Storage of phonological information in the early mental lexicon. Does the shape of target words matter?

Master's Thesis Clinical Language Speech and Hearing Sciences

Sarah Klein - 3031497

Utrecht University

July 1st , 2009

Supervisors:

Prof. dr. Paula Fikkert (RU Nijmegen)

Prof. dr. Frank Wijnen (UU)

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Abstract

Aim of the current study is to provide more insight into the question what 14-month-olds’ phonological representations of CVC words with an initial coronal consonant and a labial vowel look like. Previous research has indicated that these type of words behave peculiar. Question is whether they receive one place of articulation (PoA) feature for the whole word or whether they trigger segmentation. This is tested in a preferential looking paradigm, in which the participants are familiarized with two nonsense words: *don* and *tos* in an extensive learning phase. During the test phase, their sensitivity to correct pronunciations (CP) versus vowel mispronunciations (MPV: *din* and *tis*) and consonant mispronunciations (MPC: *bon* and *pos*) is tested. An eyetracker is used to measure infant’s eye movements. Different analyses of the results reveal that *don*-type of words do not seem to receive one place of articulation (PoA) feature for the word.

Acknowledgements

My sincere thanks are due to Prof. Dr. Paula Fikkert, for accepting me in her ‘language acquisition group’, for bringing the topic of acquisition of phonological representations to my attention and for supervising this Master’s thesis. I want to thank Drs. Nicole Altvater-Mackensen for her valuable practical and theoretical advice, Carolien van Wijngaarden for being the ‘voice’ in my experiment, all colleagues from the Baby Research Center for helpful discussions and practical assistance, and of course all participants and their parents for their cooperation. Also thanks to Prof. Dr. Frank Wijnen for being my second reader. I definitely have to mention my parents in this list of acknowledgements, for encouraging me and for providing me this opportunity. Thanks to my brother for always having a solution for my technical problems. And last but certainly not least, many thanks to Jeroen for his inexhaustible emotional support.

1. Introduction

Being able to recognize words in language requires the identification of sounds that group together in the speech we hear. This identification of sounds or word-like units is an important step in the word learning process. It implies a linkage from the acoustic signal to phonetic and phonological information to stored information about the sound structure of words in the lexicon. Once words are stored in the lexicon, those words can be recognized. In the recognition process, the incoming words have to be matched with entries in our mental lexicon. When perceived acoustic information matches stored information of a word, this leads to recognition and the meaning or semantics of the word will be activated. A question many researchers try to answer is how much detail is stored by early language learners in order to recognize words correctly.

Concerning the nature of phonological representations that are built up during word learning no consensus has been reached yet. On the one hand, it is argued that when children start learning words their representations are vague, global or holistic. However, another view exists in which it is believed that such representations are not vague, but detailed. As argued by Fikkert (in press), the controversy regarding the amount of detail in phonological representations – vague/holistic versus detailed - is found in both word comprehension studies and word production studies. Based on results from word learning, word discrimination and word production (spontaneous) experiments in 14-month-old children, Fikkert (in press) concludes that early representations in the mental lexicon are not phonetically detailed, but that they are not vague either. In these experiments, the focus has been on the acquisition of representations for place of articulation (PoA) features. It is argued by Fikkert (in press) that (a) representations are abstract and underspecified, in particular with respect to the coronal place of articulation; (b) they change in the course of development; and (c) the same representations underlie children's comprehension and production. Compelling as the results may be, it also raises a number of questions.

The present study aims at providing more insight into one of Fikkert's (in press) conclusions, that representations are abstract and underspecified, in particular in the early stage of acquisition when she claims that only the PoA of the vowel is specified to serve the whole word. Although her account works for words with a so-called coronal vowel, for words with labial vowels the situation may be different, particularly if they have coronal consonants (such as *don* and *tos*). Therefore, those type of words are the focus of the current word learning experiment with 14-month-old children.

2. Background

2.1. Previous literature

Although various studies on word learning capabilities of 14-month-old children have been done (e.g. Ballem & Plunkett, 2005; Fikkert, Levelt & Zamuner, 2005; Stager & Werker, 1997; Swingley & Aslin, 2000), their results were controversial. In these studies, the acquisition of phonological representations plays a central role.

To begin with, Stager & Werker (1997) showed that Canadian 14-month-old children could not distinguish newly learned non-words that contrast minimally, like *bih* and *dih*. These researchers used the Switch-procedure to investigate what phonetic information is used in early word learning by infants of this age. In the Switch-procedure infants are first taught word–object pairings in what is called the 'habituation phase'. During this phase, the two word-object pairs (object-A is presented with word label-A and object-B is presented with label-B) are repeated in random order until the infant becomes habituated to the pairing. Habituation is indicated by a decline in looking time below a preset criterion (Stager & Werker, 1997). Subsequently, infants are tested on their ability to detect a change in either the word, the object, or both. In their first experiment, Stager and Werker (1997) presented two test trials: one trial involved the same word–object combination ('same' trial) and the other involved the same words and objects, but also a switch in the word–object pairing ('switch' trial). It is assumed that if children are able to detect the switch, they will dishabituate and look longer in the switch condition. This indicates that the child successfully learned the words.

However, 14-month-olds did not appear to notice the switch in word-object pairing for the minimally contrasting non-words *bih* and *dih*. In a replication of this study, Pater et al. (2004) showed that 14-month-olds failed to distinguish *bin* and *din* as well. On the other hand, Stager & Werker (1997) demonstrated that younger children of only 8 months, did notice the switch in word-object pairing for *bih* and *dih,* and looked significantly longer to the objects during the switch trials than during the same trials. A control experiment using the phonetically dissimilar words *lif* and *neem*, was done to assure that 14-month-olds are able to perform successfully in a single word-object association task. It was observed that children clearly discriminated between the two labels.

These results made the authors conclude that infants of 14 months simply can no longer make use of the fine phonetic detail that they used for discrimination. A simple speech discrimination task was done to investigate this possibility. For this experiment the same procedure was used, but with a checkerboard instead of pictures. Results show that 14-month-olds can perfectly discriminate the words *bih* and *dih* in a discrimination task. It seems like infants only fail to attend to the fine phonetic information when they attempt to recognize the meaning of words.

Stager and Werker state that their experiments provide evidence that infants use different information in word learning than in speech-discrimination tasks. An explanation for the finding that 8-month-olds passed the above mentioned word-object association task, is that at this age children are not yet mapping the sound onto meaning. So to these children the word learning task was more like a discrimination task. As assumed by the authors, not paying attention to phonetic detail in word learning at the age of 14 months might be beneficial and even necessary to be successful in the demanding task of linking words with objects. They hypothesized that, at 14 months, there is no need for detailed phonetic information, because confusing a new word with the few words in the infants' lexicon is not very likely to happen.

