The role of prosodic cues in mapping meaning to words in monolingual and bilingual infants

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Abstract
To acquire a language, infants must learn to segment words from fluent speech. Infants can rely on different sources to discover word boundaries, for example prosodic cues and statistical regularities. Prosodic cues are language specific segmentation cues, because a language can have predominant trochaic or iambic stress patterns for words. However, little research is done to examine how prosodic cues are used for word segmentation by bilingual children learning an iambic and trochaic language. Furthermore, little is known about how prosodic cues influence the mapping of meaning to newly segmented words in infants. The current study proposes to investigate the effect of stress cues on mapping meaning to newly segmented words in monolingual and bilingual infants of 17 months old. A paradigm is suggested in which both word segmentation and the ability to map meaning to words can be examined. This paradigm consists of a familiarization phase, a label-object association task and a test phase, in which eye-tracking is used to see whether the infants learned the association between newly segmented words and objects. The proposed study can contribute to a deeper understanding of how monolingual and bilingual infants use prosodic cues in word segmentation and how they map meaning to words.

1. Introduction

To acquire a language, infants must learn to segment words from fluent speech. Infants can rely on different sources to discover word boundaries, for example prosodic cues and statistical regularities. Several studies examined how infants rely on these cues to segment words. It has been found that infants of 7 months rely more on statistical cues, but infants of 9 months rely more on stress cues (Thiessen & Saffran, 2003). At an age of 11 months, infants are also able to segment words that have a different stress pattern than the predominant stress pattern of their native language (Seidl, 2009). At an age of 17 months old, infants can map meaning to newly segmented words (Graf Estes et al., 2007). So far, however, the effect of prosodic cues on this ability is not investigated. Furthermore, word segmentation studies are mostly done in English infants. English has a predominant trochaic stress pattern for words, but there are also languages that have a predominant iambic stress pattern for words. Still very little research has been done to word segmentation in bilingual infants who learn a trochaic and an iambic language. This would be interesting to examine, because this could give us more insight in whether, and if so how, the language environment of an infant influences their sensitivity to different segmentation cues. The current paper is a research proposal to examine the effect of stress cues on mapping meaning to newly segmented words in monolingual Dutch and bilingual Dutch and French infants of 17 months old. This

proposal contains, thus, an acquisition as well as a typology perspective on the link between word segmentation and mapping meaning to words. A paradigm will be proposed in which both word segmentation and the ability to map meaning to words can be examined.

2. Background

In this section, literature on word segmentation will be explained. First, cues that can help word segmentation will be explained. Then, several studies that examined the use of stress cues to discover word boundaries will be discussed. Section 2.3 concerns the link between word segmentation and mapping meaning to words. Finally, the current study will be explained.

2.1 Word segmentation cues

Spoken utterances do not contain clear boundaries between words. However, to acquire a language, infants must learn to segment words from fluent speech. Word segmentation abilities start to develop between 6 and 7.5 months of age (Johnson & Jusczyk, 2001). Infants can rely on different sources to learn word boundaries, including prosodic markers, phonotactic constraints, context-sensitive allophones, and statistical regularities. From these cues, no single cue is sufficient to segment words correctly. It depends on the sound organization of a language which cues are most useful for word segmentation. Therefore, segmentation cues are language specific.

One language specific cue to word boundaries is the stress pattern of a language. For example, almost all English bi-syllabic words have a trochaic stress pattern, which is strong-weak. Take, for example, *pencil* and *paper*. Therefore, a potential strategy for English learners to segment words is treating a stressed syllable as a word onset. However, this strategy would lead to an incorrect segmentation of weak-strong (iambic) words as *guitar*. To segment words with a stress pattern other than a trochaic one, listeners need to be sensitive to other segmentation cues as well. In contrast to English, French bi-syllabic words have an iambic stress pattern, which is weak-strong. So, in general, a stressed syllable indicates a word ending in French, instead of a word onset.

