**Infant recognition of Hebrew vocalic word patterns**

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**Abstract**

The ability of infants to recognize phonotactic patterns in their native language is widely acknowledged. However, the specific ability of infants to recognize patterns created by nonadjacent vowels in words has seldom been investigated. In Semitic languages such as Hebrew, groups of multisyllabic words are identical in their nonadjacent vowel sequences and stress position but differ in the consonants interposed between the vowels. The goals of the present study wereto assess whether infants learning Hebrew show a preference for 1) a nonadjacent vocalic pattern or template, common in Hebrew nouns (CéCeC), over a non-attested nonadjacent vocalic pattern (CóCoC) and 2) a nonadjacent vocalic pattern common in Hebrew words (CaCóC) over an existing but less common pattern (CaCéC). Twenty Hebrew-learning infants aged 8 to 11 months were presented with lists of nonsense words featuring the first two patterns (Experiment 1) and 20 were presented with nonsense words featuring the second two patterns (Experiment 2). The results showed longer listening to CéCeC than to CóCoC lists and to CaCóC than to CaCéC lists, suggesting that infants recognized the common non-adjacent vocalic patterns in both cases. The study thus demonstrates that Hebrew-learning infants are able to disregard the intervening consonants within words and generalize their vocalic pattern to previously unheard nonwords, whether this pattern includes identical or different vowels and regardless of the rhythmic pattern of the word (trochaic or iambic). Analysis of the occurrence of the relevant vowel patterns in input speech in three Hebrew corpora (two addressed to children and one to adults) suggests that the exposure to these patterns in words underlies the infants’ preferences.

**Introduction**

The purpose of this study is to assess the distributional learning of nonadjacent vowel sequences by infants learning Hebrew. Although the fact that infants can generally recognize phonotactic and accentual regularities of the spoken language is widely acknowledged (e.g., Gonzalez-Gomez & Nazzi, 2012; Jusczyk, Cutler & Redanz 1993; Mattys, Jusczyk, Luce & Morgan, 1999; Thiessen & Saffran, 2007), the recognition of patterns created by nonadjacent vowels has seldom been tested. The importance of establishing such recognition is twofold. First, in many Semitic languages groups of multisyllabic open class words are similar in their vowel patterns and stress position but differ in the consonants that are intercalated across the word. Thus, in these languages recognition of similar sequences of nonadjacent vowels would support segmentation of words from fluent speech by creating a bias towards segmenting, learning and remembering units with such sequences and stress patterns (e.g., Arciuli & Cupples, 2004). Second, recognizing frequent combinations of nonadjacent vowels across words requires a unique process of generalization that operates on the phonological representation of the word as a whole, since ordering between nonadjacent vowels is meaningful only within the framework of the word and its stress pattern. Moreover, in order to recognize recurring nonadjacent vowels in words the infant has to disregard the intervening consonants. Such a word-level generalization process in infants has so far been tested mainly for consonants (Gonzalez-Gomez & Nazzi, 2012).

Numerous studies suggest that infants use implicit distributional or statistical learning to recognize common regularities in speech (Maye, Werker & Gerken, 2002; Saffran, Aslin & Newport, 1996). Infants have been found to recognize regularities in their native language at the segmental as well as the word level, including phonotactic patterns (or permissible segmental sequences) and common stress placement in words. Specifically, 9-month-old English-learning infants have been found to show a preference for segmental sequences that are common in their native language. For example, Jusczyk, Friederici, Wessels, Svenkerud & Jusczyk(1993b) tested English and Dutch-learning 6- and 9-month-old infants with two- or three-syllable English and Dutch words. Most words contained segmental sequences that were illegal in one of the two languages. It was found that 9-month-olds, but not 6-month-olds, listened longer to words made up of legal sequences in their native language. Furthermore, by 9 months infants listen longer to monosyllabic nonwords containing high-probability phonotactic sequences than to nonwords containing low-probability phonotactic sequences (Jusczyk, Luce, & Charles-Luce, 1994). In another study (Mattys et al, 1999, Exp. 1) 9-month-olds exposed to English were presented with CVC.CVC trochaic words in which the medial consonant cluster had a high or low probability of occurring within words. The study found that 9-month-old infants attended longer to lists that contained high probability within-word clusters, suggesting that infants recognized the common sequences of consonants that may appear within words.