Fikkert, Levelt and Zamuner (2005) tested these predictions for Dutch in a series of experiments. Like Stager and Werker (1997) the Switch procedure was used. Dutch 14-month-olds were tested, using the nonsense words *bin* and *din,* and *bon* and *don*. Their results were similar to those of Stager & Werker (1997): no difference in looking times between same and switch conditions was seen in the word learning task using *bin* and *din*, while infants were able to differentiate these non-words in a discrimination task. Remarkably, for the non-words *bon* and *don,* a difference in looking times was observed:

participants looked longer to the switch condition. So children seemed to detect the difference between *bon* and *don* during this task, while they could not for *bin* and *din*.

The explanation given by Fikkert (in press) relies on a previous study by Fikkert and Levelt (2008) on children's early production data (from the onset of meaningful speech). In this study, Fikkert and Levelt (2008) analyzed the Place of Articulation (PoA) structure of all words in the utterances of five children acquiring Dutch as their first language. On the basis of this analysis, the authors report some remarkable observations.

The first observation includes that at the first stage, in CVC words, both consonants (C1 and C2) share the same PoA. This is illustrated by the examples given in tables 1 and 2 (Table 1 for labial words and Table 2 for coronal words). For instance, the Dutch word for 'belly', /buik/, contains a labial first consonant and a dorsal second consonant. In early production, /buik/ is produced as [bop], which shows that the dorsal /k/ is replaced by de labial /p/. Although this looks like consonant harmony, Fikkert and Levelt (2008) made a second observation.

Dutch	**English**	**Normal production**	**Early production**
Buik	'belly'	/boeyk/	[bop]
Koffie	'coffee'	/kɔfi/	[pɔf]
Poes	'cat'	/pus/	[puf]

Table 1. Early production data of Dutch children, labial words

Dutch	**English**	**Normal production**	**Early production**
Bed	'bed'	/bɛt/	[dɛt]
Prik	'injection'	/prɪk/	[dɪt]

Table 2. Early production data of Dutch children, coronal words

It seems to be the vowel that is providing the PoA feature for the word as a whole. Some crucial examples given in table 3 can be used to illustrate this pattern. In the Dutch word 'prik' (translation: injection) coronality can only come from the vowel, since the consonants (/p/ /r/ and /k/) do not have a coronal PoA. Similarly, in 'schoenen' (translation: shoes) the labial PoA can only come from the vowel (there is no labial PoA in /s/ /ɣ/ or /n/). They argue that at this early stage of word learning the PoA of the vowel determines the PoA of the whole word. To explain this pattern, the authors refer to Jusczyk (1986) who stated that the vowel is the most salient element due to its relatively long stable interval in the signal, and hence may serve as an anchor point for building the initial phonological representation.

Dutch	**English**	**Normal production**	**Early production**
Prik	'injection	/prık/	[dıt]
Schoenen	'shoes'	/sɣunə/	[pumə]

Table 3. Early production data of Dutch children. Vowel provides the PoA feature for the whole word

As a result, Fikkert and Levelt (2008) argue that the word has one PoA feature, which is determined by the vowel. The stage at which one PoA feature is defined for the entire word, is called the 'whole word' stage. In this view, the word is not analyzed into separately targetable segments yet. This idea is not only argued for by Fikkert and Levelt, given that the authors refer to studies in which similar ideas are introduced (e.g. Waterson, 1971; 1987; Menn, 1983; and Levelt, 1994).

Another assumption made by Fikkert and colleagues, concerns underspecification. Fikkert (in press) states that the coronal place of articulation is not specified in the early lexical representation, while the labial PoA is specified. This goes back to the assumption that the contrast between labial and non-labial sounds is the first contrast children acquire. Assuming this, Fikkert argues that early labial words (table 1) are specified as [labial], while early coronal words (table 2) are still unspecified. This would hold that children's first words are either completely unspecified for PoA (coronal words), or have only the feature labial specified, which has scope over the whole word (labial words).

What must be noticed is that Fikkert also argues that such representations change in the course of development. This change involves the gradual segmentation into smaller units after the 'whole-word' stage. Instead of receiving a PoA for the word as a whole, consonants become specified separately from vowels and can receive their own PoA specification. During this second stage, coronals are still expected to be underspecified. Fikkert (in press) argues that this segmentation is already visible in 17-month-olds.

Fikkert and colleagues claim that the same lexical representations would underlie both production and comprehension. By assuming this, the findings by Stager and Werker (1997) and Fikkert, Levelt and Zamuner (2005) can be explained in terms of (a) one feature per word; and (b) underspecification of the coronal PoA. The results of the Switch experiments by Stager and Werker (1998) and Fikkert et al (2005), revealed that 14-month-olds have difficulties in distinguishing *bin* from *din*. In light of the view that 14-month-olds store the PoA feature of the vowel and use this feature for the whole word, the assumption is that at the earliest stage of acquisition children have the same representation for *bin* and *din*. Because *bin* and *din* consist of a coronal vowel, there would be no PoA representation at all since coronal is assumed to be unspecified. So how can infants distinguish these words when there is no representation available? This may clarify the difficulties the children have in this word learning task.

To make this more intelligible we can introduce a three-way matching procedure of perceived features to stored features in the lexicon. This three-way matching procedure is similar to that in the Featural Underspecified Lexicon model by Lahiri and Reetz (2002). As Fikkert points out: “The model limits the set of possible word candidates by excluding mismatches only. A perceived feature that mismatches with a phonological feature of the stored representation will not be considered a possible word candidate for that signal. For instance, if a word has the feature [labial] stored (for example *bon*), a perceived feature *coronal* in the signal (of for example *bin*) forms a mismatch, and hence the word with the [labial] feature (*bon*) will not be recognized as a possible word candidate for the signal of *bin*. If the perceived and stored features match, word candidates with the matching feature continue to be possible word candidates. A third possibility is that of a no-mismatch: this is for instance the case when the lexical representation is not specified for PoA. A perceived PoA feature in the signal, for instance [labial] does neither match nor mismatch the stored representation that lacks PoA features. Hence, it forms a no-mismatch. Such words will not be thrown out of the competition.” (p. 8) So, in the *bin-din* experiments the perceived words in the test phase always form a so called ‘No Mismatch’ with the stored PoA representation. There is no PoA representation available, since *bin* and *din* have a coronal vowel that is unspecified

(Ø) so words can never be a match with this representation, but they can never be a mismatch either (table 4).

Because the non-words *bon* and *don* share a labial vowel, another scenario occurs. Since the labial vowel provides the labial PoA representation for the whole word, both *don* and *bon* have the same representation. However, now mismatching/matching is relevant and can explain why infants are able to distinguish *bon* from *don*. In the case of *bon*, children perceive a labial initial consonant, followed by a labial vowel, what fits the labial PoA representation and is called a 'Match' (table 5). However, in the case of *don*, children perceive a coronal initial consonant, followed by a labial vowel. The initial consonant does not match with the labial representation, and therefore forms a 'Mismatch' with the representation. The phonological representation of *bon* is no longer in competition for recognition after perceiving the coronal feature of *don*.

