Bachelor Thesis

Stress as a cue for word segmentation by Dutch-learning 8-month-olds

Lianne Dekker

3901777

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Supervision:

Brigitta Keij, Utrecht University

Abstract

Among other cues, the native stress pattern is an important cue for word segmentation for infants. German infants show language-specific discrimination between stress patterns at 4 months and develop this into a preference for their native stress pattern at 6 months. From this moment on, they can start developing a stress based segmentation strategy. It has been found that English-learning infants are able to use their native stress pattern as a segmentation cue as early as 7.5 months. German, English and Dutch are stress-timed trochaic languages and it would thus be expected that Dutch-learning infants develop a preference for their native stress pattern within the period of 4 to 7.5 months and that they are also able to use this preference for word segmentation, resulting in a stress based segmentation strategy. This study investigated whether Dutch-learning infants have a preference for their native stress pattern at 6 and 8 months; whether the 8-month-olds are able to use stress as a segmentation cue and if so, which stress pattern facilitates segmentation for them. It was found that the 6-month-olds already have a preference for their native stress pattern. Furthermore, the 8-month-olds were able to segment words based on a universal cue, namely stress clash, but they did not show the ability to segment words using their native stress pattern.

Content

1. Introduction

During the first years of their lives, most infants effortlessly acquire the language that is spoken around them. Within a year, they speak their first words, but before this is achieved, some preparation has to happen. Infants start out as universal listeners, they are equally interested in their native language as in any other language and still discriminate the phonemes of all languages. In the process of learning their native language, there is a decline in the universality of their listening and they start to be more and more interested in their native language. Before the first word is produced, children have to learn the characteristics of their language. In this, production clearly lags behind perception, infants turn from universal to language specific perceivers at around six months, but only at one year they become language specific producers (Kuhl, 2004).

Until they are around 5 months old, infants still discriminate between the phonemes of all languages, after this, they start to learn to discriminate between the phonemes of their native language. At 6 months they achieve language specific perception of vowels, but it still takes until the 11th month before also consonants are only perceived in a language specific manner (Kuhl, 2004). This is an important process, as for producing their first words infants have to find out which phonemes are necessary to build up those words. Furthermore, they also have to be able to segment words from fluent speech. Human speech is a string of sounds without clear pauses between words. This can be compared to reading a text without the spaces between the words. The infants have the task to figure out where the word boundaries are before they can learn the words of the language. For word segmentation to happen, two important milestones are achieved around 8 months; infants are then able to find out the statistical probabilities between syllables and phonemes for their native language and they have learned the stress pattern of their native language (Kuhl, 2004). Both skills are important for word segmentation. The statistical probabilities help the infant to decide whether a syllable has a high probability of being attached to a previous syllable or whether this syllable has a higher probability of being the start of a new word. They base this on the frequency with which they hear these syllables following each other. If the frequency is high, the syllables are probably together in the same word, otherwise it can better be the start of a new word. The detection of the native stress pattern is also important. In disyllabic words, there are two possible stress patterns, trochaic and iambic, the first having stress on the first syllable and the latter on the last. Knowing which stress pattern their native language uses, helps infants in word segmentation because the words they segment should follow the native stress pattern. When infants have found out what words sound like in their native language and what the characteristics of their language are, they can start producing their first words.

Here I will focus on the second half of the first year of life in which children start to segment words in their native language. This thesis will focus on the role of the native stress pattern in word segmentation. Two experiments have been conducted; the first tries to answer whether 6- and 8-month-old Dutch-learning infants show a preference for their native stress pattern and when this preference develops. The second experiment tries to answer whether 8-month-old Dutch-learning infants use stress as a segmentation cue and if so, which stress patterns they use to segment words from continuous speech. Before going into detail on these experiments, some background literature will be presented. The phonology of Dutch will be reviewed with an emphasis on how stress is realised in Dutch. This is important for developing the stimuli of the experiments and for predicting whether the infants will prefer the iambic or trochaic pattern. Furthermore, other cues for word segmentation will be discussed to give a complete overview of what other processes are involved in segmentation and their relative importance. Finally, the earlier work done on word segmentation based on stress cues will be looked at to give a comprehensive understanding of the state of the art in this field.

1.1 Stress in Dutch

Dutch is a trochaic language (Kager, 1993), meaning that stress is on the penultimate syllable. In disyllabic words this will be on the first syllable and in trisyllabic words on the second syllable. However, stress in Dutch is also quantity sensitive and this property is added to the trochaic property, Dutch thus has quantity sensitive trochees that are counted from right to left (Gussenhoven, 2009). Quantity, whether a syllable is heavy or light, is determined by moras. A syllable that has one mora is considered light, a syllable with two moras is heavy and a syllable with three moras is superheavy. It depends on the language how many moras are given to which type of syllable. In Dutch, a syllable with a short vowel receives one mora and a syllable with a long vowel or a closed rhyme receives two. A syllable can maximally receive three moras, in Dutch this is the case for e.g. a long vowel followed by a closed rhyme (Gussenhoven, 2009). Quantity comes into play in cases where the penultimate syllable is not stressed. One such case is monosyllabic words, as the only syllable in these words always has to be heavy. In case of a short vowel, there always has to be a coda to make the word bimoraic, an example of this is /lɑt/ meaning *slat*, the /t/ is needed to accept this word in Dutch, without the /t/ the /ɑ/ would have been lengthened to make it a valid word: /la/ meaning *drawer*. In case of a diphthong such as /ɛi/ meaning *egg* or a word with a long vowel, a coda is not required as these are already bimoraic (Gussenhoven, 2009). The second case in which penultimate stress does not appear, is in a word with three or more syllables that has an open penult and a closed final syllable. In this case, the stress skips the open penult and moves to the antepenult which then has to be heavy. Lastly, if the word contains a superheavy syllable, the stress is automatically on the superheavy syllable. Superheavy syllables can only occur in word final position in Dutch (Gussenhoven, 2009). Quantity is thus important in assigning stress to a syllable, as multiple syllables in a word can be heavy, it is important to know how quantity influences stress. Dutch is a language that assigns stress from right to left, so the first heavy syllable from the right receives stress. If there are no phonemically heavy syllables, stress is on the penult as is determined by the trochaic character of the language.

There are two important principles for assigning stress in Dutch; the Stress-to-Weight Principle (SWP) and the Weight-to-Stress Principle (WSP). The SWP says that if a syllable is stressed it should also be heavy, so if a vowel is monomoraic when it is unstressed it has to be bimoraic when it is stressed to ensure that the stressed syllable is heavy (Gussenhoven, 2009). The WSP says that heavy syllables attract stress and thus long vowels and diphthongs have to be stressed in Dutch (Gussenhoven, 2009). Quantity is thus mostly depended on the vowels. The vowel quantity is partially determined by lexical phonology; long vowels and diphthongs always receive two moras. However, lax short vowels and tense long or short vowels receive only one mora when unstressed and two when stressed, this is due to the SWP principle which is not part of the lexical phonology. Furthermore, segmental information can also play a role, when /i,y,u/ are placed before an /r/ they are lengthened and receive two moras (Gussenhoven, 2009). It can thus be concluded that the Dutch quantity system is determined by information from lexical phonology, segmental information and phonological rules. The property of quantity sensitivity is very important for the assignment of stress in Dutch.

Suprasegmental information is also important for the realisation of stress in Dutch. Syllables with and without stress are often segmentally the same. Suprasegemental stress information can be used to distinguish between them. The most important information is provided by spectral tilt; spectral tilt is realised by a greater vocal effort in the higher frequency regions of the vowel in the stressed syllable. This is perceived as the vowel being louder. (Sluijter, van Heuven & Pacilly, 1997). However, the overall intensity level of a syllable, also realised as loudness, is not a very strong stress cue. This is logical, as noise can easily reduce the difference in intensity between a stressed and an unstressed syllable. If a listener is in a noisy environment, the speech will be overall less intense and thus the difference will be less pronounced. In the case of spectral tilt, the noise cannot interfere and the strong stress cue remains (Sluijter, van Heuven & Pacilly, 1997).

