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Master's Thesis

Compensation for nasal place assimilation in Dutch infants

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Contents

Abstract

Background: Learning about the native language's phonological rules is an important task in language acquisition, yet infant data on the perception of such rules are to date very limited. Few studies (Chambers, Onishi and Fisher 2002; Seidl, Cristiá, Bernard & Onishi 2009; White, Peperkamp, Kirk & Morgan 2008) give us the indication that infants have learned different kinds of phonological alternations between 11 and 16.5 months of age. Based on these studies we would predict that children, at least by 16.5 months of age, are able to apply native language phonological rules.

Aims: This study aims to investigate the development of knowledge about nasal place assimilation, a common phonological process of Dutch, in Dutch infants of 17 months of age. Do Dutch infants of 17 months of age compensate for nasal place assimilation?

Methods: A series of two familiarity-novelty preference experiments examined infants' capacities to detect a change from n-final to m-final word forms. The sentential contexts of the target words were unviable in Experiment 1 and viable in Experiment 2. The visual fixation procedure was used.

Results and outcomes: The infants, as a group, were able to detect the changed word forms, and thus to discriminate word-final /m/ and /n/ in an unviable assimilation context. Correct understanding of the task is reflected by this finding as well.

17-month-old infants, as a group, compensated for nasal place assimilation in a viable context. They were not able to detect a difference between the old and changed forms in an assimilation context.

Keywords: Infants, language acquisition, perception of assimilation, nasal place assimilation

1. Introduction

The formation of a lexicon is one of the earliest and most important tasks in language acquisition. It provides children with a starting point for communication, initially by comprehension and later by production. (Jusczyk, 1995). However, in typical conversational speech between adults, most of the speech consists of words strung together into sentences. The acoustic shapes of words are affected by the nature of surrounding words. Moreover, boundaries between words are often not well marked by distinct acoustic events(Quené, H. 1992). Yet every native language speaker is eventually able to cope successfully with this sort of variability and ambiguity in the acoustic shape of words. By looking at the development of sound patterns and words, it is possible to understand how language is learned, and how young language learners represent language. (Fikkert, 2007)

In Dutch, a phonological rule called place assimilation causes the place of articulation of the ending segment of one word to become the same as the place of articulation of the beginning segment of the following word. Place assimilations do not occur at random but are constrained by the phonological context.

For infants, it is a huge task to learn which speech sounds are relevant for distinguishing meaning. On the one hand, Dutch infants should be learning that it is important to distinguish /m/ and /n/, for example to distinguish the minimal pair "mee" and "nee". But on the other hand, they have to learn that the "tuim" they hear in "in de tuim bezig" is referring to the same thing as the word "tuin" in isolation.

One possibility is that they learn this via distributional learning. "Tuin" only changes to "tuim" if it is followed by a labial segment, but not otherwise, and this distributional property might lead infants to realize that the two are the same.

This study aims to investigate the development of compensation for nasal place assimilation in Dutch infants.

1.1. Assimilation

Assimilation is a common phonological process, by which one sound becomes more like a nearby sound. This can occur either within a word or between words. Place assimilation in consonant clusters involves one constituent of the cluster assimilating in place of articulation to a neighboring constituent. The focus in this study will be on non-local, regressive, cross-articulatory assimilations.

Acoustically less salient segments are more likely targets in place assimilation than acoustically more salient segments (Ohala, 1990). Nasal place assimilation is a cross-linguistically (in Dutch, German and English) common process, in which nasal stops take on the place of articulation of a following obstruent consonant.

1.2. Development of phonological knowledge in children

In the seventies and eighties researchers assumed that children pick up and perceive salient parts of the speech around them first (e.g., Ferguson & Garnica 1975; Waterson 1971, 1981, 1987 in Fikkert 2007), and initially have global representations of words that become more detailed when the lexicon grows. Changes in the lexical representations served an efficient organization of the lexicon. Today, most researchers of infant and child language perception assume that children have fairly detailed phonetic representations from a very early stage. By simply listening to language, infants are claimed to acquire sophisticated information about what sounds and sound patterns occur in the language and which of those patterns are frequent (e.g., Maye et al. 2002).

Research in child language perception has contributed two insights that have consequences for the understanding of phonological acquisition. First, children already know a lot about the sound patterns of their language before they speak their first word. Eimas and colleagues (1971) showed that young infants are especially sensitive to acoustic changes at the phonetic boundaries between categories, including those of languages they have never heard. Infants can discriminate among virtually all the phonetic units used in languages, whereas adults cannot. The acoustic differences on which these discriminations are based are very small. Stevens (in Kuhl 2004) found a change of 10 ms in the time domain changes /b/ to /p/, and equivalently small differences in the frequency domain change /p/ to /k/. The exact locations of phonetic boundaries differ across languages, and exposure to a specific language sharpens infants' perception of stimuli near phonetic boundaries in that language. At birth, infants are prepared to discern differences between phonetic contrasts in any natural language.

Another assumption that was made was that, while speech perception may start out as ‘universal’, the ability to distinguish between phonetic units must eventually give way to a language specific pattern of listening.

Werker and colleagues (1984) showed that English-learning infants could easily discriminate Hindi and Salish sounds at 6 months of age, but that this discrimination decreased by 12 months of age. English-learning infants have difficulty in distinguishing between sounds that are not used in English, in other words sounds which English infants are not exposed to. Children must be able to gather this knowledge on the basis of distributional properties of the input, as they do not yet have a lexicon.

One possibility is that children learn to compensate for assimilation via distributional properties. Children can learn rapidly from exposure to language. Distributional learning is about the acquisition of knowledge through the computation of information about the distributional frequency, with which certain items occur in relation to others, or probabilistic information in sequences of stimuli, such as the odds that one unit will follow another in a given language (Kuhl, 2004).

Chambers, Onishi and Fisher (2002) provide support to this theory of learning by finding that 16.5-month-old infants rapidly learned phonotactic regularities from brief auditory experience and that the infants generalized these regularities to unstudied syllables. Infants listened longer to new syllables that violated the experimental phonotactic constraints than to new syllables that followed them.

If distributional learning is the way by which children learn to compensate for assimilation, then the expectation will be that infants or young children initially do distinguish between the [m] and [n] in an assimilation context, because they still haven’t learned the phonological rule of place assimilation. Through distributional learning, they can acquire this rule and thus stop to distinguish between those sounds in an assimilation context.