Another cue for word segmentation is how often certain syllables (or sounds) co-occur. In other words, how likely it is that one syllable is followed by another syllable (Saffran, Aslin, & Newport, 1996). This is known as statistical cues, or statistical regularities. For instance, in Dutch, given the utterance *lieve vogel* ('sweet bird'), the probability of the co-occurrence of *lie* and *ve* is greater than the probability of the co-occurrence of *ve* and *vo*. Based on the statistical information, *lieve* is a statistical word, whereas *vevo* is a statistical part word. In other words, a part word consists of a sequence of syllables crossing word boundaries, and it has, therefore, a lower probability than a statistical word sequence. Therefore, based on the statistical information, it is more likely that *lieve* is a word than that *vevo* is a word.

2.2 The use of stress cues in word segmentation

As is noted before, word segmentation abilities start to develop between 6 and 7.5 months of age (Johnson & Jusczyk, 2001). In this section, several studies that examined the use of stress cues in infants of different ages will be discussed.

Thiessen and Saffran (2003) examined whether English infants of 7 and 9 months old attend more to statistical cues or stress cues to segment words. They used head turn preference procedures to test what happens if stress and statistical cues indicate different word boundaries. The familiarization phase consisted of either an iambic or trochaic artificial language, in which four bi-syllabic non-words occurred. In the trochaic language, the statistical regularities and stress cues indicated the same word boundaries. For example, in the two-word string *DIti#BUgo*, in which stressed syllables are capitalized, both stress and statistical cues indicated *diti* and *bugo* as words. However, in the iambic language, there was a conflict between the cues. Statistics would indicate *diTI* as word in the two-word string *diTI#buGO*, but the English stress pattern would indicate *TIbu* as word. The 7-month-old infants showed in both conditions a novelty preference for the statistical words. So, they relied on the statistical cues, regardless of stress. In contrast, the 9-month-old infants showed a familiarity preference for words (*DIti*) in the trochaic condition, but for part-words (*TIbu*) in the iambic condition. Therefore, stress cues outweigh statistical cues in word segmentation at this age. The authors suggest that infants of different ages use different segmentation strategies and that there is, therefore, a shift from using only statistical cues to using other speech cues as well.

In a study by Johnson and Seidl (2009), the weight of stress cues and statistical cues in 11-month-old infants is investigated. At this age, infants start to segment non-initially stressed words from speech. Therefore, the authors hypothesized that this ability is linked to a shift from relying on stress cues (in 9-month-old infants) to relying more on statistical cues. However, they found that infants of 11 months old still weigh stress cues more heavily than statistical cues. A potential explanation for this finding in combination with the fact that infants of this age can segment non-initially stressed words could be that the infants rely more on other segmentation cues, for example phonotactic cues.

Polka and Sundara (2003) investigated stress cues for word segmentation in monolingual and bilingual 7.5-month-old learners of English and French. French and English words have different rhythmic patterns; English words have a trochaic stress pattern, while French words have an iambic pattern. The authors conducted an experiment that contained a familiarization phase and a test phase. In the familiarization phase, infants heard two words in either French or English repeated in random order when they looked at a light. During the test phase, infants heard four different text passages. In two test passages, one of the familiarized words occurred repeatedly throughout the passage. In the two control passages, a novel word occurred repeatedly. The bilingual infants were tested on both English and French and the words were all existing words in the language they were tested in. The authors found that the bilingual infants listened longer to the test passages, regardless of the language. This indicates that they could segment the words using both stress patterns, because they preferred listening to the segmented words. The authors concluded that there is no delay in the development of word segmentation skills in bilingual infants. It is important to note, however, that the authors did not compare the test passages with passages in which part words occurred repeatedly. Therefore, they cannot be entirely sure whether the effect was only due to stress cues and not (also) to statistical cues. The syllables of words occurred, namely, automatically more often together than the part words,

because there was a random order. The fact that the words used in the experiments were existing words could also have influenced the result, because it is possible that the infants were already familiar with some words. The authors did not mention these factors in their study.