Another strong suprasegmental cue is duration. An example in which duration is important for distinguishing between syllables form the words /sʏbjɛkt/ meaning *subject* and /sʏbsidi/ meaning *subsidy*. In the first word, /sʏb/ has primary stress, but in the second word it does not, however, the two instances of /sʏb/ are segmentally the same.

Duration is in this case needed to facilitate lexical access. In e.g. English, the unstressed version of /sʏb/ would have undergone vowel reduction, which would make the two segmentally different and in this way facilitate lexical access. In Dutch, duration distinguishes the two instances of /sʏb/. (Cutler, Wales, Cooper & Janssen, 2007). In general, stressed syllables tend to be longer than unstressed syllables (Reinisch, Jesse, McQueen, 2011). Duration is one of the most important phonetic stress cues on word level in Dutch as it is preserved when the emphasis of the sentence is on a normally unstressed syllable (Reinisch et al., 2011). The duration of a syllable with primary stress is longer than that with secondary stress or no stress and syllable with secondary stress is longer than one without stress. This also means that it is easier to distinguish between a syllable with primary stress and one without stress than between a syllable with primary stress and a syllable with secondary stress as there is a smaller difference in duration (Reinisch et al., 2011). The difference in duration signals the difference in stress in the two instances of /sʏb/ and thus helps the Dutch listener to distinguish between the two words before they are fully pronounced.

Lastly, pitch is also a suprasegmental cue for stress in Dutch. It is less important for the realisation of Dutch stress than spectral tilt and duration. Pitch is dependent on sentence intonation. Thus when a word is spoken in isolation, there is no pitch accent on the stressed syllable, however, when spoken in a sentence, there is a pitch accent on the stressed syllable (Sluijter, van Heuven & Pacilly, 1997). Phonologically, stress in Dutch is assigned by trochees and influenced by quantity sensitivity. Phonetically, it is mostly realised by spectral tilt and duration and to a lesser degree by pitch.

1.2 Cues for word segmentation

Word segmentation from fluent speech is a difficult task as word boundaries are not always marked by the same acoustic cues. Across languages, there is not one unique acoustic cue for word boundaries (Saffran, Aslin & Newport, 1996). This complicates the process as infants cannot rely on a unique acoustic cue, but have to find out whether there are any acoustic cues in their native language. It may be the case that there are none and it is thus not possible to only rely on acoustic cues. Infants also have to rely on other cues for word segmentation to take place. There are several cues that may help them such as statistics, infant directed speech, functional morphemes, allophonic variation, phonotactics and prosody. As all of these are probabilistic cues none of them predicts word boundaries a hundred percent correct and the integration of multiple cues is needed for accurate word segmentation. The first cue that will be discussed is statistical learning.

Using the head-turn preference procedure (HPP), Saffran and colleagues (1996) found that in the absence of prosodic and acoustic cues, 8-month-old infants could recognise the difference between novel and familiar words. The familiar words were learned beforehand in a familiarisation phase of two minutes. The novel words contained syllables that were in the familiarisation phase but in a different order. This indicates that infants are sensitive to the serial order of syllables. However, this cannot be a sufficient cue for word segmentation because it is possible for almost any syllable sequence to occur in natural speech. Therefore, another experiment was conducted which tested infants discrimination between words that have high transitional probabilities (syllable sequences that occur often) and words that have low transitional probabilities (syllable sequences that occur rarely) (Saffran et al., 1996). The difference with the first experiment is that both sorts of words are heard in the familiarisation phase, however, some more than others. In this case, infants distinguished between the high and the low transitional probabilities and showed a novelty preference for the low transitional probability words. This leads to the conclusion that infants segmented the words with the high transitional probability just as they segmented the familiar words in the first experiment. As in both experiments the infants had a familiarisation phase of only two minutes, the ability to do statistical learning seems quite strong and clearly facilitates word segmentation (Saffran et al., 1996). However, if infants segment words based on frequent co-occurrence of syllables, they may wrongly segment often occurring pairs of monosyllabic words as one word. For example, /ðə dɒg/ are two monosyllabic words that occur frequently next to each other and would thus logically be segmented into /ðədɒg/ being one word. To prevent this from happening, it is hypothesised that infants do not only take statistics on transitional probabilities but also on the baseline frequency of the first syllable in the pair, in this case /ðə/. If the first syllable frequently occurs in different positions, the infants decide that it cannot be the first syllable of a word (Saffran et al., 1996).

Statistical learning does not take place effortlessly. It is easier for infants to do statistical learning on infant directed speech than on adult directed speech. When infant directed speech and adult directed speech are made the same on all variables, except the characteristic prosodic pattern of infant directed speech, infants only show statistical learning from the infant directed speech (Thiessen, Hill & Saffran, 2005). This is in contrast with what Saffran and colleagues (1996) found. Prosodic information was stripped from their stimuli, but the infants still showed statistical learning. The difference lies in the complexity of the stimuli, Saffran and colleagues (1996) used only four trisyllabic nonsense words in a continuous speech stream as familiarisation, whereas Thiessen and colleagues (2005) used twelve sentences of nonsense words. Thiessen and colleagues (2005) thus used more complex stimuli which makes it harder for the infants to segment words from it. The results by Thiessen and colleagues (2005) indicate that infant directed speech is another important factor in the word segmentation process. It is not only important for statistical learning. In infant directed speech, the pauses between words are often more pronounced and the sentences are shorter and less complicated which helps the infants in word segmentation (Thiessen, et al., 2005). Furthermore, infant directed speech is also better at attracting the infants' attention. This is likely to give them a better focus on the language which facilitates learning (Thiessen, et al., 2005).

Another cue for word segmentation are functional morphemes. In studies with 8-month-old English- and French-learning infants it has been shown that functional morphemes facilitate segmentation (Shi & Lepage, 2008). In any language functional morphemes are only a small set of morphemes, but most of them occur very frequently in speech. Therefore, infants are likely to pick up those morphemes. Nouns are often preceded or followed by a functional morpheme. A preceding functional morpheme makes the noun salient for infants to segment as the start of the noun is signalled by the morpheme. A following functional morpheme may be of use in finding the end of the noun. In HPP experiments, 8-month-olds were familiarised with either a real determiner morpheme followed by a noun or a fake (but plausible) determiner morpheme followed by a noun. In the test phase, the infants showed a familiarity preference for the nouns that were preceded by a real morpheme. Furthermore, when an infrequent determiner was used in the familiarisation, no difference compared to a fake determiner was shown. This indicates that determiners facilitate segmentation, but that the frequency of the determiner in natural language plays a large role. As this happened with both English- and French-learning infants, two languages that are rhythmically different, the use of functional morphemes for segmentation is thought to be universal. For languages without determiners, other functional morphemes may come in useful (Shi & Lepage, 2008). Infants thus also take statistics on the frequency a determiner occurs, this supports the hypothesis of Saffran and colleagues (1996) that infants take statistics on the baseline frequency of a syllable to prevent wrong segmentations.

Phonotactics, the principles of phonological well-formedness in a language, also function as a cue for segmentation. At 9 months, infants are able to distinguish between well-formed words such as /frul/ and words that are not well formed such as /mrul/, the problem with /mrul/ is the /mr/ cluster that is not permitted within a syllable in English (Mattys, Jusczyk, Luce & Morgan, 1999). However, if infants only have a feeling for whether a cluster is permitted in their language they should accept /fɛbr/ as a word, even though the /br/ cluster is not permitted in word final position. This is not the case, as they prefer /brɛf/ over /fɛbr/ and thus show that they also have a sense of the constraints on cluster position in words (Mattys et al., 1999). The understanding of phonotactics can be helpful in word segmentation as some clusters which are permitted between words, are not permitted within words and there should thus be a boundary between the elements of this cluster when it appears. Friederici and Wessels (1993) found that 9-month-olds can detect phonotactically marked word boundaries and start to use that knowledge in word segmentation. Mattys and colleagues (1999) further investigated this also with 9-month-olds and found that the infants can distinguish between within-word-clusters and between-word-clusters. As infants are also sensitive to between-word-clusters, they do not rely on stored lexical information but on a sub-lexical level (Mattys et al., 1999). It was also found that infants of this age know that the phonotactic cues align with prosodic cues for word boundaries (Mattys et al., 1999) and thus they already start integrating different cues for segmentation at this age.