Seidl, Cristiá, Bernard & Onishi (2009) found that French learning 11-month-olds generalized novel phonotactic patterns to new oral and nasal vowels, whereas 11-month-old English learners showed no evidence of either learning or generalizing the same patterns. English-learning 4-month-old infants seemed to have no difficulty either learning or generalizing the same patterns, likely due to the fact that they were not yet tuned to the sound inventory of their language. The authors suggest reduction of attention to allophonic contrasts by as early as 11 months. White, Peperkamp, Kirk & Morgan (2008) assessed infants' ability to learn phonological alternation rules based on distributional information. Infants were familiarized with an artificial language that incorporates voicing alternations for either stops or fricatives. For 12-month-old infants the test phase shows different listening times to novel stop or fricative sequences depending on the familiarization condition, while in 8.5-months-old infants there was no difference. White et. al. (2008) found evidence that phonological alternations can be acquired by 12 months of age. However, this study has problems. The experimental manipulation in Experiment 1 and 2 is confounded with different transitional probabilities and in Experiment 3 and 4, the novel words are presented without their assimilation context. Moreover, the alternations chosen are artificial and do not have any articulatory or perceptual motivation.

The above studies give us some indication of the age-group in which infants learn such alternations, namely that they have learned different kinds of alternations between 11-16.5 months of age.

1.2. Children coping with assimilation

Based on the above studies we would predict that children, at least by 16.5 months of age, do compensate for native assimilation. However, Jusczyk, Smolensky, and Alloco (2002) found that infants, whether in the initial state at 4.5 months, or after considerable learning at 10 months, and again at 20 months of age, except for the 15-month-olds preferred the assimilated clusters over canonical forms. These results imply that infants in most age-groups do discriminate between assimilated and unassimilated sequences, and do not show compensation for assimilation. However, in light of adult studies that do show compensation for nasal place assimilation in the native language (cf. section 1.3.), these results are rather striking; and one would rather expect that older infants do not attend to the difference anymore. One reason for the results could be that they presented infants with triplets like "on/pa/ompa", in which infants could make a direct comparison between the /n/ and the /m/. This is usually not the case in natural speech, so it is not clear if their results reflect infants' perception of place assimilation in natural speech.

Skoruppa, Mani & Peperkamp (in press) suggest that compensation for language-specific assimilation occurs by the age of three years. They found that English toddlers do compensate for native place assimilations, but not non-native voice assimilation. Reversely, French toddlers do not compensate for a hypothetical non-native place assimilation rule. These authors thus show that compensation for place assimilation is in place by three years of age and that it is a language-specifically learned process. These data are relevant with regard to a controversy as to the nature of place assimilation in the adult literature: While some authors argue that assimilation is a universal process, thus does not have to be acquired (e.g. Gow, 2004), others argue that it is acquired knowledge of a language. Skoruppa et al.'s study is suggestive of the latter possibility. It is, however, of interest if these effects would also occur in younger age-groups.

1.3. Other relevant data

In assuming that infants *learn* to compensate for nasal place assimilation at a certain age, one necessary precondition is that they are able to hear the difference between word-final /-m/ and /-n/ in the first place. To our knowledge, no study directly tests this assumption. However, Zamuner (2006) found that infants by 16 months of age are able to discriminate word-final place of articulation contrasts. By 16 months of age infants were able to discriminate place of articulation contrasts in word-final position, although showing no discrimination of the word-final voicing contrast. Unfortunately, they use plosives and not nasals. So we cannot be entirely sure about the nasals, but at least there is some indication that they can distinguish place of articulation in word-final position by 16 months.

Another important precondition for our study is how adults, thus learners that have acquired their native language phonology to perfection, cope with assimilation. Mitterer & Blomert (2003) assessed adults in coping with assimilation in a viable and an unviable context. Adults did not hear the difference between "tuin" and "tuim" in a viable assimilation context like in "tuinbank", while they heard the difference in an unviable context like "tuinstoel". This fits in with the distributional learning account laid out above: /n/ would never get assimilated to /m/ in an unviable context, and there is thus no necessity to compensate.

Looking at compensation for assimilation in infants will result in knowledge about the dissociation between universal perceptual and knowledge-based processes, as the effect of language exposure can be controlled for.

The current study will also lead to a contribution to the knowledge about language development of the child. This knowledge can, eventually, be used to understand development problems better, and to detect children who are at risk of developmental disorders, faster.

1.4. Research question

This study aims to investigate the development of knowledge about place assimilation in Dutch infants. Do Dutch infants compensate for place assimilation (i.e., stop distinguishing between /m/ and /n/ in an assimilation context) at 17 months of age? Is there a significant difference in infant's looking time to the screen in both test trials (OLD vs. CHANGE).

H_0 $\mu1 - \mu2 = 0$ *Infants in 17 months of age do compensate for nasal place assimilation. i.e. there is no significant difference in infant's looking time to the screen in OLD and CHANGED in assimilation context.*

H_a $\mu1 - \mu2 \neq 0$ *Infants in 17 months of age do not compensate for nasal place assimilation. i.e. there is a significant difference in infant's looking time to the screen in OLD and CHANGED in assimilation context.*

1.5. General experimental design

Both experiments consist of a familiarization phase and a test phase. During the familiarization phase, infants hear two /n/-final target non-words for a predefined time. In the following test phase, they are tested on their preference for three non-words embedded in sentences. One of the test non-words will be exactly the same as one of the familiarized non-words (OLD). The second will be modified from the second familiarized non-words to an /m/-final non-word (CHANGE). The third test item will be a completely novel non-word (NEW). This item is added in order to make sure the task itself is working: In general, disregard less of the outcomes for the /m/-final CHANGE test item, we expect a difference in looking time to the NEW and the OLD item. The sentential contexts of the target words will be unviable in Experiment 1 and viable in Experiment 2, and will be explained in more detail below.

2. EXPERIMENT 1

Experiment 1 is designed to ensure that infants are indeed able to distinguish between syllable-final /n/ and /m/. This is a necessary predisposition to any claims on compensation for assimilation, because otherwise any lack of discrimination found in the viable context could also be due to a general lack of ability to discriminate the contrast.

Adult studies have shown that adults do not hear the difference between "tuin" and "tuim" in a viable assimilation context like in "tuinbank", while they hear the difference in an unviable context like "tuinstoel" (Mitterer & Blomert 2003). If, therefore, infants are compensating for assimilation rather than just not being able to discriminate between syllable-final /n/ and /m/, they should in any case be able to hear the difference in an unviable context.

In Experiment 1, the infants will hear the /-n/ final non-words in the familiarization phase. In the test phase, both /-n/ final and /-m/ final non-words embedded in *unviable* context sentences, will be heard. Given the adult data, we can assume that infants are able to hear the difference in the unviable case. It will be important to show that infants can perceive the difference in the unviable condition. Then, the results of the viable condition can go either way, and we can conclude that 17-month-olds either do or do not compensate for assimilation.

2.1. Methods

2.1.1. Participants

Twenty-four typically developing, monolingual Dutch infants of 17 months of age, (mean age= 519 days) participated. Twelve additional infants were tested, but not included in the analysis due to parent interference (n=2), or not completing the experiment due to fussiness or crying (n=10).