2.3 Word segmentation and mapping meaning to words

In a study by Graf Estes, Evans, Alibali and Saffran (2007) the link between word segmentation and the process of mapping meaning to words is examined. The authors conducted a statistical word segmentation task in infants of 17 months old, which was followed by an object-label-learning task. In this task, words were either statistical words or part words from the previous segmentation task or non-words that were not part of the segmentation task. The words were linked to 3-D images of novel objects. During the habituation phase, infants received two different label-object combinations. In each trial, an object moved across the screen while its corresponding label was played. During the test phase, infants viewed either the label-object combinations from the habituation phase or switched label-object combinations. So, for example, in the switched combination Label 1 occurred with Object 2, instead of with the associated Object 1. The authors compared the looking times for same and switched test trials. They found that the infants looked longer to the switched trials, but only in the statistical word condition. This result indicated that the infants learned the segmented words. Therefore, the authors concluded that segmented words are easier to link to objects than part words or novel words in 17-month-old infants. The findings of this study show that there is a link between word segmentation and mapping meaning to words. However, the authors examined only the effect of statistical cues on mapping meaning to words. It would be interesting to see whether other speech cues, for example prosodic cues, facilitate word learning as well.

2.4 Current study

The study of Graf Estes et al. (2007) showed that 17-month-old infants can map meanings to words they segmented based on statistical cues. They did not examine the effect of stress cues on the ability to map meaning to words. However, it is explained in the previous sections that infants of 9 to 11 months old rely more on stress cues than on statistical cues. Therefore, it could be that stress cues still outweigh statistical cues in infants of 17 months old. So far, however, no studies have investigated this nor whether stress cues facilitate mapping meaning to words.

Because languages can have different predominant stress patterns, it would also be interesting to see how bilingual infants of two languages with contradicting stress patterns rely on stress to segment words. This was done in the study by Polka and Sundara (2003) (see section 2.2). They found no difference between bilingual and monolingual infants in the use of stress cues to discover word boundaries. However, the authors did not take statistical cues into account in their analyses. In addition, the words in their experiments were existing words embedded in text passages. It is possible that the infants relied on different stress cues to segment words in their different languages. So, for example, if they listen to French they segment words iambically, but if they listen to English they segment words in a trochaic way. It would be interesting to see whether bilingual infants have a

preference for one of the two stress patterns they are familiar with in words of a different (non-existing) language. This could give us insight in how the language environment of an infant plays a role in their sensitivity to different cues for word segmentation.

So, no research has been done to examine the effect of prosodic cues on the ability to map meaning to words, nor to the use of prosodic cues in bilingual infants of different stress pattern languages. Therefore, the aim of the current study is to examine the effect of stress cues on mapping meaning to newly segmented words in monolingual Dutch infants and bilingual Dutch-French infants of 17 months of age. The research questions are:

(i)   What is the effect of stress cues on mapping meaning to newly segmented words in 17-month-old infants?
(ii)   Is there a difference in how stress cues influence mapping meaning to words in monolingual and bilingual infants?

To examine these questions, a segmentation task in combination with a word-learning task will be conducted in monolingual Dutch and bilingual Dutch-French infants of 17 months of age. The segmentation task will consist of a trochaic and iambic artificial language. In this way, the effect of stress cues on word segmentation can be investigated. Dutch and French have, namely, different predominant stress patterns for bi-syllabic words, respectively a trochaic and an iambic pattern. Thus, the stress cues for segmenting words contradict in these languages; a stressed syllable indicates either a word onset (Dutch) or a word ending (French).

One hypothesis is that stress cues will outweigh statistical cues in infants of 17 months of age. This is expected, because the study of Graf Estes et al. (2007) showed that 11-month-olds rely more on stress than on statistics. They suggested that infants use a combination of multiple cues for word segmentation at the age of 11 months, and it is likely that this strategy develops to the use of more cues at an age of 17 months. So, statistical cues will probably not outweigh stress cues at an age of 17 months. If stress and statistical cues indicate different word boundaries, it is expected that the monolingual Dutch infants will rely on stress cues to segment words and, therefore, that they will treat statistical part words as words. This would also mean that they only map the meanings of part words to objects.