Somewhat later, infants also become sensitive to allophonic cues for word segmentation. Already at 2 months, English-learning infants can discriminate between the allophones of the phonemes /t/ (such as /t/ and /t^h/) and /r/ (such as /r/ and /ɹ/) and thus they have started to gather information about allophones. As the distribution of allophones is correlated with word boundaries in speech, infants that have learned to distinguish allophones from each other, may be able to use this as a cue for word segmentation (Jusczyk, Hohne & Bauman, 1999). To accomplish this, infants have to discover the systematic distribution of the allophones. Jusczyk and colleagues (1999) found that this ability develops between 9 and 10.5 months. The 10.5-month-olds were also able to use this information to segment words. This is rather late for a word segmentation strategy to develop, as most strategies develop before or around 9 months. One possible explanation is that it may be easy for infants to discriminate between allophones in isolated words, but in continuous speech there may be a too high cognitive load for them until they turn 10.5 months (Jusczyk et al., 1999). Furthermore, it may also be that the differences in allophonic distribution are only noticed in isolation and that infants have to gather this information from the words that they have segmented. Between 9 and 10.5 months, they may have gathered enough information to identify the systematic distribution and only then they start to use it as a cue for word segmentation (Jusczyk et al., 1999). Allophonic cues are thus not the primary cue for word segmentation, but they may be a good addition to the set of cues that the infants already have.

Up until 9 months, infants seem to rely on only one cue at the time for word segmentation. Between 9 and 10.5 months, they learn that they can integrate the knowledge that they get from using all cues to find the best solution to the segmentation puzzle (Thiessen & Saffran, 2003; Mattys et al., 1999). When infants have segmented a word, they form a representation of it in memory. Kooijman, Hagoort and Cutler (2005) did an EEG study with Dutch-learning 10-month-olds and found that the infants already recognise previously familiarised words in fluent speech after the first syllable of the word was uttered. This indicates that the infants cannot be matching whole-word templates to the speech, but that they have to be relying on memory representations with enough internal structure to link the first syllable of the word they hear, to the first syllable of a word they remember. The ability to segment and recognise words thus seems already well developed at 10 months. Kooijman and colleagues (2005) hypothesise that stress may be an important cue for the segmentation and recognition process.

1.3 Word segmentation using the native stress pattern

Infants as young as two months are already able to detect a long syllable in a sequence of short syllables. However, detecting a short syllable in a sequence of long syllables is clearly harder. This may be due to the fact that longer syllables are more salient than short syllables. Because it is easier to detect a salient syllable between non-salient syllables than a non-salient syllable between salient syllables, the long syllable is easier to detect (Friederici, Friedrich & Weber, 2002). This indicates that 2-month-old infants are already able to hear the difference between a long and a short syllable and as the duration of syllables is linked to stress in some languages, it is likely that the infants are already gathering information on their native stress pattern at 2 months.

Two months later, infants have gathered enough information to be able to discriminate between trochaic and iambic disyllables (Friederici, Friedrich & Christophe, 2007). Both German and French 4-to-5-month-old infants listened to pseudo words with either an iambic or trochaic pattern and once in a while a pseudo word with a deviant stress pattern would come into the sequence. The brain activity of the infants were recorded with an electroencephalogram (EEG) whilst listening to the stimuli. The German infants showed a positive mismatch response for the deviant iambic pseudo words. A mismatch response indicates that there is discrimination between the two sorts of stimuli and that these stimuli are likely to be processed by different memory structures. Furthermore, positive mismatch responses are hypothesised to represent less mature mismatch responses than negative mismatch responses. The positivity is thought to arise when more effort is needed for processing the deviant stimulus as it has been heard less often. Therefore, it is likely that the mental representations for the deviant stress pattern are less well developed (Friederici et al., 2007). As German is a trochaic language, the mismatch response for the iambic pattern indicates that this pattern is novel for them and that they discriminate this from the regular trochaic pattern of their native language. The French infants showed the opposite results; they had a positive mismatch response for the trochaic pattern. French is claimed to be an iambic language and infants learning this language also show that they have learned to discriminate between the two stress patterns and that the trochaic pattern is not regularly used in their language (Friederici et al., 2007). Around 4 to 5 months, infants are thus able to discriminate between iambic and trochaic patterns and more particular, show language-specific discrimination for one of the patterns.

Numerous studies have determined that English-learning infants have a preference for the trochaic stress pattern of their native language by 9 months (Jusczyk, Cutler & Redanz, 1993; Morgan, 1996; Thiessen & Saffran, 2003). Jusczyk and Aslin (1995) later found that infants of 7.5 months can segment words from sentential input and recognise segmented words in sentences. They segment the whole word, so not only a salient vowel or syllable rhyme, which indicates that their segmentation is not a reaction to saliency. Infants younger than 7.5 months do not show this ability yet. It is suggested that the infants use a stress-based segmentation strategy (Jusczyk & Aslin, 1995). Newsome and Jusczyk (1995) confirmed that 7.5-month-olds infants seem to use the trochaic stress pattern as a segmentation cue and should thus also have developed a preference for this stress pattern. Dutch-learning 7.5-month-olds are also learning a trochaic language which is close to English and were thus expected to also show the capability of segmenting previously familiarised trochaic words from fluent speech. However, this is not the case, both when familiarising the Dutch infants with Dutch materials and with English materials, they do not show a preference for the familiarised trochaic words in fluent speech (Kuijpers, Cooien, Houston & Cutler, 1998). The 7.5-month-olds are thus not able to segment these words from fluent speech. Dutch 9-month-olds do show a preference for the familiarised words in fluent speech and are therefore thought to be able to segment those words (Kuijpers et al., 1998). English-learning infants are thus faster to pick up stress as a segmentation cue. The discrepancy between Dutch- and English-learning infants can be explained by looking at the realisation of stress in these languages. In English, stress is marked more saliently than in Dutch, because there is more variation in pitch. Furthermore, unstressed vowels in English are often reduced to a schwa, whereas in Dutch they stay full. This may also cause the stressed syllables to be less salient for Dutch-learning infants. As stress is less salient, it is likely that Dutch-learning infants are somewhat delayed compared to English-learning infants in picking up this information and in using it as a segmentation cue (Kuijpers et al., 1998).

English-learning infants thus have a preference for their native stress pattern at 7.5 months and are able to use it in segmentation. As around this age, infants also start segmenting words from speech, there is a strong hypothesis that stress is an important factor in the segmentation process. Thiessen and Saffran (2003) tested this hypothesis and also tested whether stress is the earliest segmentation cue and could thus be used for bootstrapping into segmentation. This was done by familiarising infants with input containing conflicting cues. At 7 months, infants showed a preference for the words that they segmented relying on statistics, whereas at 9 months they preferred the words that were segmented on the basis of stress cues. Earlier, Johnson and Jusczyk (2001) found that 8-month-olds already rely more heavily on stress than on statistics, indicating that between 7 and 8 months, children switch from statistical segmentation to segmentation based on stress. This implies the first bootstrapping possibility, that not stress but statistical information is the earliest cue and that stress becomes an important cue around 8 months. This seems odd as infants start gathering information on duration, which is important for stress, around 2 months and already show language-specific discrimination of stress patterns around 4 months. However, they do not identify stress as a reliable and preferred cue to word segmentation until they are around 9 months. Does it take them 5 months to figure this out? Thiessen and Saffran (2007) claim that it takes familiarity with words for infants to identify correlations between acoustics and lexical structure. These correlations in turn can then develop the infants' preference for a stress pattern to also use this as a cue for segmentation. Infants should first bootstrap themselves into segmentation in another way before they can start to use stress as a segmentation cue. Thus, infants are not yet able to use stress as a segmentation cue at 7 months because they have not learned enough words yet to make the right correlation between the acoustics and the lexical structure to find out that a strong syllable often indicates word onset (in e.g. English). Thiessen and Saffran (2007) thus argue that statistical information is the first cue that is used in word segmentation and that only later infants have gathered enough information to use other cues such as stress. Johnson and Tyler (2010) do not agree with this. They tested 5.5-month-old and 8-month-old Dutch-learning infants on their ability to segment words from an artificial language containing either 4 disyllabic words or 2 disyllabic and 2 trisyllabic words based on transitional probabilities. Both groups of infants showed that they were able to segment words from the artificial language when all the words were the same length. However, when the words varied in length, neither group was able to segment the words. Johnson and Tyler (2010) argue that as natural language is far more varied than either of the artificial languages and that as infants were only able to segment words from the constant word length language, the ability to use statistical learning is fragile and could thus not be used for bootstrapping.