Learned word	**Stored representation**	**Perceived form in test**	**Matching**
Bin/din	Ø	Labial coronal (*bin*)	No mismatch
		Coronal coronal (*din*)	No mismatch
Prediction: infants will not perceive the difference between *bin* and *din*. Results Stager and Werker (1997) and Fikkert et al (2005): infants did not perceive the difference between *bin* and *din*.			

Table 4. Switch procedure using *bin* and *din*

Learned word	**Stored representation**	**Perceived form in test**	**Matching**
Bon	[labial]	Labial labial (*bon*)	*Match*
		Coronal labial (*don*)	Mismatch
Don	[labial]	Coronal coronal (*don*)	*Mismatch*
		Labial labial (*bon*)	Match
Prediction: infants will hear the difference between *bon* and *don*. Results Fikkert et al (2005): infants did hear the difference between *bon* and *don*.			

Table 5. Switch procedure using *bon* and *don*

Although the above called theory of PoA and underspecification explains the results of the experiments of Stager and Werker (1997) and Fikkert et al (2005), one remarkable observation has caught the attention. This holds for the non-word *don* in the habituation phase of the Switch procedure. As seen in table 5, *don* is a mismatch with itself after habituation, while *bon* is correctly matched with the representation of *don* (italicized). The initial coronal consonant does not match with the labial PoA representation of the whole word. This observation needs some more investigation, and that is the purpose of the present study.

But before we continue, it is proper to give a short notice about the second consonant since we did not mention this before. All test words have a coronal nasal at final position. Fikkert (in press) reports that the influence of word final consonants is ignored, because they are much less salient. Fikkert grounds this by mentioning that Dutch 10-month-old infants do not discriminate PoA contrasts in final position, although they can discriminate the same contrast in initial position. There is evidence suggesting that only at 16-month of age infants are able to discriminate PoA in final consonants reliably (Zamuner 2006).

2.2. Research question

So far we discussed Fikkert's proposal (in press) that not all details perceived in the speech signal are used for storage of words in the mental lexicon. Children hear the relevant details, use them in the matching procedure during the word recognition process, but do not store all details in their lexicon. The storage is limited to just the phonologically relevant features. Initially it is even limited to place features of the stressed vowel.

In this study we want to take a closer look at the behavior of *don*-type of words, since *don* has shown to be a mismatch with itself after habituation (italicized in table 5). *Don*-type of words are uncommon in children's productions and the question is why. We want to know what is special about *don*. Question is whether *don* receives a labial PoA representation for the whole word, whether *don* triggers segmentation, or whether it comes down to the task (in particular the habituation) that has been used in the above described experiments (Switch). The last possibility, whether the Switch procedure is suitable or not to test recognition of *don*-type of words, deserves some more explanation.

The Switch paradigm uses a habituation phase to teach children specific words. The duration of this phase lasts as long as the child pays sufficient attention to the objects on the screen. When the child reaches the saturation level, the test phase begins. But how can children habituate to *don* if it is true that *don*' mismatches with its own representation? Moreover, this procedure is not a very good copy of normal word learning in the real world, because of this unnatural habituation.

An alternative to this procedure, the preferential looking paradigm, can be seen as a better imitation of normal word learning, since it uses no saturation level and children can be familiarized with new word-object pairs in a more natural and variable way (Yoshida, Fennell, Swingley & Werker, 2009). Word learning happens, for example, by playing with the object (pre phase) before the experimental test phase begins. In the test phase of the preferential looking procedure trials consisting of two objects are presented on a screen: one object referring to the word that was learned in the pre phase, and one other object that has not been displayed before. At the same time, an auditory stimulus is naming the target (e.g. *don*) or asking the child to look at the target. It is assumed that a longer duration of looking time to the named target, reflects that the child is able to recognize the named word.

Yoshida et al. (2009) showed that the used method is of great interest. They investigated whether the failure of 14-month-olds to distinguish *bih-dih* and *bin-din* (Stager & Werker, 1997; Pater et al, 2004) in word learning tasks using the Switch procedure, lies in the learning or testing phase. Similar to the Switch, a habituation phase was used, but they used a visual choice test phase instead of the typical Switch test. Their results show that, in this new procedure, the infants succeeded in distinguishing *din* from *bin*. This success might suggest that infants' learning ability was previously masked by the demands of the testing phase in the Switch procedure.

Because of this disadvantage of the Switch procedure compared to the preferential looking (or visual choice procedure), the latter is used in the present study. The specificity of 14-month-olds'phonological representations is examined by comparing their sensitivity to correct pronunciations (CP) versus mispronunciations (MP) of two nonsense words with a coronal initial consonant and a labial vowel: *don* and *tos*.

2.3. Hypotheses

In reflection of Fikkert's (in press) theory, it is expected that CVC words with an initial coronal consonant and a labial vowel (like *don* and *tos*), in the 'whole word' stage receive a labial PoA representation and therefore form mismatches with its selves. Moreover, it is expected that CVC words with an initial labial consonant and a labial vowel will form a better match with the PoA representation of the learned words. Therefore, *bon* and *pos* occur as consonant mispronunciations (MPC) during the test phase to check this prediction. If our prediction is true, we would expect longest looking times to the target in MPC trials. CVC words with both a coronal initial consonant and a coronal vowel (like *din* and *tis*), are expected to be mismatches since they do not match with the labial PoA representation of *don*. Hence, *din* and *tis* are used as vowel mispronunciations (MPV). We expect children to display shortest looking times to these trials, based on the result by White, Morgan and Wier (2005) that 19-month-olds displayed shorter looking times to the target object when more features of the target word are mispronounced. Tables 6 and 7 illustrate our predictions.

Learned word	**Stored representation**	**Perceived form in test**	**Matching**
Don	[labial]	CP: Coronal labial (*don*)	Mismatch /d/
		MPV: Coronal coronal (*din*)	Mismatch /d/ /i/
		MPC: Labial labial (*bon*)	Match

Table 6. CP and MP conditions for '*don*'

Learned word	**Stored representation**	**Perceived form in test**	**Matching**
Tos	[labial]	CP: Coronal labial (*tos*)	Mismatch /t/
		MPV: Coronal coronal (*tis*)	Mismatch /t/ /i/
		MPC: Labial labial (*pos*)	Match

Table 7. CP and MP conditions for '*tos*'

Finally, one might argue - a priori - that a PoA change in the vowel is much more likely to notice in comparison to a PoA change in the initial consonant (for instance: /d/ to /b/). However, the experiments of Fikkert and colleagues (2005) showed that 14-month-olds do not hear the difference in vowel change in *don*-*din*, but they do hear the difference in consonant change in *bon*-*don*. Hence, the mispronunciations used in this study were chosen on the basis of previous experiments.