Furthermore, it is hypothesized that stress cues that indicate the same word boundaries as statistical cues facilitate the ability to map meaning to newly segmented words in monolingual infants. This is hypothesized, because multiple cues to a word boundary will probably result in a more reliably segmented word. The hypotheses for the bilingual infants are less clear, because no research is done so far to examine the difference between the weight of stress cues and statistical cues in bilinguals. Based on the study by Polka and Sundara (2003), it is expected that the bilingual infants rely on different stress patterns in their languages. So, if they listen to Dutch, stress indicates a word onset, but in French it indicates a word ending. However, it is not clear how they treat stress cues in an unfamiliar language. If the bilingual infants do not have one predominant language, it is possible that they rely less on stress cues in a language they do not know. This could

be the case, because they know that stress can indicate different word boundaries in different languages. Therefore, they cannot be sure which stress pattern the new language has. This would mean that they rely on other cues than stress to segment words in a new language. It is, therefore, expected that they rely more on statistical cues than on stress cues to segment words in an artificial language. So, if stress and statistics indicate different word boundaries, it is hypothesized that they segment the statistical words as words, regardless of stress. Therefore, it is expected that they learn the combinations of objects and statistical words the best.

3. Methodology

3.1 Participants

The participants will be 40 infants of 17 months old. The age of 17 months is chosen, because Graf Estes et al. (2007) found that monolingual English children are able to map meanings to newly segmented words. Half of the infants will be monolingual learners of Dutch and the other half will be bilingual learners of Dutch and French. The bilingual infants should be exposed to both languages in a comparable amount, so that they are similarly familiar with both stress patterns. This will be checked by a questionnaire that the parents will have to fill in.

3.2 Stimuli and procedure

The experiment consists of three parts: a familiarization phase, a label-object association task, and a test phase. In the first part, the infants will be familiarized with the artificial language. In the second part, the infants will learn objects and their associated labels. Finally, they will be tested on whether they linked the labels to the objects.

3.2.1 *Familiarization phase*

In the familiarization phase, infants will hear a continuous speech stream of four bi-syllabic words. Two languages will be created; one trochaic language and one iambic language. Each infant will only listen to one of the two languages. Both languages will consist of the same four words spoken in the same randomized order, without pauses between the words. The words that will be used are the same as those used in the study by Thiessen and Saffran (2003); *dapu, dobi, bugo*, and *diti*. The words will be naturally produced by a native speaker of English to avoid influences of Dutch or French. Stress is manipulated in the same way as is done in the study by Johnson and Jusczyk (2001). Syllables will be recorded in isolation pronounced either with or without stress. Because the syllables are recorded in isolation, there will be no influence of the English trochaic stress pattern of the speaker. Stressed syllables will be higher in average pitch and amplitude and longer in duration. In the trochaic language, the word onsets of the statistical words will be stressed. An orthographic representation of this language would look as follows ...*DApuDObiBUgo...* (stressed syllables are capitalized). In the iambic language, the word-final syllables will be stressed. An orthographic representation of this language would look as follows ...*daPUdoBIbuGO...* The statistical probabilities of the words in both languages are 1.0, and the statistical probabilities of the part words are 0.33. The infant will sit on the parent's lap on the middle of a three-sided booth during the whole experiment. The parent will wear headphones so (s)he cannot hear the stimuli. The familiarization phase will last approximately two minutes.

3.2.2 Label-object association task

After the familiarization phase, the infants will do a label-object association task. In this task, they will view two different label-object combinations that will be presented one at a time and in a random order. One of the labels will be a statistical word, the other label will be a statistical part-word. A statistical part word of the iambic language is a word based on Dutch stress cues, because the first syllable is stressed. The objects will be non-existing 2D objects that will move across the screen. During the presentation of the object, the associated label will be played repeatedly. The object-label combination will be presented as long as the infant looks at the screen. The habituation criterion will be reached when looking times across three following trials decrease to 50% of the average looking time across the first three trials, as was the case in Graf Estes et al. (2007).