The hypothesis by Thiessen and Saffran (2007) is also in contrast with the results from Friederici and colleagues (2007) who found that infants are already able to discriminate language-specifically between stress patterns between 4 to 5 months. Also Höhle, Bijeljac-Babic, Herold, Weissenborn and Nazzi (2009) have another view than Thiessen and Saffran (2007) and present a second bootstrapping possibility. They conducted stress pattern preference experiments on French and German 4- and 6-month-olds and found that whilst German 6-month-olds show a preference for their native trochaic pattern the 4-month-olds do not. The French infants were able to discriminate between the stress patterns at 6 months, but did not show any preference. The German-learning infants thus show that the trochaic bias that was found at 4 months by ERP evidence (Friederici et al., 2007), develops into behavioural evidence at 6 months. However, the French learning infants showed a iambic bias at 4 months supported by ERP evidence (Friederici et al., 2007), but they do not show it behaviourally at 6 months. As French does not have stress on the word level, but only on the phrase level (Grammont, 1965), the information of stress on the phrase level may not be relevant for them in word segmentation and thus the bias may not develop further. As German infants already show a bias for their native stress pattern at 6 months, before the segmentation of their first words, Höhle and colleagues (2009) argue that infants do not initially have to use statistical cues as a bootstrap for segmentation, but that they can use the rhythmic unit of their language as a bootstrap. The rhythmic unit of German is a trochee, so using trochaic units for the segmentation of words would be beneficial. Furthermore, the rhythmic unit of French is the syllable and it has been shown that French learning infants use the syllabic unit at the onset of segmentation (Höhle, et al., 2009).

A third bootstrapping possibility is the universal trochaic bias hypothesis which says that all infants are born with a preference for trochees (Allen & Hawkins, 1978). This hypothesis implies that infants would start segmentation by finding trochaic units in speech and treating these as words. One problem with this is that infants learning an iambic language would extract words that do not actually exist. This seems rather inefficient and the results from Höhle and colleagues (2009) also make this possibility less plausible as French-learning infants do not show a trochaic bias. Keij and Kager (submitted) found that Turkish learning infants show a trochaic bias between 4 and 8 months even though Turkish is not a trochaic language. Contrary to French, Turkish does have final stress on the word level, not on the phrase level, thus an iambic preference was expected. However, the speaker of their experiments was Spanish, a non-native language for the Turkish infants. As a trochaic bias in learning Turkish seems inefficient, Keij and Kager (submitted) argue that infants may have a trochaic bias when listening to a foreign language and, plausibly, not when listening to their native language. The universal trochaic bias, if it exists, thus seems unlikely to bootstrap segmentation across different languages.

Once infants start to use stress as a cue for segmentation, they seem to only attend to the prosodic cues. Houston, Jusczyk, Kuijpers, Coolen and Cutler (2000) found that when they familiarised both Dutch and English learning infants of 9 months old with a Dutch passage, both groups were able to segment the disyllabic trochees in the test phase. The phonetic features of the Dutch words were very different from English words. This difference can be detected by 9-month-olds, thus the English-learning infants should have noticed that the input in the familiarisation phase was not in English, but still they segmented the words. Both English and Dutch have a trochaic stress pattern, thus both groups had already acquired a preference for this pattern. Therefore, the ability to segment words on the basis of prosodic cues seems to be an almost automatic process when the preferred stress pattern can be used.

So far, the focus has been on segmenting disyllabic words from fluent speech. However, languages also contain longer words which also have to be segmented on basis of the same cues. Houston, Santelmann and Jusczyk (2004) conducted a study investigating the ability of 7.5-month-old English-learning infants to segment trisyllabic words from speech. They found that if primary stress was on the first syllable and secondary stress on the last, infants could segment these words. However, when primary stress was on the last syllable and secondary stress on the first, the infants did not show this ability. This study shows two findings. Firstly, infants can use a stress-based segmentation strategy when they are 7.5 months. This result is in line with the hypothesis that 7.5-month-olds can use a stress-based segmentation strategy that both Jusczyk and Aslin (1995) and Newsome and Jusczyk (1995) had after their experiments. This is now further confirmed by Houston and colleagues (2004). Furthermore, the stress-based segmentation strategy was found earlier than at 9 months as Thiessen and Saffran (2003) found. Thiessen and Saffran (2003) familiarised the infants with conflicting information on stress and statistical cues, which may be the reason why the 7-month-olds did not use stress as a cue for segmentation. However, when non-conflicting information is given, they are able to use stress as a cue in segmentation. Secondly, Houston and colleagues (2004) also show that 7.5-month-olds can already segment trisyllabic words from speech. They theorise that infants start segmentation when hearing a syllable with primary stress, then include the following weak syllable in the word, which is the same as happens in disyllabic segmentation. Contrary to disyllabic segmentation, they do not close their processing window after hearing the weak syllable, but leave it open as there has been no closing cue. When the syllable with secondary stress comes in, they are still able to include this into the segmented word. Furthermore, if the primary stress was on the last syllable, the infants only segmented that syllable and closed their processing window after it as another strong syllable followed (Houston et al., 2004). English-learning infants thus have a preference for words with primary stress on the first syllable. The cue for closing the processing window seems to be two adjacent stressed syllables, as the infants know that there cannot be two adjacent stressed syllables in a word. This would be a stress clash. The Alternating Stress Rule and Rhythm Rule (Chomsky & Halle, 1968) together prohibit the occurrence of two adjacent stressed syllables within a word. Although these rules were developed for English, they were later found to be a natural phenomenon that occurs in many languages. (Liberman & Prince, 1977). These rules support the hypothesis that the stress clash is a cue for closing the processing window.

Curtin, Mintz and Christiansen (2004) also investigated segmentation of trisyllabic words by English-learning 7- and 9-month-olds after hearing input with a SWWSWW pattern. The infants were tested on either words with a SWW pattern, a WSW pattern and a control that never occurred in the familiarisation or on words with a WWS pattern, a WSW pattern and a control that never occurred in the familiarisation. One group thus received test words with initial or medial stress and one group with final or medial stress. The 7- and 9-month-olds show the same results. Within the group with final and medial stress, no differences were found. However, the infants in the group with initial and medial stress showed a difference between the initial stress and the control item. As in neither condition a difference between the medial stress, which is a trochaic pattern, and the control item was found, infants are not likely to rely on a trochaic segmentation strategy. The difference between initial stress and the control item indicates that infants have a stress initial strategy for word segmentation. This may be driven by a trochaic preference which they have developed by 7 months, as disyllabic trochaic words also have initial stress. However, to be able to say this with any certainty an additional experiment with infants learning a iambic language needs to be done, who would have to have a preference for the WWS targets. Curtin and colleagues (2004) and Houston and colleagues (2004) both show that English-learning infants prefer words with stress on the initial syllable and thus are likely have to developed an initial stress strategy for word segmentation.