3. Methods

3.1. Overview

The preferential looking paradigm using an eye-tracker is applied in this experiment. Basically, the experiment is divided into two parts. First, the 14-month-olds are taking part in a word learning phase, in which each child learns two non-words: *don* and *tos*. The objects referring to the non-words are cuddly non-existing 'animals' (figure 1) and are presented to the child in a live situation (on site) in addition to a video-presentation. As a start, the infant is familiarized with the newly learned word by seeing and touching the cuddly objects in real life for a few minutes. Meanwhile the experimenter mentions the names of the objects (*don* and *tos*) 11 times each in sentences that describe the characteristics of the objects. The experimenter follows a script during this live act in order to mention the non-words to each child in the same sentences (context) and in the same amount (see Appendix A for full script).

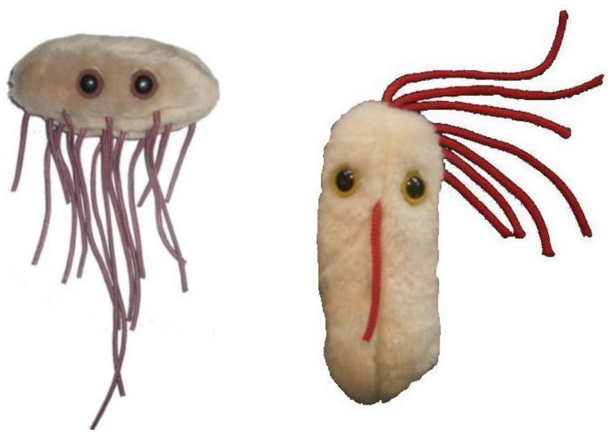

Figure 1. Left picture: the *don* object. Right picture: the *tos* object.

After the live word learning phase, the second part of the learning phase is started. Therefore, children are seated on their caregiver's lap in a child's seat (Maxi Cosi) facing a screen which measures 1280 pixels in width and 1024 pixels in height. Consequently, the new objects are presented to the participants on the screen, with the pictures at eye level. For each non-word there are three trials in which their names are mentioned four times (in sentences such as: *"Kijk! Een don"*. Translation: *"Look! A don",* see Appendix B for full script). This means that the infant is presented to each non-word 15 times in the two-phased learning period. One trial in the video has a duration of 4.0 seconds and is followed by an attention getter of 2.0 seconds. Hence, the duration of the word-learning video is about 36 seconds.

Second, by the end of the word learning period (pre phase), infants are presented with images of two objects side by side on the screen (test phase). Meanwhile the child is hearing a word that refers to one of the objects on the screen (target). The voice gives the child the instruction to look at the target object. such as: *“Kijk naar de [target]”* (translation: “look at the [target]) and *“Waar is de [target]”* (translation: “Where is the [target]”). The feature of interest here is the amount of time (in ms) the infant looks at the target picture.

Infant’s eye movements are measured with the Tobii Eyetracker. Infrared cameras are integrated in the framework of the screen. The eyetracker is thought to be a valid method: it provides a validity code that indicates the certainty that the system has recorded the correct data.

It is assumed that if the infant increases his or her attention to the named object (as measured in a greater amount of time the infant is looking at the target), this is evidence that he or she was able to recognize the named word.

The test phase consists of 12 test trials and 12 filler trials. In a test trial the auditory stimulus is offered in the sentence: *“Kijk naar de [target]*”. The target can be a: (1) Correct Pronunciation (CP: *don*; *tos*) in which the target is spoken in its normal form; (2) a mispronunciation by a PoA change in the vowel (MPV: *din*; *tis*); and (3) a mispronunciation because of a PoA change in the initial consonant of the target word (MPC: *bon*; *pos*).

CP conditions are displayed two times and MP conditions two times each, in pseudo random order. In addition to the test-trials, fillers and attention getters are presented to the child. Fillers consist of two non-target pictures. This means that both *don* and *tos* objects, do not appear in these trials. Instead of non-existing objects like the *don* and the *tos*, child familiar pictures appear in the filler trials. Fillers contain pictures of: a dog and a frog; a cat and a duck; or a ball and a car. They are used to prevent children from getting a feeling of them being fooled and to make the task more pleasant. The twelve fillers are presented pseudo randomly as well. Attention getters are used to make sure the child's focus is directed towards the center of the screen. They are displayed at the beginning of the word learning phase; between each word learning phase trial; at the end of the word learning phase / at the beginning of the test phase; halfway the test phase and at the end of the test phase. The attention getter halfway the test phase can be used as a break for the child and it marks the beginning of the second block of the test. In the first block of the test phase, all conditions and fillers appear once (12 trials: 6 test trials and 6 filler trials). After the attention getter break, all trials are repeated. However, in these trials the position of the pictures, in terms of left and right, are opposite. Concluding, the test consists of:

- 4x CP (2x '*don*'; 2x '*tos*') + 4x MPV (2x '*din*'; 2x '*tis*') + 4x MPC (2x '*bon*'; 2x '*pos*') + 12x fillers + attention getters

3.2. Participants

Participants are 33 14-month-olds Dutch speaking children (*M* = 1;2.17, *s.d.* = 0.07). Eighteen of these participants are boys while 15 are girls. Two additional children were tested, but excluded from the analysis due to equipment failure. All children have normal hearing and vision, and are from homes where Dutch was the principal language in use. All children are tested at the Baby Research Center in Nijmegen and selected from the Baby Research Center database.

During the week prior or after their visit, parents completed the Dutch Communicative Development Inventory (NCDI) (Zink & Lejaegere, 2002) for their child. A NCDI is the Dutch adaptation of the MacArthur CDI that can be used to determine the participant's perceptive and productive vocabulary sizes. NCDI's are helpful to check whether there is any relation between children's performance on the perception experiment and their vocabulary size.

3.3. Visual stimuli

Visual stimuli are digitized photographs of objects on a white background. The picture next to the *don* target, is a teddy bear in all test trials. The *tos* is always accompanied by a cuddly cow. Pictures are of similar sizes, averaging about 450 pixels in length, and are separated by about 200 pixels. In filler trials, no target picture is presented (figure 2).