None of the participating infants had a history of hearing loss. The infants were registered at the Baby Research Center Nijmegen by their parents.

2.1.2. Stimulus and apparatus

A female native speaker of Dutch recorded the stimuli in an infant-directed register. The stimuli used in the familiarization phase consisted of 3 monosyllabic non-words with coda /n/. Multiple isolated tokens of these words were recorded, and five unique tokens of each selected. Acoustic analysis of the stimuli showed no systematic difference between the length of the words in viable and in unviable context. This was done by the program PRAAT (Boersma & Weenik, 2012). One familiarization list consisted of ten tokens (2 replications of 5 tokens) of one non-word, repeated at random in one list. The length of each non-word list was about 18000 ms. Tokens were separated by 500 ms pauses.

For the test phase the same non-words were recorded embedded in five different sentences, in unviable contexts (Table 1). Additionally, sentences containing the /m/-final versions of these non-words were also recorded. The speaker was encouraged to read the passages in a lively voice, as if she were reading them to a baby.

There were three blocks with three trials each. In total there were nine test trials. In every test trial there were five sentences. Sentences were separated with 500 ms. The maximal duration of the passages was 19000 ms in one block. In order to ensure that there were no coarticulation effects, the target non-words in the passages were replaced by non-words recorded in isolation. One trial consisted of five sentences containing the same non-words. There were thus six different test trials. Sentences were separated by 500 ms. One test block consisted of a combination of three of these trials: One old, one /m/-final, and one novel trial. The maximal duration of the passages was 19000 ms in one block.

Table 1 The five-sentence passages used in experiment 1

Unviable context	
KEIN-KEIM	
1. De kein staat daar in de kast	1. De keim staat in de kast
2. De kein kiest een kleur	2. De keim kiest een kleur
3. De kein zoekt naar papier	3. De keim zoekt naar papier
4. De kein rolt naar beneden	4. De keim rolt naar beneden
5. De kein raakt de goede knop	5. De kein raakt de goede knop
TAN-TAM	
1. De tan komt vandaag binnen	1. De tam komt vandaag binnen
2. De tan stond op het fornuis	2. De tam stond op het fornuis
3. De tan ruikt naar bloemen	3. De tam ruikt naar bloemen
4. De tan zaagt in het hout	4. De tam zaagt in het hout
5. De tan ratelt maar door	5. De tam ratelt maar door

SEEN-SEEM

1. De seen kookt de aardappels	1. De seem kookt de aardappels
2. De seen sorteert de pennen	2. De seem sorteert de pennen
3. De seen rookt een sigaret	3. De Seem rookt een sigaret
4. De seen zakt naar beneden	4. De seem zakt naar beneden
5. De seen raast door de straat	5. De seem raast door de straat

Infants were familiarized to two out of the three non-words. The critical comparison is between a changed and a non-changed version of these words, not in relation to any other new item. We tested half of the children on a non-changed (OLD) and a changed version (CHANGE), and the other half on a changed (CHANGE) and a non-changed version (OLD), and add one NEW control item. This item is added in order to ensure that the task itself is working, and that the infants do differentiate between OLD and NEW.

We rotate these three items so that three groups of infants are familiarized to seen/kein, tan/seen, kein/tan respectively (table 2).

Table 2 Design experiment 1 with C is condition

	C1–C2	**C3–C4**	**C5–C6**	**C7–C8**	**C9–C10**	**C11–C12**
Familiarization	seen/kein		tan/seen		kein/tan	
Test *old*	kein	seen	seen	tan	tan	kein
Test *change*	seem	keim	tam	seem	keim	tam
Test *new*	tan		kein		seen	

Auditory stimuli were presented over the speakers of a TV screen. A visual stimulus was presented on the TV screen. Directly below the TV-monitor a video camera was installed to record each test session. The response box, which was connected to the computer, was equipped with buttons that started and stopped the audio stimuli, recorded the duration of fixation, and terminated a trial when the infant looked away for more than 2 seconds. Information about the duration of the fixation and the total trial duration were stored in a data file on the computer for an offline coding.

2.1.3. Procedure

The visual fixation procedure was used. The infant sat on its parent's lap in front of a TV monitor on which various images were presented. First, the infant's attention was drawn to the screen with a visual display (e.g. with a moving light accompanied by audio stimuli) as a pre-test stimulus. This pre-test stimulus (with an accompanying post-test stimulus displaying exactly the same) serves the purpose of measuring general attention decline during the experiment. The maximum trial duration of the pre-test stimulus was 15000 ms. Subsequently, once the infant was looking at the TV monitor, another image (e.g. a bulls-eye) was presented as a silent stimulus, with a trial duration of 5000 ms. This bulls-eye was used throughout the following experimental phases, and the infant was therefore first familiarized for 5000 ms with this visual stimulus in silence before it was paired with sounds. After this the familiarization phase was initiated. The bulls-eye image was presented again, now accompanied by audio speech stimuli. The audio speech stimuli played as long as the infant was looking at the screen with a maximum trial duration of 19000 ms. A trained coder observed the infant's face and coded if the infant fixated the screen. Whenever the infant looked away for more than 2000 ms, a trial ended and a flashing light was presented to draw the infant's attention again. A new trial started to play as soon as the infant looked back at the screen. During the familiarization phase, infants heard repetitions of two of the target words until they accumulated at least 60 s of listening time to the target words. Due to constraints of the experimental software used, it was not possible to set the criterion to 30 s for each stimulus. Therefore, the 60 s overall criterion was employed, and infants deviating largely from the 30/30 criterion were excluded post-hoc.

The test phase began immediately after the familiarization. The stimuli for the test phase consisted of the three five-sentence blocks. The order of the sentences within each of the trials was fixed. The order of the trials within a block was pseudo-randomized. Each infant was tested on three blocks, for a total of nine test trials. Figure 1 gives us a sample of the experiment in condition 1.