Trochaic languages also include iambic words. It would be impossible to segment these words based on the rule that words start with a syllable with primary stress. Furthermore, these exceptional words would also conflict with the dominant stress pattern of the language. However, English-learning 10.5-month-olds are also able to segment disyllabic words that have a weak-strong stress pattern. Instead of using stress cues, they rely on statistical cues to segment those words (Johnson & Jusczyk, 2001). At this age, they have learned to integrate different segmentation cues. Segmentation of disyllabic words with a deviant stress pattern is thus likely to be based on the integration of different cues. Dutch-learning 10-month-olds have not acquired this skill completely. With their EEG study, Kooijman, Hagoort and Cutler (2009) found that the infants recognise weak-strong words in isolation already after the first, weak syllable is pronounced. However, when the words are later spoken to them in a sentence, the infants only show a recognition response at the second, strong syllable. When strong-weak words starting with the same syllable as the strong syllable from familiar weak-strong words are spoken to them in a sentence, the infants also respond after the strong syllable, which is in this case the first syllable. However the ERP curve has the opposite polarity when they recognise the strong syllable of the new strong-weak words compared to when they recognise the strong syllable of the weak-strong words. This indicates that the infants do not simply respond to the strong syllable, but that they also pay attention to the syllables surrounding it. They thus recognise that the strong-weak words do not match the words they were familiarised with. As the infants do recognise the weak-strong words after the first syllable when spoken in isolation and perceive the difference between the weak-strong and strong-weak words when spoken in a sentence, Kooijman and colleagues (2009) argue that Dutch-learning 10-month-olds are not yet fully able to segment iambic words. However, they are certainly developing this ability. The Dutch-learning infants are thus again delayed compared to the English-learning infants as was also seen in the study by Kuijpers and colleagues (1998), the same explanation for this delay can be given.

All studies taken together show that infants as young as 2 months start to take in information on their native stress pattern and that they have started forming a preference for a stress pattern at 4-5 months. Around 6 months they have developed a bias for their native stress pattern and at 7.5 months they are able to use stress as a cue for segmentation, however this differs between languages. Around 10.5 months, infants are able to also segment words that are opposite to their native stress pattern. Whether stress is the cue that bootstraps infants into segmentation is not clear, but it is certainly an important cue.

Based on the reviewed literature, from the first experiment in this study I expect that Dutch-learning 6-month-olds already show a bias for their native stress pattern. Dutch is a stress-timed trochaic language like English and German, so it is expected that Dutch infants show similar behaviour. The 8-month-olds are expected to maintain this bias for trochaic stimuli. The second experiment could show three kinds of results. Firstly, Dutch learning 8-month-olds do not use stress as a segmentation cue and only show a preference for the novel target, which would be in line with the results by Kuijper and colleagues (1998) who found that Dutch-learning infants only start using a stress-based segmentation strategy at 9 months. Secondly, the infants have developed a stress-based segmentation strategy for the trochaic pattern of their native language and show a preference for the pseudo words that were preceded by this pattern. Lastly, the infants have learned about stress and start segmenting at the first strong syllable and close their processing window at the next strong syllable as the 7.5-month-olds in the study of Houston and colleagues (2004) did. This would indicate that the infants have a preference for the clash condition. From the literature reviewed above the second and the third option seem to be the most plausible options.

2. Methodology

2.1 Experiment 1 - Preferential listening

Participants

The participants in this experiment were 119 monolingual Dutch-learning infants. Of these, 65 were around 6 months old and 54 were around 8 months old. The age of the 6-month-olds ranged between 174 and 220 days and the mean age was 202 days. For the 8-month-olds the age ranged between 237 and 283 days and the mean age was 258 days. All participants were healthy full-term infants and did not have any known hearing or visual impairments. From the 6-month-old group 16 infants were excluded and from the 8-month-old group also 16 infants were excluded. They were excluded due to fussiness, crying or technical problems. Infants were only included if they completed at least half of the experiment.

The data of 71 of the 119 infants were taken from another, but similar, experiment than that is described below (Keij & Kager, submitted). The main differences between the experiments are the pseudo word used, the speaker of the stimuli, the type of eye tracker that has been used and that the second experiment was infant controlled whereas the first was not. Infant controlled means that the infants had an influence on the trial length, if they did not show interest for more than two accumulative seconds, the trial would stop. These differences did not influence the results as the experiments show a similar pattern in outcomes. The additional data were added to the analysis to increase power.

Material

During the experiment, the infants listened to either of three stimuli, /nɔldɑf/, /mɛrnɛl/ or /dɑrnɑm/. All stimuli are pseudo words that conform to the Dutch phonotactics. They are disyllabic words, so that the stress pattern can be reversed from weak-strong (WS) to strong-weak (SW). Both syllables of the words are closed and thus both receive two moras which makes both heavy syllables. This is important for keeping the information on syllable weight the same in both the SW and WS condition. Furthermore, the stimuli were also checked for suprasegmental factors, the duration, intensity and pitch of the syllable. The strong syllable was always longer, louder and higher than the weak syllable. Multiple tokens of the same pseudo word were recorded and included in the experiment. There is thus no segmental variation within subjects, however, there is variation in the acoustic information.

The speaker of the stimuli was a Dutch-Turkish bilingual woman who was in Dutch-mode when recording the stimuli. A bilingual speaker was chosen as the experiment was also performed on Turkish children and they received the stimuli recorded in Turkish-mode. In this way, the voice of the speaker was kept the same while giving both groups the stimuli as spoken in their native language. The speaker of the stimuli of the experiment from which the additional data were taken, was a Spanish speaking woman. She was chosen as this experiment was also performed on Turkish children and in this way neither the Dutch nor the Turkish group had the advantage of hearing the stimuli as spoken in their native language.

Procedure

The experiment is a variation on the Head-turn Preference Procedure (HPP), in which an experimenter scores the infant's attention. In this experiment however, the attention was measured by an eye tracker. The eye tracker provides a more objective measure than an experimenter and it also eliminates the inter-experimenter variation in scoring. Furthermore, the infants are now only required to turn away their eyes instead of their head to signal disinterest, which is presumably easier for younger infants. The EyeLink 1000 eye tracker was used with an 940 nm modified illuminator and a 16mm lens with the iris removed. These are special adjustments for infants. The eye tracker was attached underneath a computer screen, which together formed a moveable unit. The eye tracker was connected to a computer with MS-DOS as the operating system. The eye tracker that was used for the experiment from which the additional data were taken was a Tobii 1750 eye tracker with an infant add-on and was connected to a Paradigit MSI 945P Platinum computer.

The infant and caregiver were seated in a soundproof room with the eye tracker and the computer screen in front of them. The infant was seated in Bumbo seat that allowed him or her to sit upright independently and to move rather freely, while staying in approximately the same position. The caregiver was seated behind the infant and was allowed to hold the infant, but not to talk to him or her. The caregiver listened to music over headphones while the infant participated in the experiment, in order to make sure the caregiver could not influence the infant's response to the auditory material in any way.

The eye tracker and computer screen were set in the right position for every infant separately so that the distance between the child and the eye tracker and the angle of the eye tracker to the eye were optimal for eye tracking. The infant had a target sticker on the forehead which was used as a reference for the eye tracker to find the eye. When the eye tracker was in the right positon, a three point calibration was performed by showing the infant a moving image on three points on the screen, both bottom corners and the middle of the upper end of the screen. Automatically, the infant would look at these points and the eye tracker would record what the position of the eye was. The position of the eye relative to the place on the screen was used as a reference for the eye tracker to determine whether the infant is looking at the Area of Interest (AoI) on the screen or looking away. The AoI was defined as the picture of a female face that was shown during the trials.

After the calibration, the actual experiment started. The experiment consisted of twenty trials with ten trials per stress condition, preceded by a short familiarisation phase. The very first trial was a familiarisation trial in which the infant could get used to the visual and auditory stimuli. The familiarisation phase had the same input as the other trials but was shorter. Furthermore, the data of this trial were not taken into account in the analysis. The trials started with an attention grabber to make sure that the infant was looking at the screen at the start of the trial. The attention grabber was a chime sound accompanied by a moving image of a doll. This was followed by the first trial of the test phase which showed a female face and played a female voice repeatedly saying one of the pseudo words (depending on the version of the experiment either /nɔldɑf/, /mɛrnɛl/ or /dɑrnɑm/). It also depended on the version of the experiment whether the first trial consisted of SW or WS pseudo words. Throughout the experiment, SW and WS trials alternated.

During the trials, the eye tracker tracked the eye movements of the infant and the looking times on the AoI were measured. If the child looked away from the AoI on the screen for more than two accumulative seconds the trial would stop and the next trial would start. This was not the case for the experiment from which the additional data were taken. After twenty trials there was a 'thank you'-phase, showing colourful pictures and playing a children's song. If the infant would start crying during the experiment and would not stop crying when the attention grabber of the next trial appeared, the experiment was ceased by the experimenter.