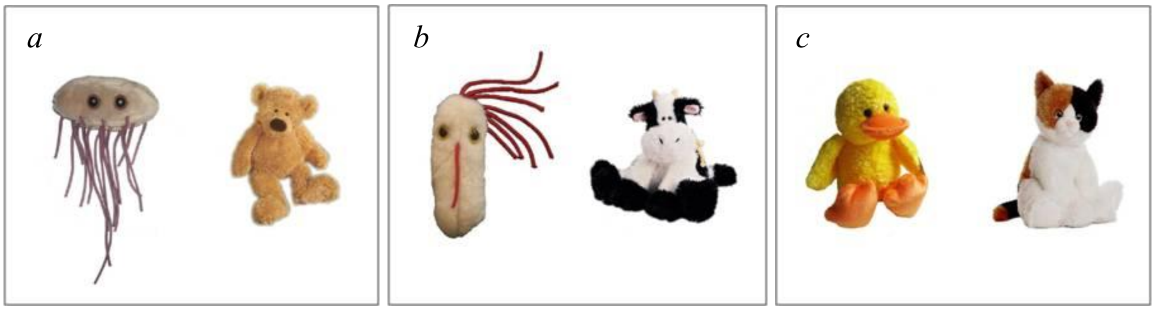

Figure 2: (*a*) Test trial target object *don* with teddy-bear distracter; (*b*) Target object *tos* with cuddly cow distracter; (*c*) Filler trial duck-cat: no target object (see Appendix C for all trials).

3.4. Auditory stimuli

The speech stimuli are digitally recorded by a young female native speaker of Dutch, in a soundproof booth. The stimuli are spoken in moderately infant-directed speech.

As pointed out before, auditory stimuli are offered to the subjects in short sentences. One carrier phrase is used in test trials while two carrier phrases are used in filler trials:

- Test-trials: "Kijk naar de [target]!"
  For example: "Kijk naar de *don!*". Translation: "Look at the *don!*"
- Filler trials: (1) "Waar is de [target]?"
  For example: "Waar is de *hond?*". Translation: "Where is the *dog*?"
  (2) "Zie je de [target]?"
  For example: "Zie je de *eend*?". Translation: "Can you see the *duck*?"

Table 8 shows the length of the carrier phrase ("*Kijk naar de..*") and target word for both correct (CP) and incorrect (MPV and MPC) pronunciations in test-trials.

Five seconds after the onset of each trial a second phrase emerges. For test-trials second phrases are: "Leuk hè?" (Nice, isn't it?) or "Mooi hè?" (Beautiful, isn't it?). In filler-trials second phrases are either "Kun je 'm vinden?" (Can you find it?) or "Vind je 'm mooi?" (Do you like it?).

TEST TRIALS		Duration carrier phrase	Duration target word	Carrier phrase starts at:	Target word starts at:	Second phrase starts at:
Kijk naar de *DON*	CP	0,648171	0,458317	2.298	3.00	5.00
Kijk naar de *DIN*	MPV	0,679564	0,415774	2.245	3.00	5.00
Kijk naar de *BON*	MPC	0,704368	0,42537	2.265	3.00	5.00
Mean duration (s)		**0,6773677**	**0,4331537**			
Kijk naar de *TOS*	CP	0,643685	0,570982	2.274	3.00	5.00
Kijk naar de *TIS*	MPV	0,637432	0,544367	2.260	3.00	5.00
Kijk naar de *POS*	MPC	0,645153	0,546513	2.265	3.00	5.00
Mean duration (s)		**0,64209**	**0,553954**			

Table 8: Length of auditory stimuli (sec.) for correct and incorrect pronunciations.

4. Results

4.1. Analysis I: Frame-by-frame

To begin with, a frame-by-frame analysis for each trial is done to calculate the percentage of children looking to the target (instead of the distracter) in each frame of the test trials. A trial consists of approximately 350 frames, since each frame lasts about 20 milliseconds. Figure 3 represents the outcome of this analysis.

The black line in figure 3 at frame 151 marks the onset of the target-word (TW) at 3000 ms. Participants' looking behaviour to the target when hearing a CP (*don* and *tos*) is represented by the blue line. The red line represents the MPV condition (*din* and *tis*) and the green line the MPC condition (*bon* and *pos*). Our interest goes to the differences between conditions from frame 169 – 251 (3367-5000 ms). This green shaded area is our post naming phase. Frame 169 (at 367 ms after TW onset) is chosen as a start for the post naming window, since it is clear that children need some time to process the stimulus. Responses to the spoken word cannot be instantaneous since they require the mobilization of an eye movement (Swingley & Aslin, 2000). Ballem & Plunkett (2005) report that there is some variation across studies in where to start this post naming phase: Bailey & Plunkett (2002) use a phase shift of 400 ms, Ballem & Plunkett (2005) themselves use 200 ms, but there are also researchers who measure the effect of naming from the onset of the target word (Golinkoff, Hirsh-Pasek, Cauley & Gordon, 1987;

Schafer & Plunkett, 1998; Meints et al.,1999). The beginning of our post naming phase is in line with Swingley & Aslin (2000; 2002) and Yoshida et al. (2009). Frame 251 (2 seconds after TW onset) ends the post naming window since we do not want to include children’s looking behaviour when they start losing their attention from the task. Previous research has suggested that the few eye movements occurring after this time are usually spontaneous re-fixations unrelated to the spoken stimulus (Swingley & Aslin, 2002).

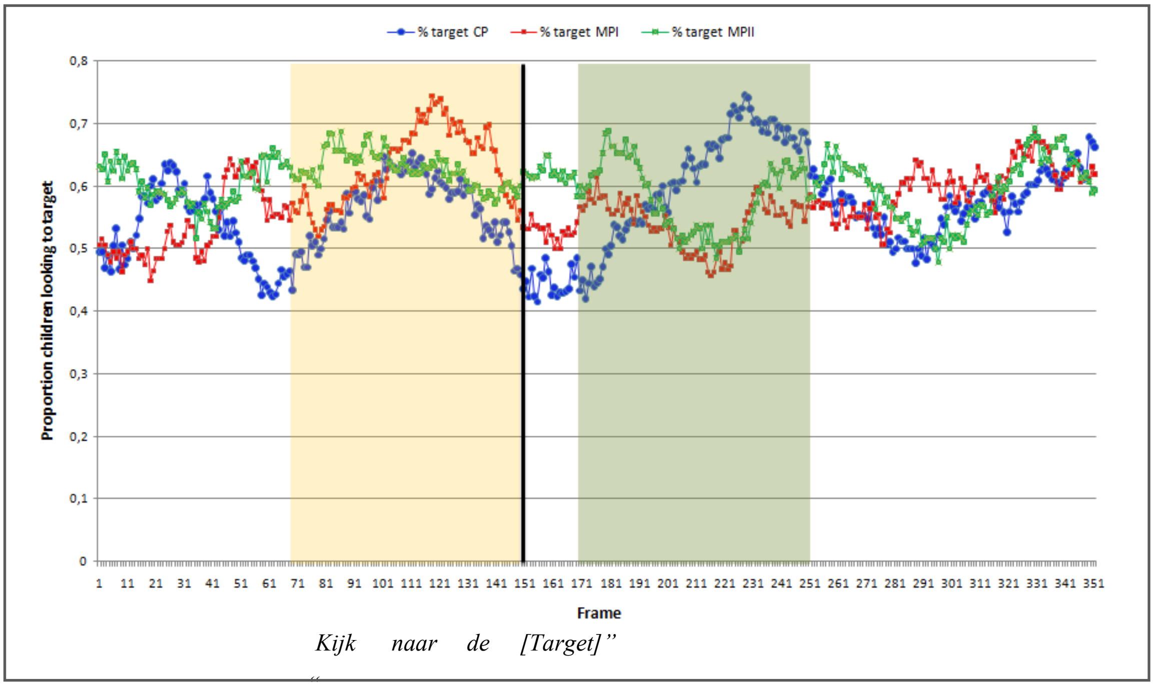

Figure 3. Frame-by-frame analysis. Frames are represented on the x-axis; the y-axis represents the proportion of children looking to the target object (Appendix D provides a full size image of the graph).