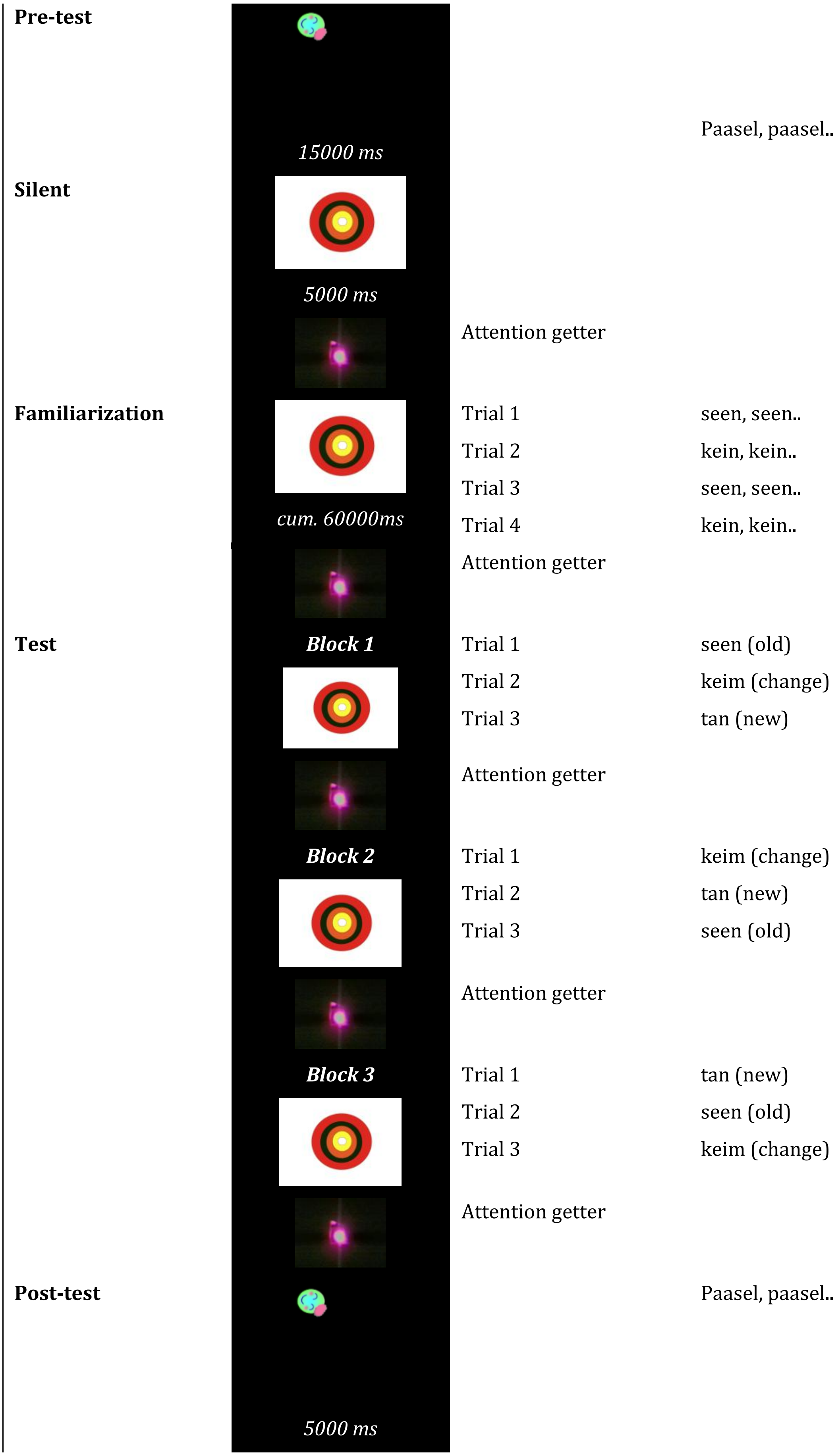

Figure 1 Sample experiment condition 1

At the end, again the moving light was presented, as a post-test stimulus, making sure the infant's attention was similar during the test phase.

If 17-months-old infants perceive the difference between coda /n/ and /m/, the looking time to CHANGED versions should be dissimilar to the OLD versions and similar to the NEW trials.

2.1.4. Statistical analysis

2.2. Results and Discussion

Reliability in coding

With the observer reliability we can indicate how stable the coding obtained is from the same experimenter in different coding settings (online and offline). The greater the difference between these two settings, the smaller the observer reliability of the experimenter.

Infants' looking behavior was coded online using the Lincoln Infant Lab Package (Meints & Woodford, 2008) software, and offline using the SuperCoder software (Hollich, 2003). All test sessions were coded by one experimenter who was blind to the experimental conditions. The response box of the online coding, was equipped with buttons that started (6) the audio stimuli and coded looks to the screen (5). Fixation durations were recorded on the hard drive.

The SuperCoder software for the offline coding was equipped with buttons that register the start of the trial (T), center look (C), look away (A), and the stop of the trial (S). This program creates a 30 frames per second transcript of the test session and allows a frame-by-frame analysis of the infants' looking behavior. The observer coded the looking time offline of the first two and the last two chosen participants. The correlation between online and offline coding will be described in section *3.2. Results and discussion*, where both Experiment 1 and Experiment 2 are taken into account.

Vocabulary size

We let the parents fill in the NCDI-questionnaires 2a (Zink & Lejaegere, 2003) to obtain a raw overview of the lexicon of the participating infants for later comparison between the two experiment groups. In Experiment 1 the infants had a range in the raw scores of 101 (max = 111, min = 10,) receptive, and a range of 46 productive (max = 47, min = 1). The mean score in Experiment 1 receptive was 50, and 15 in the productive scores.

Results

A descriptive look at the data set gets us a sense of the typical values of the looking times, as well as a sense of how spread out the values in the data set are. The mean looking time for all children per trial was 5128ms (SD = 2699ms). We defined an outlier as an infant whose overall average looking time was more than 3 SD away from the mean, and found one infant fulfilling this criterion in our dataset. The outlier was removed, and a new infant was added instead. After this, the mean and standard deviation of the looking time to each target word in the familiarization phase were calculated[1]. Overall there was a 50% of looking time to each word, with a mean percentage of 50 for familiarization token 1, and 50% for familiarization token 2. We decided to remove any infant that had a looking time ratio of more than 75%/25% for the two target words from the data set, as she would have too little exposure to one of the tokens. No infant had to be removed. Subsequently, we turned to the test phase. For having a valid task there should be a difference between looking times to NEW and OLD versions in the test phase, thus infants should recognize the words they have been familiarized to. However, overall descriptive statistics showed no difference between these two versions. The mean looking time to the NEW versions was 5909ms, to the CHANGE ones 6363ms, and to the OLD versions the mean looking time was 6151ms (cf. Figure 2).

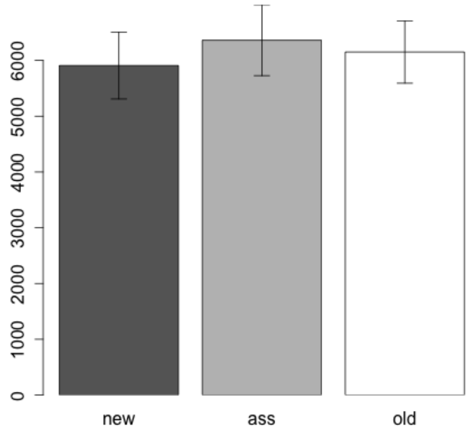

Figure 2 Descriptive statistics Experiment 1 'Mean looking time per trial'

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[1] Recall that we were not able to present the familiarization stimuli for exactly 30 s each as described in the Methods section.