2.2 Experiment 2 – Segmentation

Participants

The participants in this experiment were 24 Dutch-learning monolingual infants that were around 8 months old. The age ranged between 237 and 278 days and the mean age was 252 days. All participants were healthy full-term infants without any known hearing or visual impairments. Another 3 infants were tested but were excluded due to fussiness, crying or technical problems.

Material

The stimuli in the test phase were eight possible targets, /bɛr/, /dim/, /fɑr/, /sum/, /bɛm/, /dɑr/, /fim/ and /sur/. These are all monosyllabic pseudo words that conform to the Dutch phonotactics and were controlled on duration, intensity and pitch and do not have meaning in Dutch. There were two versions of the experiment and therefore only four of the eight targets occurred in each version. The familiarisation phase consisted of 6-syllable phrases which were spoken to the infant. Only three of the four targets occurred in these phrases, the fourth target was only added in the test phase and was thus always novel for the infants. The stimuli per version can be seen in table 1. The targets in the stimuli in the familiarisation phase had the natural stress as given by the speaker. The syllables preceding the targets were manipulated by re-synthesis with the programme PRAAT to change the stress pattern.

Within each version there were different lists varying which target was the new one. This was done to avoid a target-effect. Lastly, multiple tokens of the same pseudo word were recorded and included in the experiment. There is thus no segmental variation within a test trial, however, there is variation in the acoustic information. The speaker of the stimuli was the same bilingual Dutch-Turkish woman as in the first experiment.

Table 1: *The blocks that occurred in the familiarisation phase per version. Per list, one of these blocks was not used, the target word of this block would occurs as novel target in the test phase.*

Version 1	**Version 2**
The /bɛr/ block	The /bɛm/ block
bi se mi BER ne de	mi fe fi BEM de bi
re me le BER si fi	re bi de BEM si le
se ri fi ne BER bi	si re de ri BEM bi
fe li fi ri BER de	bi me ne li BEM le
di si mi li fe BER	ri me si fi di BEM
fi le me ri di BER	ne di mi re le BEM
The /dim/ block	The /dɑr/ block
si de fe DIM bi re	fu ba na DAR sa fa
mi le ri DIM li fi	ra lu du DAR nu mu
fe si mi ni DIM se	ru ba fu bu DAR ma
fe le be ne DIM de	nu ma fa la DAR ba
me ri ni li be DIM	sa nu su la lu DAR
re ni de mi me DIM	ba ru mu nu ra DAR
The /sum/ block	The /sur/ block
du ra ru SUM bu sa	fu ma da SUR du ru
ra ma da SUM lu ru	fa ma fu SUR bu nu
bu nu na fa SUM sa	la nu lu bu SUR sa
ma ru lu sa SUM du	mu du fu fa SUR na
ra bu fa da fu SUM	da bu mu ru sa SUR
lu mu bu ba ra SUM	fu nu sa ru mu SUR
The /fɑr/ block	The /fim/ block
bu ru da FAR na ma	mi ne re FIM be ni
nu fu ba FAR su ru	ri ne mi FIM li ni
ra mu la nu FAR ba	si ne fe li FIM de
ru du lu na FAR mu	ri be mi di FIM si
fu bu ba su du FAR	bi be de me le FIM
bu nu lu da la FAR	se fe mi de ni FIM

Procedure

The preparation and equipment for this experiment were the same as for experiment 1. The experiment consisted of a fixed familiarisation phase and an experimental phase of eight trials. During the familiarisation phase the infants saw colourful images and heard a female voice say strings of syllables with varying stress. There were three unique blocks in the familiarisation and each block was heard twice. The blocks all had a target word which was put into six different strings of syllables that all had the same stress pattern. The stress patterns that were used were: *strong weak weak (SWW) target*, which is a control stress pattern as it is not the Dutch stress pattern and should thus not be facilitative of word segmentation, *weak strong weak (WSW) target* which is the Dutch stress pattern and could thus be facilitative of word segmentation and *weak weak strong (WWS) target* which has a clash formed by the strong target and the preceding strong syllable which could be a universally facilitative cue to word segmentation. The familiarisation phase was not infant controlled, but the looking times were measured with the eye tracker, to be able to control for attention during the familiarisation phase in the analysis afterwards. The test phase was infant controlled. Each trial started with an attention grabber followed by a female face and a female voice. The stimulus was either one of the three target words from the familiarisation or a word that was not in the familiarisation phase, the word was said continuously until the infant looked away for two accumulative seconds. There were two blocks of four targets in the test phase, so each target was tested twice.

3. Results

3.1 Results of experiment 1

The purpose of this experiment was to see whether infants of 6 and 8 months show a preference for their native stress pattern and when this preference develops. The preference was measured by the time the infant was looking at the AoI on the screen during the different trials. On the raw data from the eye tracker several scripts were run to extract the total looking time (TLT) per trial. Gaze samples that were included in the TLT were on the AoI on the screen, determined by X and Y coordinates and had to be longer than the sampling interval of the eye tracker. During the trial the infant could look away, these moments were not included in the TLT, but if the infant looked back within two seconds the following gaze samples were again included in the TLT of the trial.

The data were not normally distributed. Thus, before starting the analysis, the data were first normalised using Blom's formula (Blom, 1958) because this is a prerequisite for the statistical analysis that was chosen to analyse the data with. The data were analysed using an ANCOVA with the TLT per trial as the dependent variable, age group and condition as the independent variables and trial number and whether the data were from the first or second experiment as covariates. These covariates were included because both showed a main effect in a preliminary analysis.

There is a significant effect of the factor condition on the TLT, $F(1,2132)=4.68$, $p=.031$, which is longer during the SW pattern compared to the WS pattern, as can be seen in figure 1. The mean TLT for the SW condition was 6265 ms (SD= 3958 ms) and the mean TLT for the WS condition was 5941 ms (SD=3790 ms). Overall, the infants thus have a longer TLT for the SW condition.

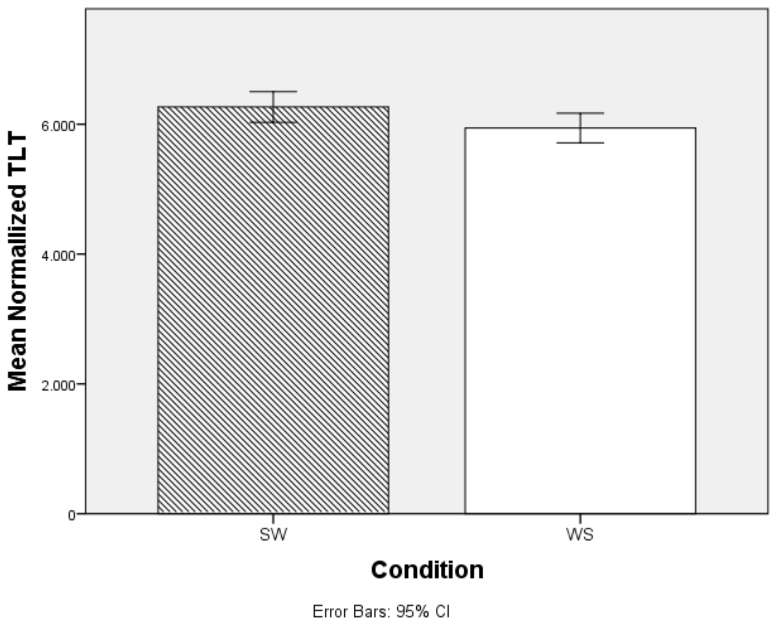

Figure 1: *The mean TLT in ms for all infants per condition (SW vs. WS).*

An effect of age was also found, $F(1,2132)=15.02$, $p=.000$. The mean TLT for the 6-month-olds was 5976 ms (SD= 3945 ms) and for the 8-month-olds 6258 ms (SD= 3789 ms). The 8-month-olds thus have a longer TLT overall as can be seen in figure 2.