The mean of the blue line (CP) in the post naming phase is 60,3% (s.d. = 8,2%). This means that in the 367 - 2000 ms after naming the target word (TW), sixty percent of the participants is looking at the target object, which is significantly different from chance ($t(82) = 11.449$, $p = .000$). In MPV and MPC conditions the mean percentages of participants looking to the target object in the post naming phase are 54,1% (s.d.= 3,9%) and 58,1% (s.d.= 5,6%) respectively. MPV and MPC differ significantly from chance as well (MPV: $t(82) = 9.41$, $p = .000$; MPC: $t(82) = 13.30$, $p = .000$). A repeated measures ANOVA test with condition as factor shows that the difference between the blue, red and green line in the post naming window is significant: ($F(2,164)= 19{,}031$; p<.001). Posthoc comparisons are performed using the Bonferroni adjustment for multiple comparisons. More children look at the target-object in CP in comparison with MPV ($p < .001$). For MPC there is no such difference with CP ($p > \alpha$). Less participants look to the target-object in MPV than in MPC trials ($p < .001$). Interpreting these results, we can say that our prediction of MPC being the best match with the phonological representation of *don*, does not totally come true. However, it is obvious that, in accordance to our expectation, children look least to the target in MPV trials.

These results do not rule out the possibility that participants have a preference for looking to the target object because they liked the target object more than the distracter image. By comparing the proportion of children looking at the target object in the post naming phase with the proportion of children looking at the target object in a window before naming the TW, this bias can be ruled out. Because, if there is one, the preference would be present before target naming already. This pre naming starts at frame 68 and ends with frame 150 (83 frames before target naming: 1340-3000 ms after trial onset) and corresponds with the yellow shaded area on the left of the vertical black line at frame 151.

In the pre naming phase, for the CP condition, the mean percentage of participants looking to the target object is 56,1% (s.d.= 5,4%). Comparing this with 60,3% from the post-naming phase in a paired samples t-test, a significant difference is obtained ($t(82) = -5.23$, $p = .000$). For MPV and MPC, percentages are 62,8% (s.d.= 6,2%) and 62,7% (s.d.= 2,7%) respectively. Note that both percentages for MP conditions in pre naming are higher than the percentages after naming TW. Pre naming versus post naming differ significantly for both, MPV and MPC (MPV: $t(82) = 8.648$, $p = .000$; MPC: $t(82) = 6.521$, $p = .000$, table 9). However, while more children look at the target object after naming TW for CP trials, in MP trials the effect is reversed: more children look to the target object before naming TW in MP conditions. If we take a closer look to the MP conditions, it becomes clear that more children look to the target object after naming a MPC (*bon* or *pos*) than after naming a MPV (*din* or *tis*) ($t(82) = -9.977$, $p = .000$). Moreover, before target naming, this difference between MPV and MPC was not obvious ($t(82) = 0.155$, $p > \alpha$)

	CP	MPV	MPC
Pre-naming	56.1%	62.8%	62.7%
***Post*-naming**	60.3%	54.1%	58.1%
Difference	+ 4.2%*	-8.7%*	-4.6%*

Table 9. Percentages of participants looking to target object pre- and *post*-naming.
* marks a significant difference using α = .05)

4.2. Analysis II: Mean looking times

A second analysis is performed by computing mean looking times to the target object for each participant in CP, MPV and MPC conditions. This is done for pre naming and post naming, so two means per condition are obtained. The mean value for each subject and each condition consists of proportions looking times to the target object in four test trials (CP: 2x *don* 2x *tos*; MPV: 2x *din* 2x *tis*; MPC: 2x *bon* and 2x *pos*). To ensure that children were participating in the task, only trials with at least two third (54/83 frames = 1080 ms) of looking in both pre and post naming phases were included in the analysis. Also, each subject had to provide at least three (of four) values to compute a mean for the condition as a whole. Due to these criteria, some participants could not provide a mean for certain conditions, or only for pre or post naming. Table 10 shows how many participants are in accordance with the criteria and are involved in the analysis.

	CP	MPV	MPC
Pre-naming	24	26	29
***Post*-naming**	23	20	20

Table 10. Number of participants in accordance with analysis criteria.

Overall, mean percentages of looking times to the target object post naming were as follows: CP: 59,7% (*s.d.* = 16,9); MPV: 54,6% (*s.d.* = 14,4); MPC: 60,11% (*s.d.* = 13,3). Comparing these means with chance in one sample t-tests with test value 0.5 showed significant results for CP and MPC, not for MPV (CP: $t(22) = 2.769$, $p = .011$; MPV: $t(19) = 1.423$, $p > .05$; MPC: $t(21) = 2.143$, $p = .044$). However, a repeated measures ANOVA using condition as factor made clear that differences between CP, MPV and MPC post naming did not differ significantly (F (2,24) = 0.549, $p > .05$). Moreover, after subtracting the proportion looking time to the target object pre naming from post naming (post minus pre) for each subject and each condition, no significant differences were found in one sample t-tests with test value 0. For CP the percentage post naming minus pre naming was: 4,8% (*s.d.*=2,7%); for MPV: -7,3% (*s.d.* = 1,9%); and for MPC: -5,9% (*s.d.*= 2,3%). A repeated measures ANOVA confirmed that there were no significant differences between conditions after subtracting the proportion looking time pre naming from post naming (F (2,16) = 1.668, p > .05).

4.3. Vocabulary Analysis

NCDIs were obtained for 29/33 participants. Reported comprehension vocabulary ranged from 7 to 95 (out of 103) words (M = 39.5, *s.d.* = 23.2) and reported production ranged from 0 to 39 (out of 103) words (M = 10.7, *s.d.* = 10.1). No correlation between children's receptive or productive vocabulary and their looking behaviour in non of the conditions was found (all p's > .05).

5. Discussion

The present study tested 14-month-olds' sensitivity to mispronunciations of *don*-type of words in a preferential looking experiment. Children's looking behaviour was investigated when hearing correct pronunciations (CP) versus two types of mispronunciations: one with a PoA change (from labial to coronal) in the vowel (MPV), the other with a PoA change (from coronal to labial) in C1 (MPC). In accordance to the theory of a 'whole-word' stage, it was expected that participants would display longest looking times in the direction of MPC trials since these target words were predicted to form the best match with the phonological representation. Shortest looking times were expected in the direction of MPV trials.

