stress and vowel quality were formed for this study. Studying these characteristics is important to find out if it might play a role in the difference in language acquisition trajectories of boys and girls. It was expected that duration would be longer, mean pitch and pitch range would be higher and vowel space would be bigger for IDS directed to girls than IDS directed to boys. It was also expected that for stressed syllables, this exaggeration in IDS directed to girls would be even more apparent.

In this study, therefore mean pitch, pitch range, duration, minimum pitch and maximum pitch were studied on the vowel and syllable level. Furthermore, the first three formants of the vowels were studied. The outcomes of these dependent measures were tested with three types of independent measures. It was tested whether stress, condition and gender of the infant influenced the outcomes of these measures. Both the analysis of syllables and vowels showed an expected significant effect of mean pitch. Mean pitch was exaggerated more in stressed syllables of IDS than in ADS. This was also found for vowels. While no significant effects are found for minimum pitch on the syllable level, this is found on the vowel level. The difference between vowels in stressed and unstressed syllables in ADS follow an expected pattern. In vowels of stressed syllables the minimum pitch is lower than in unstressed syllables. However, for IDS unexpected results were found. Minimum pitch was found to be higher overall in the IDS condition. A trend was also found where stressed syllables in IDS were actually higher in

minimum pitch than unstressed syllables. For maximum pitch expected significant effects were found. Maximum pitch was higher overall in the IDS condition and the exaggeration of maximum pitch was higher in stressed syllables of IDS than of ADS. Though there are differences in minimum and maximum pitch, there were no significant effects of pitch range. This might be due to the higher values for minimum pitch in IDS.

Because a higher mean pitch is found on both the vowel and syllable level, it can be probably be said that a higher mean pitch is the main cue for stress in Dutch IDS. Furthermore, it seems that the vowel is most susceptible to pitch changes. This indicated that the vowel might play the biggest role in cueing stress, as regards to stress, in Dutch IDS. What is notable, is the overall trend on both the vowel and syllable level. On both levels it can be seen that the different pitch measures are overall higher in IDS, especially for stressed syllables. It might be that the higher mean pitch found in stressed syllables boosts the other pitch measures, including minimum pitch, as well. While the effect is not significant, on both the vowel and syllable level a greater pitch range can be found for IDS in general and for (vowels in) stressed syllables of IDS especially. Further research with a higher number of participants should indicate if the found trends in this study are representative for Dutch stress in IDS. If these results would be replicated, it would indicate that stress in IDS has a didactive role, because the contrasts in pitch are higher than in ADS, making a stressed syllable more clear. Furthermore, it would provide evidence for a clear affective role, because different pitch measures are found to be higher overall, making the speech appeal more to infants.

For vowel quality no significant effects were found. There were also no significant effects of duration on both the vowel and the syllable level. For vowel quality a trend is found that vowel space is reduced in IDS and that this reduction is bigger in unstressed syllables. However it is hard to interpret the outcomes for vowel quality and duration, because all of the measures for different stressed syllables were added up and then averaged. The same was done for the unstressed syllables. In this study, the (vowels in) unstressed and stressed syllables were then compared. We are aware however, that the different syllables in the words had very different intrinsic durations. Because syllables (and vowels) of different lengths were put together in a same group and then averaged it is possible that there were differences for stress and condition, but that they were washed out by means of this analysis. A similar conclusion can be made about the vowel quality. The words used for this analysis had a range of different

vowels. Each type of vowel has its own, intrinsic, characteristic vowel quality. Because of the way the vowels were analyzed, it cannot clearly be said if vowel space generally reduces in Dutch IDS. For further research we would therefore recommend analysis on all of the five words, to make sure that the intrinsic characteristics of the syllables and vowels are not lost. Only then, it can clearly be said if duration is not a stress marker in Dutch IDS and if vowel quality is generally reduced.

No main effect was found for gender. The only measure that proved to be significantly different was F3, for both stressed and unstressed syllables. In IDS directed to boys F3 was found to be higher than in IDS directed to girls. However, it is difficult to interpret this difference. F1 and F2 are most important to depict vowel quality for most vowels in Dutch, while F3 has no independent contrastive value. Furthermore, no significant differences or clear trends can be found for F1 and F2 for the different genders. For vowel quality in IDS directed to the different genders, the same notes can be made as have been made for vowel quality in general. Analysis of each word separately would provide more and clearer data on how vowel quality for the different genders. The general remarks for duration are also applicable to the gender analysis of duration. What is interesting to note, is that the overall trend that was apparent in IDS, can also be seen in IDS directed girls. Overall, on both the syllable and vowel level, different measures for pitch are higher in IDS directed to girls, even for minimum pitch. This occurs for both stressed and unstressed syllables (or vowels), but the effect is biggest for stress. Even more so, pitch range is also generally found to be more exaggerated in IDS directed to girls. Even though the effects are slightly less consistent than for the ADS-IDS difference, there is no denying that the same overall trend is found. The slightly less consistent pattern is probably due to a lesser amount of participants for the gender analysis. Thus, even though the findings of a higher minimum pitch in IDS in general and IDS directed to girls seemed to go against our predictions, in the end these predictions still seem to be mostly true. The pattern that is found in IDS in general is mostly replicated in IDS to girls. This means that IDS directed to girls can still be seen as an exaggerated version of the IDS characteristics. Naturally, further research with a higher number of participants should conclude if this is true.

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