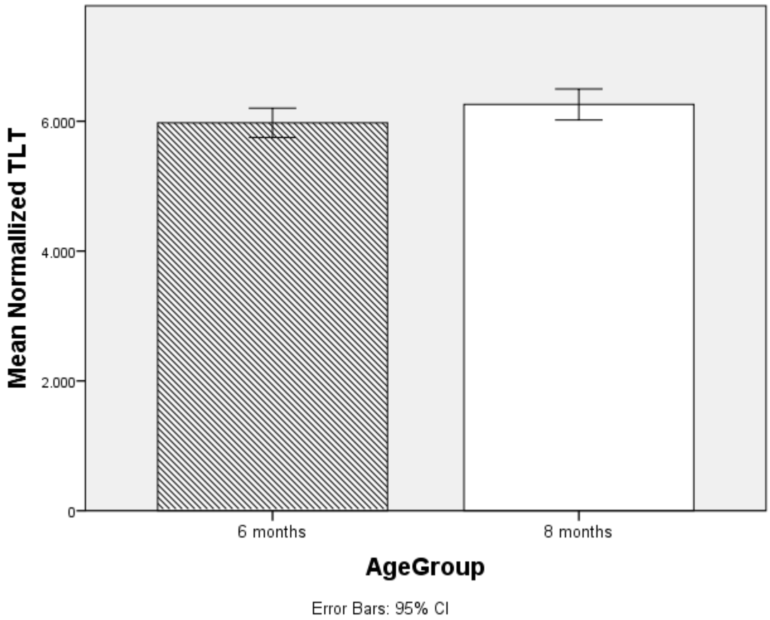

Figure 2: *The mean TLT in ms for all conditions per age group (6-month-olds vs. 8-month olds).*

The mean TLTs and SD per age group and per condition can be found in table 2. From this table and figure 3 it can be seen that the 6-month-olds show a clear preference for the SW pattern over the WS pattern. The 8-month-olds do not seem to show this preference as clearly anymore. However, no interaction between age group and condition was found $F(1,2132)=2.72$, $p=.099$ so nothing can be concluded about the development of the preference for the stress patterns between age groups.

Table 2: *The mean TLT in ms per age group (6-month-olds and 8-month-olds) and per condition (SW vs. WS).*

	6-month-olds	**8-month-olds**
SW condition (SD)	6263 (4024)	6268 (3880)
WS condition (SD)	5691 (3848)	6249 (3700)

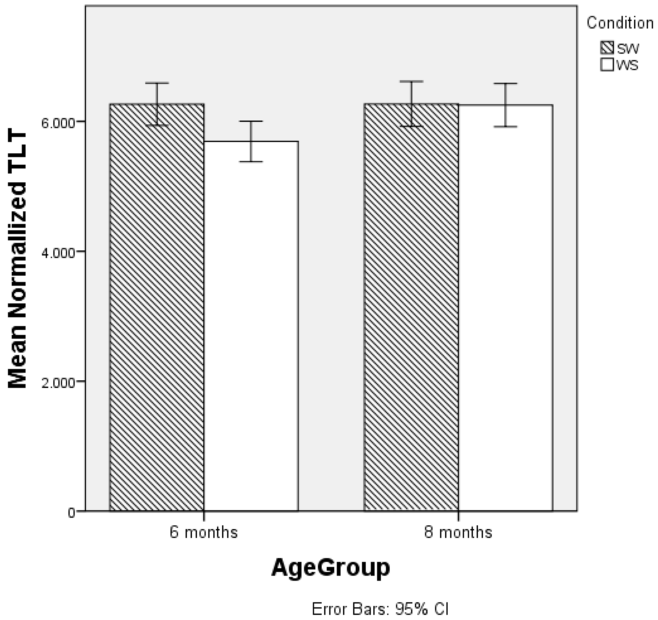

Figure 3: *The mean TLT in ms per age group (6-month-olds and 8-month-olds) and per condition (SW vs. WS).*

Additionally, both covariates showed an effect. The effect of item $F(1,2132)=526.28$, $p=.000$ is due to the decline in TLT as the experiment proceeds, the infants are less interested at the end of the experiment compared to the start, which was to be expected. The covariate experiment controlled for the data being from two different experiments. As mentioned earlier, this was not thought to have an effect as the results from the two experiments separately showed the same pattern. However, an effect of experiment was found, $F(1,2132)=416.03$, $p=.000$. This effect is due to the significantly longer looking times in the first experiment ($M=7202$ ms, $SD=3584$ ms) compared to the second ($M=4312$ ms, $SD=3666$ ms) which can be attributed to the fact that the first experiment was not infant controlled and the second was.

3.2 Results of experiment 2

The data for this experiment underwent the same pre-analysis as the data for experiment 1. These data were also not normally distributed and were therefore normalised using Blom's formula (Blom, 1958) before starting the analysis. Also for this analysis an ANCOVA was used with TLT as the dependent variable, condition as the independent variable and trial number and mean TLT during the familiarisation phase as covariates. These covariates were included because both showed a main effect in a preliminary analysis. The mean TLT during the familiarisation was included to control for the fact that some infants paid in general more attention during the familiarisation phase than others. This could explain part of the variance between infants in the test phase, which is not of interest for the differences in TLT between the conditions.

The purpose of this experiment was to find out whether Dutch-learning 8-month-olds use stress as a segmentation cue and if so, which stress patterns Dutch-learning 8-month-old infants use to segment words from continuous speech. The infants showed no significant difference in looking times between the conditions $F(3,164)=1.18$, $p=.318$. However, when taking a look at figure 4, it still seems that the infants differentiate between the conditions but that the problem is that the variation is rather large and that there is not enough power. It is therefore still interesting to look at the post hoc comparisons. The condition with the new word is the most interesting to start with. This condition specifies whether the infants have an overall novelty or familiarity preference. The new word yields a mean TLT of 7347 ms (SD=4962 ms) which is a long looking time compared to the mean TLT during the other three conditions, representing words they could have noticed in the familiarisation phase (M=6651 ms). This indicates that the infants have a novelty preference. Comparing the mean TLT of the new word to the mean TLTs of the other words individually, it can be seen that the word preceded by the weak strong weak (WSW) stress pattern is not significantly different and very close to the mean TLT of the new word condition (M=7574 ms, SD=5538 ms, p=.984), and is thus also novel for the infants. The word following the strong weak weak (SWW) stress pattern is also not significantly different from the new word (M=6535 ms, SD=4798 ms, p=.322), this word also seems to be a novel word for the infants. However, when looking at the word in the weak weak strong (WWS) condition, there is a trend visible (M=5843 ms, SD=4376 ms, p=.137) which may have shown a significant effect if the power had been greater. The infants had less interest in the word in the WWS condition than in a novel word and may thus have recognised the word in the test phase because they had already segmented it during the familiarisation phase.

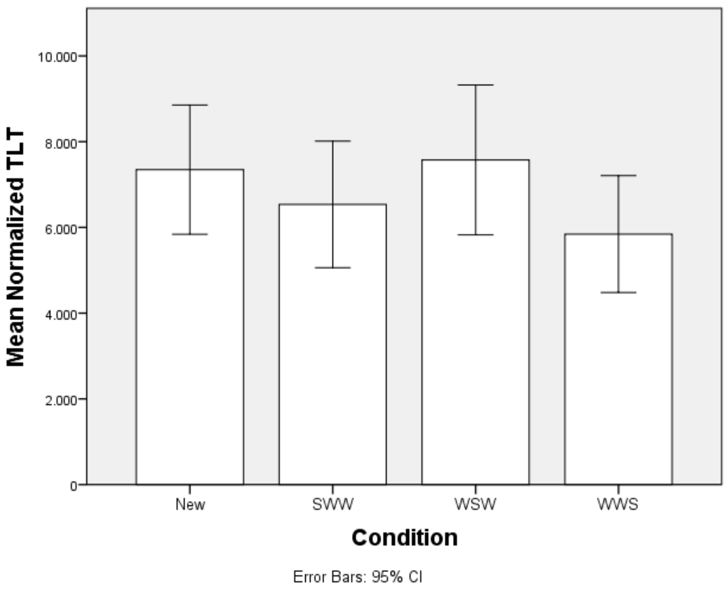

Figure 4: *The mean TLT in ms per condition (new word vs. preceded by SWW stress pattern vs. preceded by WSW stress pattern vs. preceded by WSS stress pattern).*

4. Discussion and Conclusion

The aim of this study was to find an answer to two questions. Firstly, whether 6- and 8-month-old Dutch-learning infants show a preference for their native stress pattern and when this preference develops. Secondly, whether 8-month-old Dutch-learning infants can use stress as a cue for segmentation and if so, which stress patterns they use to segment words from continuous speech. It was hypothesised that the 6-month-olds would already show a preference for their native stress pattern and that the 8-month-olds would maintain this preference. The 8-month-olds were hypothesised to be able to use their native stress pattern in segmentation and it would be possible that they use stress clash as a segmentation cue.