The results did not provide a perfect match to our pattern of expectations, based on the theory of a 'whole-word' stage in which words are expected to receive one PoA for the whole word. It seems like *don*-type of words do not stick to the rules of this 'whole-word' phase, because if they would, 14-month-olds would not recognize *don* as *don* (CP condition), since the /d/ in *don* is coronal and does not match with its labial stored PoA representation based on the labial vowel. Participant's looking behaviour is in fact above chance in CP trials. Moreover, the result from the second analysis that CP and

MPC (*don*/*bon*) do not differ (which in part also follows from the first analysis), is interesting. It raises our interest because this result shows us that the obtained results do fit in another pattern of expectations, based on the theory of segmentation. Fikkert argues that after the 'whole word' stage words are gradually segmented into smaller units, which can have their own PoA specification. Such a segmentation pattern is believed to be present in older children. Fikkert (in press, exp.6) and Van der Feest (2005) observed this pattern in 17- and 20-month-olds (the latter using existing, familiar words such as *poes* and *duif* (Dutch for cat and pigeon respectively)). Our results can be explained if we assume segmentation, and hence specification of the consonant and vowel separately: Table 11 gives the prediction on the assumption that the coronal consonant is underspecified (as assumed in Fikkert, in press and Van der Feest 2007), but the labial vowel is specified for [labial].

Learned word	**Stored representation**	**Perceived form in test**	**Matching**
Don	Ø [labial]	CP: coronal labial (*don*)	C: No mismatch V: Match
		MPV: coronal coronal (*din*)	C: No mismatch V: Mismatch
		MPC: Labial labial (*bon*)	C: No mismatch V: Match
Prediction: infants will hear the difference between *don* and *din*, not between *don* and *bon*.			

Table 11. Expected result if segmentation takes place in *don*-words.

So maybe we can say that because *don*-type of words mismatch with itself during word learning, segmentation of these words is a necessary and inevitable consequence. In that view, *don*-type of words are hypothesized to trigger segmentation.

An alternative explanation for our results is that the procedure used in this experiment is more sensitive than the Switch, as argued for by Yoshida et al. (2009). Since Fikkert et al. (2005) showed that 14-month-olds succeeded in distinguishing *don/bon* in a Switch experiment, while they do not in the current, this might be evidence for the claim that both word learning tasks elicit different outcomes. However, Yoshida et al. (2009) argue that 14-month-olds are less successful under the demanding learning conditions of the Switch task, compared to a visual choice procedure. So in that case, the opposite outcome should be expected in which 14-month-olds would be able to distinguish *bon/don* in the current study while they would not be able to do so in the Switch. Moreover, our results are similar to those reported in Van der Feest (2007) for coronal-initial words. The task in this work is arguably even less demanding as well-known words are used with children of 20- and 24-months of age. These results seem to support our first explanation based on underspecified, but segmented representations for *don*-words in14-month olds, rather than an explanation based on task demands or task sensitivity.

Anyhow, the hypothesis of one PoA feature per word for *don*-words is not justifiable with our results. Moreover, although our analyses strongly suggest that vowel mispronunciations are worse than vowel mispronunciations on the basis of our results we cannot be entirely sure of this conclusion because not all of our analyses show that MPVs behave differently than MPCs. However, the importance of the vowel seems to be limited to very early stages of development. At later stages consonants seem more important, just like in lexical decision tasks with adults (Cutler et al., 2000) and older children, as shown by Nazzi (2005) and New, Araujo and Nazzi (2008) for 2- and 3-year old children.

Summarizing, learning *don*-type of words may speed up phonological acquisition, since for those words one PoA feature for the whole word is not sufficient. What exactly goes on is still unclear and we therefore suggest further research to investigate this issue. We would suggest an experiment similar to the one currently discussed, using test words *bin* and *pes* instead of *don* and *tos*. *Bin* and *pes* are com*pos*ed of a coronal vowel and a labial initial consonant (what means that they are opposites of *don*-words). It would be interesting to see whether these words behave, as we would expect, differently from *don*-words. In other words, will *bin*-words receive one PoA or will they also trigger segmentation? We would expect them to receive one coronal PoA, which is underspecified, and therefore all target words (CP, MPV and MPC) will be 'No Mismatches' with the representation. However, if *bin*-type of words in fact are segmented, we would only expect MPC (*din*) to mismatch with the stored PoA representation (Table 12).

Learned word	Stored representation	Perceived form in test	Matching
Bin	[labial] Ø	CP: labial coronal (*bin*)	C: Match V: No mismatch
		MPV: labial labial (*bon*)	C: Match V: No mismatch
		MPC: coronal coronal (*din*)	C: Mismatch V: No mismatch
Prediction: infants will hear the difference between *bin* and *din*, not between *bin* and *bon*.			

Table 12. Expected result if segmentation takes place in *bin*-words.

This latter pattern of behaviour is suggested for the 17-month olds in the switch paradigm. If the method used in this paper is more sensitive than the switch paradigm, it may show that the earlier results are due to the specifics of the task, rather than the representation.

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APPENDIX A

Script word learning phase – LIVE

1. Kijk, dit is een *DON*.
2. De *DON* is lief.
3. Wil je even met de *DON* spelen?
4. Houd de *DON* maar even vast.
   Filler phrases:
   Zacht he?
   Daar kan je lekker mee knuffelen.
   En je kan 'm aaien.
   Zo… nu heeft ie genoeg geknuffeld.
5. Mag ik de *DON* nu weer?
   Filler phrases (bij niet terug geven):
   Geef 'm maar terug aan mij.
   Ik weet dat ie heel leuk is, maar hij wil nu een spelletje spelen met mij.
   Let maar eens op.
6. O jee, waar is de *DON* nu?! (achter je rug houden)
7. Zie jij de *DON*?
8. O daar is de *DON* weer!
9. De *DON* had zich verstopt!
10. Nu is de *DON* moe.
11. De *DON* gaat even weg.

Wie hebben we daar?

1. Dat is een *TOS*.
2. De *TOS* is ook lief.
3. Wil je even met de *TOS* spelen?
4. Houd de *TOS* maar even vast.
   Filler phrases:
   Zacht he?
   Daar kan je lekker mee knuffelen.
   En je kan 'm aaien.
   Zo… nu heeft ie genoeg geknuffeld.
5. Mag ik de *TOS* nu weer?
   Filler phrases (bij niet terug geven):
   Geef 'm maar terug aan mij.
   Ik weet dat ie heel leuk is, maar hij wil nu een spelletje spelen met mij.
   Let maar eens op.
6. Oeps, waar is de *TOS* nu?! (achter je rug houden)
7. Zie jij de *TOS*?
8. O daar is de *TOS* weer!
9. De *TOS* had zich verstopt!
10. Nu is de *TOS* moe.
11. De *TOS* gaat even weg.