The lack of difference is likely due to the fact that some babies showed a novelty preference, and some babies a familiarity preference. This conforms to the logic of the familiarization-novelty preference paradigm that preferences are free to vary in two conditions. If infants are given familiarization they could demonstrate either a familiarization preference or a novelty preference in the test trial.

The direction of a looking preference is largely irrelevant when infants' discrimination ability or recognition memory is of primary interest; any deviation from random behavior indicates that a difference between the stimuli has been detected. (Houston-Price & Nakai, 2004). Though there are a number of hypotheses, still no consensus in as to what factors affect the direction of preferences, has emerged. (McMurray & Aslin, 2005)

We sorted the infants into two groups in the same way as McMurray & Aslin (2005) did, on the basis of their looking times to the stimuli. The direction of preference for each child was determined by subtracting their overall looking time to OLD from NEW. When the value of this subtraction was positive, the baby was defined as showing a novelty preference. When the value of this subtraction was negative, the baby was defined as showing a familiarity preference. By this, the group was divided into infants with a novelty preference (n=11) and infants with a familiarity preference (n=13).

It could be problematic to divide the babies into these two groups, because one could divide any random set this way and get a difference just by this division. Yet, in the case of this study the interest primarily is in the behavior of the CHANGE word forms relative to the NEW and OLD versions. Again, the division of a random set would automatically lead the CHANGE forms to fall in between the divided NEW and OLD forms. However, assuming an effect of experimental manipulation, we can make clear predictions for the CHANGE forms for both experiments: they should be treated like the NEW forms in Experiment 1, and like the OLD forms in Experiment 2. Therefore, we can justify this division for the current study.

Moreover, McMurray & Aslin (2005) conducted a Monte Carlo simulation, to verify that sorting infants like this did not inflate the likelihood of finding reliable effects.

After this division, the mean looking times per trial were calculated for each group. In both groups, for each child, two measures were calculated by substraction: the difference between NEW and CHANGE, and the difference between OLD and CHANGE.

For all the infants with a familiarization preference, the algebraic sign of the subtraction measures NEW-CHANGE, and OLD-CHANGE were reversed by multiplying the measure with -1. The logic of this is that the relative differences between NEW, OLD and CHANGE remain the same, but now the basis difference in novelty and familiarity preference is taken into account. Figure 3 shows the results. The null line shows the baseline and would express no difference in looking time.

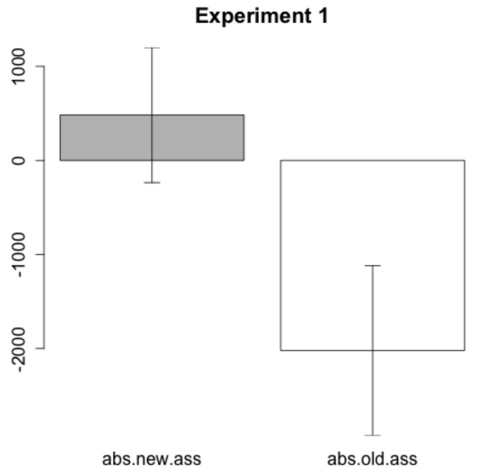

Figure 3 Basis difference in looking time between NEW-CHANGE and OLD-CHANGE

The question now is if there are significant differences in looking time between these two conditions. The expectation is that the babies treat CHANGE like NEW. Thus they are able to discriminate coda /m/ and /n/. Therefore the results should show no difference of NEW-CHANGE from zero (thus, the no-difference line), but a difference of OLD-CHANGE from zero.

A one-sample t-test indicated that the difference in average looking times between NEW-CHANGE and 0 was not significant. [t(23) = 0.67, p = .509].

The difference in average looking times between OLD-CHANGE word forms and 0 was found to be significant. [t(23) = -2.24, p < .05]. These results are consistent with the hypothesis that the infants are able to discriminate coda /m/ and /n/ in an unviable context.

Zamuner (2006) found that infants by 16 months of age are able to discriminate word-final plosive place of articulation contrasts. Now it is possible to extend this finding by suggesting that infants by 17 months of age are able to discriminate word-final nasal place of articulation contrasts. The results are in consensus with the adult data, where Mitterer & Blomert (2003) found that adults do hear the difference between coda /n/ and /m/ in an unviable assimilation context.

2.3. Conclusion

These results indicate that 17-month-olds, as a group, did not differentiate between NEW and CHANGE word forms in the unviable condition, while they did differentiate between CHANGE and OLD word forms . In this respect, the behavior of the 17-months-olds suggests that they are able to detect the change, and thus discriminate word-final /m/ and /n/ in the unviable condition.

3. EXPERIMENT 2

After making sure that infants have the general ability to discriminate between coda /n/ and /m/ in Experiment 1, Experiment 2 investigated if infants do compensate for assimilation, thus stop distinguishing the same contrasts as in Experiment 1 in a viable assimilation context. If they compensate for assimilation, they should not hear the difference and do not prefer a specific list. If they do not compensate, they either show a familiarity preference or a novelty preference.

3.1. Methods

3.1.1. Participants

Twenty-four typically developing, monolingual Dutch infants of 17 months of age (M= 516 days), were tested. Six additional infants were tested, but not included in the analysis due to fussiness or crying.

None of the infants had a history of hearing loss. The infants were registered at the Baby Research Center Nijmegen by their parents.

3.1.2. Stimulus, apparatus and procedure

These were identical to those in the previous experiment. The only difference was that we used new sentential contexts for the test phase such that the non-words embedded in sentences were viable now. (Table 3)

Table 3 The five-sentence passages used in Experiment 2

Viable context	
KEIN - KEIM	
1. De kein breekt in twee stukken	1. De keim breekt in twee stukken
2. De kein bakt op het fornuis	2. De keim bakt op het fornuis
3. De kein post een brief	3. Je kan de keim pakken
4. De kein boven kan je gebruiken	4. De keim boven kan je gebruiken
5. De kein bedenkt een spelletje	5. De keim bedenkt een spelletje
TAN – TAM	
1. De tan barst uit elkaar	1. De tam barst uit elkaar
2. De tan botst tegen de auto	2. De tam botst tegen te auto
3. De tan beweegt langzaam op en neer	3. De tam beweegt langzaam op en neer
4. De tan past niet in de tas	4. De tam past niet in de tas
5. De tan bloeit in de zomer	5. De tam bloeit in de zomer
SEEN-SEEM	
1. De seen bewaart het koekje	1. De seem bewaart het koekje
2. De seen pakt zijn fiets	2. De seem pakt zijn fiets
3. De seen beneden is vol	3. De seem beneden is vol
4. De seen bezoekt de dokter	4. De seem bezoekt de dokter
5. De seen bedoelt het niet zo	5. De seem bedoelt het niet zo

If 17-months-old infants do not compensate for nasal place assimilation, the looking time to changed versions should be dissimilar to the old versions. There should be a significant difference in looking time. If they compensate for assimilation, they should not hear the difference and not prefer a specific list.