The results of experiment 1 show that 6-month-old Dutch-learning infants have a clear preference for the SW pattern, which is trochaic. However, the 8-month-olds do not show this preference as clearly. The behaviour of the 6-month-olds is in line with the expectations; Dutch is a stress-timed trochaic language and it was thus expected that the infants would prefer the trochaic pattern. This is also in line with the behaviour of German-learning infants that learn a similar language and also show a preference for the native stress pattern at 6 months of age (Höle et al., 2009). However, it is odd that the 8-month-olds do not show this behaviour as clearly as the 6-month-olds do. As infants learning English, another stress-timed language, use stress as a segmentation cue at 8-months (Johnson & Jusczyk, 2001), it is expected that they have a preference for their native stress pattern at this age. Therefore, the Dutch-learning 8-month-olds were expected to still prefer their native stress-pattern. Furthermore, the 6-month-olds have developed a preference for their native stress pattern, so it would be expected that they maintain this preference. The explanation that 8-month-old Dutch-learning infants do not recognise their native stress pattern anymore, thus does not seem plausible. A better explanation can be found when looking at the difficulty of the experiment. For a 6-month-old, the experiment was sufficiently challenging and thus familiarity preferences were expected. For 8-month-olds, it is likely that the experiment was not challenging enough and that they thus were not interested enough in the familiar stress pattern only, but started to also prefer the unfamiliar stress pattern by means of a novelty preference. This seems plausible as also in the segmentation experiment, testing infants of the same age, a novelty preference was found (Hunter & Ames, 1988). Therefore, it is still assumed that 8-month-old Dutch-learning infants recognise the native trochaic stress pattern when analysing the results of experiment 2.

Experiment 2 suggests that 8-month-old Dutch-learning infants segment pseudo words following the WWS pattern. Segmentation following this pattern shows that infants have learned to use stress as a segmentation cue. Specifically, they know that two adjacent strong syllables clash and thus should not be in the same word. This result is in line with the findings by Houston and colleagues (2004) who found that infants close their processing window after the first strong syllable when two strong syllables follow each other. This is also in line with the Alternating Stress Rule and the Rhythm Rule (Chomsky & Halle, 1968) that together prohibit the occurrence of adjacent stressed syllables across languages.

However, the infants did not show segmentation of the pseudo words that followed the WSW pattern, which is the trochaic pattern, the native stress pattern of the infants. If the infants had learned to use their native stress pattern in word segmentation, these words would have been segmented. The trochaic pattern is the preferred stress pattern of the infants and this result can thus not be explained by assuming that the infants do not recognise their native stress pattern yet. It can also not be explained by saying that the fact that there was no segmentation after the WSW stress pattern and that there was segmentation after the WWS stress pattern was due to chance. The infants did not show segmentation after the SWW pattern and as this is neither the Dutch stress pattern nor a clash condition, the infants were not expected to segment the target following this stress pattern. This result indicates that the results are not likely to be due to chance.

A more plausible explanation could be that the infants left their processing window open after hearing the SW sequence in the WSW pattern because there had not been a closing cue of two clashing strong syllables. Just as the infants in the experiment by Houston and colleagues (2004), they know that there can be two strong syllables in one word, one carrying primary stress and the other secondary stress, and they thus did not have a problem including the strong target in the word, creating a trisyllabic word. The fact that the strong target had primary stress and that two primary stressed syllables cannot be together in one word, may not have influenced them in this decision. As previously discussed, it is easier for infants to distinguish between a primary stressed syllable and an unstressed syllable than between a primary and a secondary stressed syllable. The infants may thus not yet have the notion of primary and secondary stress or the ability to distinguish between them and thus accept two stressed syllables in a word, regardless of whether these syllables have primary or secondary stress. Curtin and colleagues (2004) give further evidence for this possibility, they found that infants between 7 and 9 months have an initial stress strategy for word segmentation, segmenting words that start with a stressed syllable. Therefore it is likely that the infants started segmentation after the SW sequence in the WSW condition and created a trisyllabic word with a strong initial and final syllable.

Another possible explanation can be found when looking at English-learning 8-month-olds who are able to use their native stress pattern as a segmentation cue (Johnson & Jusczyk, 2001). As both Dutch and English are stress-timed trochaic languages, it could have been expected that Dutch-learning infants also show segmentation based on their native stress pattern. However, Kuijpers and colleagues (1998) and Kooijman and colleagues (2009) both found that Dutch-learning infants lag behind on English-learning infants in terms of stress. They explained that this is likely to be due to the fact that in Dutch, stressed syllables are less salient than in English. Therefore, it may take the Dutch-learning infants more time to learn that they can use their native stress pattern as a cue for word segmentation and to actually start using this cue.

Lastly, a difference in procedure may account for the differences between the present result and the results by other studies assessing 8-month-olds ability to segment words by using their native stress pattern as a segmentation cue. Most studies discussed first familiarised the infants with words in isolation and then tested whether the infants recognised and thus segmented the words from fluent speech. It can be argued that this is not segmentation, the fact that a previously familiarised word is recognised does not mean that the infants are able to segment other, unfamiliar words, from fluent speech. In the present study, the opposite was done; the infants were familiarised with fluent speech with varying stress patterns from which they could segment target words and were then tested on the recognition of the target words in isolation. This may have been somewhat more complicated as the infants were confronted with completely novel fluent speech from which they had to start segmenting whereas in the other studies the target words were not novel to them and may thus have popped out, making the task easier. The experiment in this study, however, is able to show segmentation as the infants have to segment unfamiliar words from speech. Curtin and colleagues (2004) had a similar procedure as the one in this study and also did not find a trochaic segmentation strategy but did find evidence for the easier initial stress strategy. This indicates that with a more complex task, the more complex trochaic segmentation strategy cannot be used. It may even be the case that infants do not use a trochaic strategy for actual segmentation as in both experiments investigating actual segmentation, this was not shown.

Dutch-learning 8-month-olds thus do not seem fully able to use their native stress pattern as a segmentation cue. However, they are able to use a stress-based based segmentation strategy, namely paying attention to clashing stressed syllables. An explanation for this could be that using stress clash requires less cognitive processing than using their native stress pattern. There are no Dutch words that have two primary stressed syllables next to each other and thus it is easy to place the boundary between these words. However, there are iambic words in Dutch and thus the segmentation based on the native stress pattern is not as universal. Furthermore, when two syllables clash, the infant only has to process the information on the two syllables that it heard last whereas when using the trochaic stress pattern, it has to process information on at least three syllables; the two last syllables of the preceding word and the first syllable of the new word. Using the trochaic stress pattern may thus put a higher cognitive load on the infants which they are not yet able to handle.

In conclusion, 6-month-old Dutch-learning infants have developed a preference for the trochaic stress pattern which is their native stress pattern. Dutch-learning 8-month-olds do not show this preference as clearly but are still assumed to recognise their native stress pattern and may show this preference under the right testing conditions. Furthermore, at 8 months, Dutch-learning infants have learned to segment words based on clashing stressed syllables. However, they do not show segmentation using their native stress pattern. There are three possible explanations for this. Firstly, the infants adopted a stress initial strategy and as they did not hear a closing cue, they segmented trisyllabic words instead of the monosyllabic target word and thus were not able to show recognition of the target word as an isolated word in the test phase. Secondly, Dutch-learning infants are somewhat slower in starting to use the native stress pattern as a segmentation cue compared to English-learning infants. This is most likely due to the fact that in English stress is more salient than in Dutch. Lastly, the task in the present study was more difficult than that of earlier studies and therefore the infants were not able to show an effect of the native stress cue which is more complex than using a universal stress cue, namely clash, for segmentation.

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