3.2.3 Test phase

To test whether the infants have learned the label-object combination, a variant of the visual world paradigm will be used. In this paradigm, two objects of the label-object association task will be shown presented with one label. Eye-tracking will be used to measure the eye-movements of the infants. Each trial consists of a 3-seconds period in which only the objects are shown. After this period, a label will be presented that is associated with one of the objects. The next 3 seconds, the infant's looking times will be measured. A similar paradigm is used in a study by Vouloumanos and Werker (2009). These authors point out that "infants who have learned a word-object link look longer at the object that matches the word being played" (p. 1612). So, longer looking times to the associated object will reflect that the infant can map the meaning of the learned words to objects.

3.3 DESIGN

There will be two groups of infants: a monolingual and bilingual group. In the familiarization phase, infants of both groups will be randomly assigned to one of the two speech streams: the trochaic language or the iambic language. Therefore, the study will have a mixed design. The dependent variable is the looking times of the infant during the test phase. The independent variables are the language conditions and whether the infant is mono- or bilingual.

In the test phase, the looking times of the infants will be measured. Looking times to the objects associated with statistical words and with statistical part words from the familiarization phase will be compared. If an infant learned the object-label association, (s)he will look longer to the associated object than to the other presented object. The longer an infant looks to an associated object, the better (s)he has learned the association.

4. PREDICTIONS

In the trochaic language condition, it is expected that the monolingual infants will learn the object-label associations better if the labels are statistical words. This would, thus, be reflected by longer looking times to objects associated with statistical words than to objects associated with statistical part words. In this condition, the stress cues and statistical cues indicate, namely, the same word boundaries for Dutch infants. In the iambic language condition, it is expected that the monolingual infants look longer to the objects

associated with the statistical part words, because it is hypothesized that stress cues outweigh statistical cues at the age of 17 months. It is possible that the monolingual infants look longer to the objects linked to words in the trochaic language condition than to the objects linked to part words in the iambic condition, because in the former the cues indicate the same word boundaries. This could lead to more robust word boundaries, and, thus, better learning.

The hypothesis for the bilingual infants is that they will rely less on stress cues for word segmentation. Therefore, it is expected that they will learn the associations between objects and statistical words better than the associations between objects and statistical part words, regardless of whether they were exposed to the trochaic or iambic language. So, if this is the case, they will always look longer to the objects associated with a statistical word than to the objects associated with a statistical part word.

If the results will be as hypothesized, there will be an effect of stress cues on mapping meaning to newly segmented words, but bilingual and monolingual infants will differ in how much they rely on stress cues compared to statistical cues. This would, thus, mean that it depends on the language environment of an infant which segmentation cues they use to discover words.

If there is no difference between the language conditions in the monolingual infants, this would mean that bilingual infants rely only on statistical cues to segment words, and not on stress cues. In this case, it would also be possible that there is no difference between the monolingual and bilingual infants. This would suggest that infants rely on the same segmentation cues, irrespective of their language environment. Finally, a possibility is that some bilingual infants will segment words with stressed syllables as word onsets, and some will segment stressed syllables as word endings. This would mean that there is variability in how bilingual infants use stress cues in word segmentation. This result would suggest that children use different segmentation strategies to discover word boundaries.

5. Conclusion

This is a research proposal to examine the effect of stress cues on mapping meaning to newly segmented words in monolingual and bilingual infants of 17 months old. A paradigm is proposed that consists of a familiarization phase, an object-labelling task and a test phase. Using this paradigm, both word segmentation and the ability to map meaning to words can be examined. Longer looking times will reflect that an infant learned the object-label combination. Whether the infants segmented the statistical words or part words is reflected by which object-label combinations are learned. It is expected that the monolingual infants will rely more on stress cues to segment words, and will, thus, look longer to objects associated with statistical part words in the iambic language condition. In contrast, it is expected that bilingual infants will rely more on statistical cues and will, thus, look longer to objects associated with statistical words, regardless of the language condition. The proposed study can contribute to a deeper understanding of how monolingual and bilingual infants use prosodic cues in word segmentation and how they map

meaning to words. Furthermore, examining bilingual infants could give us more insight in whether or not the sensitivity to different segmentation cues is determined by the language environment of an infant. ■

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