3.1.3. Statistical analysis

3.2. Results and Discussion

Reliability

Infants' looking behavior was coded online using the Lincoln Infant Lab Package (Meints & Woodford, 2008) software, and offline using the SuperCoder software (Hollich, 2003). For the description of the observer reliability, we took both experiments into account. At this point we are looking at the relationship between online and offline coding. The greater the difference between these two settings, the smaller the observer reliability of the experimenter, the smaller the reliability of the results.

For each infant the mean looking time in seconds, in each condition, was calculated. There were three conditions with eight infants each, so twenty-four data-points are conducted.

The chart (figure 4) shows the scatter plot of the data.

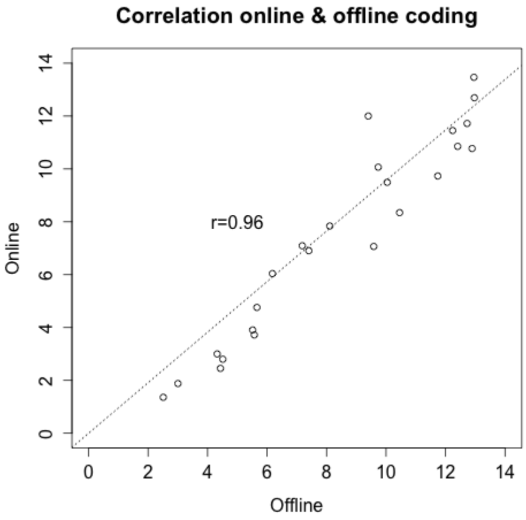

Figure 4 Correlation online & offline coding, with on the x- and y-as, time in seconds.

Because of the ratio measurements, and the linear data themselves, we used the Pearson's correlation coefficient to indicate the reliability of the coding.

The average correlation between the online and offline coding was 0.96. The results indicate that the strength of association between the variables is very high (r = 0.96).

In conclusion we can say there is a very high intra observer reliability.

Vocabulary size

The range in vocabulary size, according to filled NCDI questionnaires, in Experiment 2 was 68 (max = 72, min = 4, med = 34) receptive, and 33 in productive scores (max = 33, min = 0, med = 7). In Experiment 2 the means were 35 for receptive and 11 for the productive raw scores.

Results

As in the previous experiment, mean looking times to the three different trials were calculated, for each infant. The mean looking time for all children per trial was 3770ms. (SD = 2100ms). No outliers were found.

Overall there was a 50% of looking time to each word, with a mean of 56% for familiarization token 1, and 44% for familiarization token 2.

Any infant that had a looking time ratio of more than 75%/25% for the two target words from the data set, had to be removed, as she would have too little exposure to one of the tokens. No infant had a looking time ratio of this percentage.

Regarding the test phase, across all subjects, the average looking times were 4556 ms to the NEW versions, 5400 ms to the CHANGE and 4380 ms to the OLD ones. (figure 5) Overall descriptive statistics showed no difference between the OLD and NEW versions.

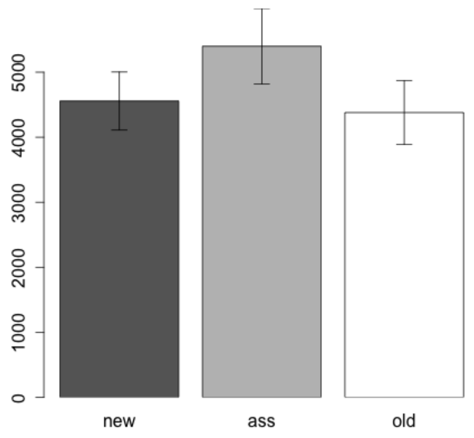

Figure 5 Descriptive statistics experiment 2 'Mean looking time per trial'

Again, the missing difference is likely due to the fact that some babies showed a novelty preference, and some babies a familiarity preference.

The group was divided into infants with a novelty preference (n=11) and infants with a familiarity preference (n=13) like in Experiment 1. In the case of this experiment the interest primarily is in the behavior of the CHANGED word forms, relative to the NEW and OLD versions. Therefore, we can justify this division for the current study.

The mean looking times per trial were calculated for each group. As in Experiment 1, in both groups, three measures (NEW-OLD, NEW-CHANGE, OLD-CHANGE), for each child, were calculated. If the results were random, the expectation will be that after splitting the data, the CHANGED form is away from NEW, likewise it is away from OLD. If the results were not random, the CHANGED versions are expected to be closer to the OLD word forms.

For all the babies with a familiarization preference, the algebraic sign of the subtraction measures NEW-CHANGED, and OLD-CHANGED were reversed by multiplying the measure with -1. The logic of this is that the relative differences between NEW, OLD and CHANGED remain the same, but now the basis difference in novelty and familiarity preference is taken into account. Figure 6 show the results. The null line shows the baseline and means that there is no difference in looking time.

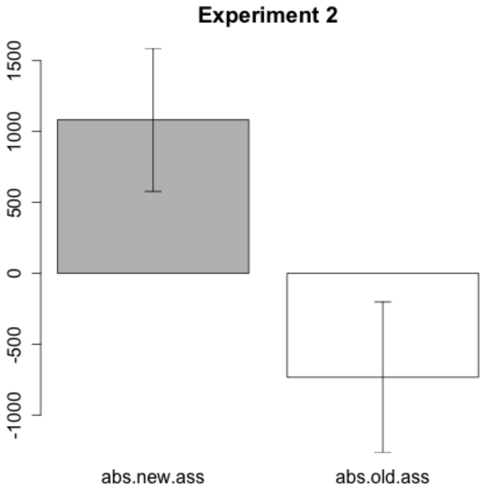

Figure 6 Basis difference in looking time between NEW-CHANGE and OLD-CHANGE

The question again, is if there are differences in looking time between these two conditions. The expectation of experiment 2 is that when the infants do compensate for assimilation, the babies treat CHANGE like OLD. Thus they are not able to discriminate coda /m/ and /n/ anymore in the viable context. Therefore the results should show a difference between NEW-CHANGED, but no difference between OLD-CHANGED.

An one-sample t-test indicated that the difference in average looking times between NEW and CHANGED was significant. (t(23) = 2.14, p < .05)
The difference in average looking times between OLD and CHANGED word forms was not significant. (t(23) = -1.38, p = .181) These findings conform to the predictions.

3.3. Conclusion

17-month-old infants, as a group, do compensate for nasal place assimilation in a viable context. They were not able to detect a difference between OLD and

CHANGED in this context. A descriptive look showed overall a longer looking time to the CHANGED word forms. This is rather striking because of the equality between OLD and NEW.