APPENDIX B

Word learning phase – MOVIE

Trial 1: “Kijk, dit is een *DON*. Een *DON*.”
→ picture of *don* zooming in and out

Trial 2: “Zie je de *TOS*? De *TOS*.”
→ picture of *tos* zooming in and out

Trial 3: “Daar is de *TOS*.”
→ picture of *tos* zooming in and out

Trial 4: “Vind je de *DON* mooi?”
→ picture of *don* zooming in and out

Trial 5: “Kijk, een *TOS*!”
→ picture of *tos*, zooming in and out

Trial 6: “Hier is de *DON*.”
→ picture of *don*, zooming in and out

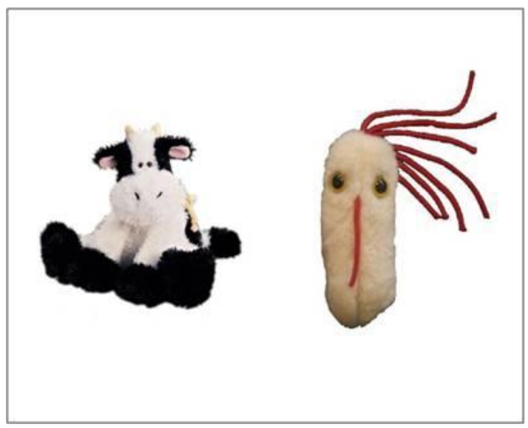
APPENDIX C

Visual stimuli – Test trials

Don / *din* / *bon* – Left

Don / *din* / *bon* – Right

Tos / *tis* / *pos* – Left



Tos / *tis* / *pos* – Right

Visual stimuli: Filler trials

Ball – Car

Car - Ball

Duck – Cat

Cat - Duck

Frog – Dog

Dog - Frog

APPENDIX D

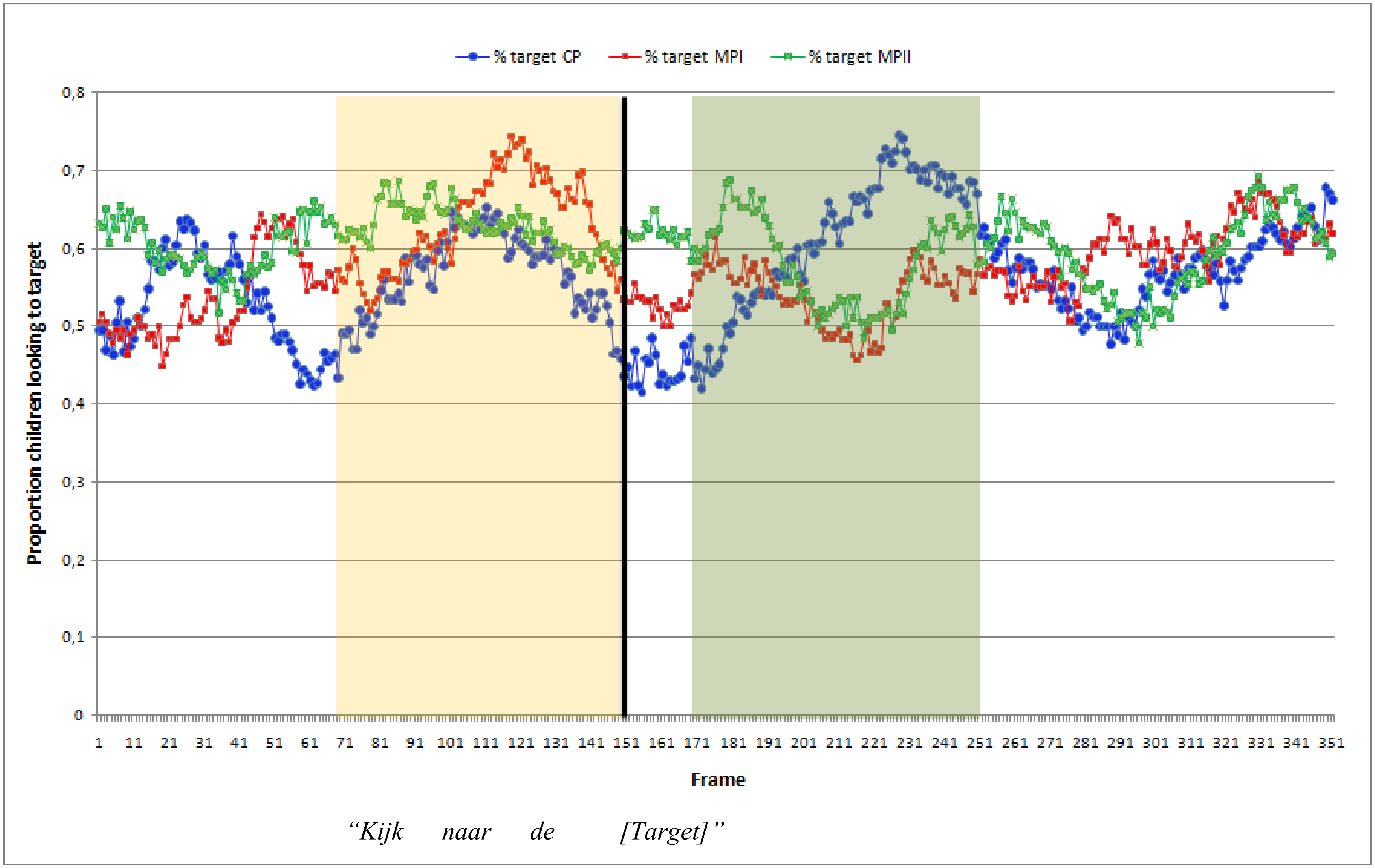

% target CP
% target MPI
% target MPII
Proportion children looking to target
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1 11 21 31 41 51 61 71 81 91 101 111 121 131 141 151 161 171 181 191 201 211 221 231 241 251 261 271 281 291 301 311 321 331 341 351
Frame
"Kijk naar de [Target]"

Figure 3 Full size. Frame-by-frame analysis. Frames are represented on the x-axis (each frame is about 20 ms); the y-axis represents the proportion of children looking to the target object (in percentile). The black line at frame 151 marks the TW onset at 3000 ms. Looking behavior to the target when hearing Correct Pronunciations ("*don*" and "*tos*") is represented by the blue line. The red line stands for the vowel mispronunciation (MPI) condition ("*din*" and "*tis*") and the green line for the consonant mispronunciation (MPII) condition ("*bon*" and "*pos*"). Yellow shaded area: pre naming phase: frame 68 – 150 (1340 – 3000 after trial onset). Green shaded area: *pos*t naming phase: frame 169 – 251 (367-2000 ms after TW onset).