4. General Discussion

The main question of the present study was whether Dutch infants of 17 months of age do compensate for nasal place assimilation. A series of two experiments examined infants' capacities to detect CHANGED word forms. The sentential contexts of the target words were unviable in Experiment 1 and viable in Experiment 2.

If infants are compensating for assimilation rather than just not being able to discriminate between syllable-final /n/ and /m/, they should be able to hear the difference in the unviable context. Given the adult data, we expected that infants are able to detect the changed word forms in the unviable case. The question is whether they do detect these word forms in a viable context.

The results of Experiment 1 demonstrated that the infants are able to discriminate coda /m/ and /n/ in an unviable context. This is consistent with the hypothesis. Zamuner (2006) found that infants by 16 months of age are able to discriminate word-final place of articulation contrasts, but they use plosives at the time. Now it is possible to extend this finding by suggesting that infants by 17 months of age are able to discriminate word-final nasals.

The infants were not able to detect the difference in the viable context in Experiment 2.

These findings suggest that 17-months-old infants do compensate for nasal place assimilation.

The results do agree with the adult data, mentioned in the introduction, where Mitterer & Blomer (2003) also found that adults do notice the difference between coda /n/ and /m/ in an unviable assimilation context, while they did not hear the difference in a viable assimilation context.

The results fit in with the distributional learning account: /n/ would never get assimilated to /m/ in an unviable context, and there is thus no necessity to compensate. Through this distributional learning, children can acquire this rule and thus stop to distinguish between those sounds in an assimilation context.

Few studies (Chambers, Onishi and Fisher 2002; Seidl, Cristiá, Bernard & Onishi 2009; White, Peperkamp, Kirk & Morgan 2008) gave us the indication that infants have learned different kinds of phonological alternations between 11-16.5 months of age. The current results are compatible with this indication, finding that infants of 17 months of age do compensate for nasal place assimilation.

However, Jusczyk, Smolensky, and Alloco (2002) found that infants in most age-groups (4.5 months, 10 months, 20 months, except for the 15-month-olds) do not show compensation for assimilation. The results of the 15-month-old infants in the study of Jusczyk et. al. (2002) is of interest, because this age-group is the closest to the age-group of the present study. The 15-month-old infants did compensate for nasal assimilation. Recall that Jusczyk et. al. (2002) explain the results in terms of faithfulness and markedness constraints.

One possible explanation Jusczyk gives is that at this age, infants are dealing with another possible constraint, call it constraint X, that is competing with the nasal assimilation constraint. Perhaps at 15 months of age, infants are demoting the nasal assimilation constraint below constraint X, temporarily losing the initial dominance of nasal assimilation, which is regained by 20 months of age.

One reason for their overall results could be that their results do not reflect the perception of place assimilation in natural speech, because they presented infants with triplets like "on/pa/ompa", in which infants could make a direct comparison between the /n/ and the /m/. This is usually not the case in natural speech. The strength of our design is that we used more natural conditions and that our results do reflect the perception of place assimilation in connected speech. Gaskell and Snoeren (2008) find that strong assimilations do occur if recording conditions are rendered more natural. This finding fits to our results.

While some authors argue that assimilation is a universal process, thus does not have to be acquired (e.g. Gow, 2004), others argue that it is acquired knowledge of a language (Skoruppa et.al. in press). Because the present study only shows that infants of 17 months of age do compensate for assimilation, and thus only gives us the indication of one age-group, an unanswered question is still in how far compensation for assimilation is a universal or language specific process.

Gow’s account (2004) assumes that assimilation is an universal perceptual process independent of specific language experience. In a cross-linguistic study, Gow and Im (2004) show that English and Korean speakers show similar assimilation affects, suggesting that universal perceptual mechanisms operate. Mitterer, Csepe, and Blomert (2006) correspond to this account supporting the notion of language-independent mechanisms playing a role in compensation for assimilation. Mitterer found that Dutch and Hungarian listeners compensate for Hungarian liquid assimilation in both an identification and a discrimination task.

The study of Darcy, Ramus, Christophe, Kinzler, & Dupoux, (2009) shows that compensation effects are larger for assimilations that exist in the native language, but also non-native assimilations are still compensated for to a certain degree.

All these studies give evidence for the universal account, where current results corresponds to.

A related issue that demands further investigation could be the role of vocabulary size. In the current study we let the parents fill in the NCDI-questionnaires 2a (Zink & Lejaegere, 2003) to obtain an overview of the lexicon of the participating infants. We found some interesting differences in the descriptive statistics between both experiment groups. Overall the infants in Experiment 1 show a higher vocabulary size. This could have affected the results. For the infants with a relatively smaller lexicon, phonological neighborhoods are sparse, and there are few competitors for word recognition. On the other hand, as the lexicon grows, phonological neighborhoods become denser, and there is a need to consider finer phonetic details to access the correct item. The infants with a larger lexicon could have payed more attention to phonetic details, and detected the difference between coda /m/ and /n/ better. More definitive answers regarding the affect of vocabulary size on compensation for assimilation, may come from research where the two experiment groups have more balanced scores. It is remarkable that the infants in Experiment 2 show overall smaller looking times. This could fit with the assumption that children with a larger lexicon need to consider finer phonetic details, therefore they are more interested and use more time.

To conclude, while these findings contribute to our understanding of the early learning profile of children, further research is needed to expand the infant data on the perception of assimilations.

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6. Appendix

Stimuli for each type of experiment[2]

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Familiarization	**seen/kein**				**tan/seen**				**kein/tan**			
Test	*kein/seem/tan*		*seen/keim/tan*		*seen/tam/kein*		*tan/seem/kein*		*tan/keim/seen*		*kein/tam/seen*	
Block1	change	new	old	new	ass	old	ass	new	ass	old	old	new
	new	old	ass	change	old	new	old	change	new	change	new	old
	old	change	new	old	new	change	new	old	old	new	change	change
Block2	new	change	change	change	old	new	new	old	change	old	new	old
	change	old	old	new	change	change	old	new	old	new	change	new
	old	new	new	old	new	old	change	change	new	change	old	change
Block3	change	old	old	new	old	new	new	change	change	new	change	old
	new	change	change	old	new	old	old	new	old	change	new	change
	old	new	new	change	change	change	change	old	new	old	old	new

---

[2] In each row, each stimulus type 4 times. For each condition, each block has a different stimulus order. The first trial in each block differs within condition. The same order of stimuli does not repeat within one order.

Data Experiment 1

SID	group	change	new	old	new.old	new.change	old.change	pref	abs.new.old	abs.new.change	abs.old.change	CDIrec	CDIprod
31MW	C7	1641	2384	2846	-462	743	1205	fam	462	-743	-1205	10	1
45SvtB	C12	1108461538	4271333333	1285966667	-8588333333	3162871795	1175120513	fam	8588	-3163	-11751	13	2
41IL	C10	5503.75	2189	2048222222	1407777778	-3314.75	-3455527778	nov	141	-3315	-3456	24	6
44SK	C12	1418666667	2051333333	2258111111	-2067777778	6326666667	8394444444	fam	207	-633	-839	26	3
12SV	C3	3605.6	5878	7608	-1730	2272.4	4002.4	fam	1730	-2272	-4002	32	6
37MF	C9	6003333333	2904.2	1932375	971825	-3099133333	-4070958333	nov	972	-3099	-4071	33	3
28VV	C5	1484.4	1764142857	1007181818	756961039	2797428571	-4772181818	nov	757	280	-477	37	1
34	C8	2595	6128875	4787666667	1341208333	3533875	2192666667	nov	1341	3534	2193	39	15
15EJ	C4	9783	7009333333	8741666667	-1732333333	-2773666667	-1041333333	fam	1732	2774	1041	41	5
17HR	C5	9649.75	6457.8	3792333333	2665466667	-3191.95	-5857416667	nov	2665	-3192	-5857	43	20
11BB	C3	4476.5	7345	1322766667	-5882666667	2868.5	8751166667	fam	5883	-2869	-8751	48	20
38LJ	C10	3000.25	2784.8	3092.25	-307.45	-215.45	92	fam	307	215	-92	53	9
5MH	C2	1784966667	6781833333	7764.8	-9829666667	-1106783333	-1008486667	fam	983	11068	10085	53	13
33QvR	C8	8724666667	4456571429	2541166667	1915404762	-4268095238	-6183.5	nov	1915	-4268	-6184	56	28
6LV	C2	5652166667	6582333333	7652333333	-1070	9301666667	2000166667	fam	1070	-930	-2000	61	12
35	C9	2252.6	5309666667	1989285714	3320380952	3057066667	-2633142857	nov	3320	3057	-263	68	33
27PZ	C4	8008.6	13942	10996	2946	5933.4	2987.4	nov	2946	5933	2987	75	26
32TT	C7	4583	2567583333	6058428571	-3490845238	-2015416667	1475428571	fam	3491	2015	-1475	80	25
53LJ	C6	6186166667	3708.2	9727.25	-6019.05	-2477966667	3541083333	fam	6019	2478	-3541	100	47
49WK	C11	6793.75	3048666667	4667	-1618333333	-3745083333	-2126.75	fam	1618	3745	2127	111	41
42JV	C11	1202692308	2616333333	3056.2	-4398666667	1413641026	1853507692	fam	440	-1414	-1854		
2SN	C1	5658666667	7189.25	4432	2757.25	1530583333	-1226666667	nov	2757	1531	-1227		
4PO	C1	1240733333	12893	4322666667	8570333333	4856666667	-8084666667	nov	8570	486	-8085		
52CB	C6	7043.8	7404333333	5245571429	2158761905	3605333333	-1798228571	nov	2159	361	-1798		

Data Experiment 2

SID	group	change	new	old	new.old	new.change	old.change	pref	abs.new.old	abs.new.change	abs.old.change	CDIrec	CDIprod
7L M	C2	2491375	3232.75	2038111111	1194638889	741375	-4532638889	nov	1194638889	741375	-4532638889	4	2
16RK	C4	2224	1090222222	4898235294	6003986928	-1133777778	-1734176471	nov	6003986928	-1133777778	-1734176471	5	2
24ML	C6	1119.5	1036375	2023857143	-9874821429	-83125	9043571429	fam	9874821429	83125	-9043571429	10	0
5MD	C2	4697333333	3808.25	4972	-1163.75	-8890833333	2746666667	fam	1163.75	8890833333	-2746666667	10	2
23MM	C6	5718.25	1625714286	1020.6	6051142857	-4092535714	-4697.65	nov	6051142857	-4092535714	-4697.65	20	7
3MM	C7	2068.25	1802	3343	-1541	-266.25	1274.75	fam	1541	266.25	-1274.75	20	7
2SS	C1	1045566667	1691875	2510333333	-8184583333	-8763791667	-7945333333	fam	8184583333	8763791667	7945333333	21	12
11IS	C3	2232	3690.2	2089857143	1600342857	1458.2	-1421428571	nov	1600342857	1458.2	-1421428571	26	8
21RdW	C11	1496	3895333333	5286.4	-1391066667	2399333333	3790.4	fam	1391066667	-2399333333	-3790.4	28	7
22LdW	C11	4196833333	4579857143	3377428571	1202428571	3830238095	-8194047619	nov	1202428571	3830238095	-8194047619	29	0
12TV	C3	2110555556	4058.8	2916.5	1142.3	1948244444	8059444444	nov	1142.3	1948244444	8059444444	31	5
19JM	C5	3168666667	2492714286	1888.8	6039142857	-675952381	-1279866667	nov	6039142857	-675952381	-1279866667	33	6
13IvdW	C9	5246.75	3777	7212333333	-3435333333	-1469.75	1965583333	fam	3435333333	1469.75	-1965583333	35	4
26LdH	C12	2498.2	9981538462	2952666667	-1954512821	-1500046154	4544666667	fam	1954512821	1500046154	-4544666667	35	16
8QW	C8	3657.5	4397	3600333333	7966666667	739.5	-5716666667	nov	7966666667	739.5	-5716666667	36	5
17BN	C10	3487666667	4149333333	2669125	1480208333	6616666667	-8185416667	nov	1480208333	6616666667	-8185416667	39	8
25TK	C12	6153666667	6680	3979857143	2700142857	5263333333	-2173809524	nov	2700142857	5263333333	-2173809524	43	10
14RL	C9	3882	4169	4828333333	-6593333333	287	9463333333	fam	6593333333	-287	-9463333333	48	11
18AA	C10	10802.75	1380866667	5201	8607666667	3005916667	-5601.75	nov	8607666667	3005916667	-5601.75	50	17
28MK	C5	1272533333	7183333333	10039	-2855666667	-5542	-2686333333	fam	2855666667	5542	2686333333	50	33
51MS	C1	5841.6	3533090909	4865.2	-1332109091	-2308509091	-976.4	fam	1332109091	2308509091	976.4	58	16
10SH	C8	6509.6	6415.2	3349.25	3065.95	-94.4	-3160.35	nov	3065.95	-94.4	-3160.35	59	17
4FM	C7	1776166667	3864444444	2524.2	1340244444	2088277778	7480333333	nov	1340244444	2088277778	7480333333	63	32
15rv	C4	3894545455	1602714286	4110375	-2507660714	-2291831169	2158295455	fam	2507660714	2291831169	-2158295455	72	6