Studies of the recognition of stress position at the word level suggest language-specific distributional learning. Between 6 and 9 months of age infants develop recognition of the dominant word-stress pattern of their native language (Höhle, Bijeljac-Babic, Herold, Weissenborn & Nazzi 2009, for German; Jusczyk et al., 1993a, and Turk Jusczyk & Gerken 1995, for English; Pons & Bosch, 2010, for Spanish). For example, Jusczyk et al. (1993a) found that English-learning 9-month-old (but not 6-month-old) infants listened longer to lists of words with the dominant trochaic (strong-weak) stress pattern of English than to a list of iambic (weak-strong) words. A similar effect was found for 6-month-old German-learning infants (Höhle et al., 2009). Nine-month-old Spanish-learning infants showed a listening preference for the more frequent trochaic stress pattern only in CVC.CV structures, reflecting the close interaction of syllable weight and accent in Spanish (Pons & Bosch, 2010). Recently, Segal and Kishon-Rabin (2012) provided evidence from Hebrew, an iambic language whose characteristic rhythm is an alternation of stressed and unstressed syllables, but without vowel reduction (Bolozky, 1982). The data from Hebrew show that 9-month-old Hebrew-learning infants listen longer to lists of words with the dominant iambic pattern than to words with the less common trochaic pattern. (In contrast, evidence from infants learning French, in which accent is not word- but phonological-phrase-based, suggests that 6-month-olds show no preference for either *strong-weak* or *weak-strong* stress patterns: Höhle et al, 2009). Taken together, these findings support the notion of emergent language-specific distributional learning leading to a preference in infants for the common stress pattern of their language, whether it is trochaic or iambic.

Until recently studies concerned with phonotactic learning focused mainly on the ability of infants to recognize common sequences of adjacent segments. However, the recognition of nonadjacent segments – that is, consonants separated by vowels or vowels separated by consonants within words – has been investigated less often. The recognition of nonadjacent segments might be difficult for infants because it involves the ability to detect, remember and generalize a pattern of nonadjacent dependencies (Gomez & Maye, 2005). Limited information is now available on the ability of infants to recognize common nonadjacent segments, specifically consonants (Gonzalez-Gomez & Nazzi, 2012; Nazzi, Bertoncini & Bijeljac-Babic, 2009). At 10 months of age French-learning infants showed a preference for disyllabic words containing a Labial-Coronal sequence (e.g., *beta*) over words containing a Coronal-Labial sequence (e.g., *tuba*), and for monosyllabic Labial-Coronal sequences (e.g., *bad* ) over words containing a Coronal-Labial sequence *(dab*). (Gonzalez-Gomez & Nazzi, 2012; Nazzi, Bertoncini & Bijeljac-Babic, 2009). Furthermore, infants learning French were able to segment Labial-Coronal sequences (nonwords, e.g., *pid*) from running speech at 10-months, but Coronal-Labial sequences (e.g., *dip*) only at 13 months of age, suggesting that common sequences of nonadjacent segments can serve as a cue for word segmentation in 10-month-olds (Gonzalez-Gomez & Nazzi, 2013) and also influence early word-learning (Gonzalez-Gomez, Poltrock, & Nazzi, 2013).

The results of studies with nonadjacent *consonants* raise the question whether infants can recognize nonadjacent sequences of *vowels* as well. To our knowledge, only one study has investigated the ability of infants to detect non-adjacent vowel sequences within words. Turkish (but not German) words have vowel harmony, that is, phonological constraints on within-word vowel sequences. For example, within-word vowels must all be either front or back. Van Kampen, Parnakzis, van de Vijer and Höhle (2008) found that 6-month-old infants learning Turkish show a listening preference for nonwords with vowel harmony (e.g., *paroz)* over nonwords that violate vowel harmony (e.g., *nelock*), whereas 6-month-old infants learning German show no such preference.

The study of infant recognition of nonadjacent sequences of *vowels* is related to a broader debate on the role of consonants and vowels in speech processing and language acquisition, which has been investigated mainly in Germanic and Romance languages (e.g., Nespor, Peña & Mehler, 2003). It has been suggested that consonants are more informative than vowels for word segmentation and identification, whereas vowels may be more informative for identifying morphosyntactic properties of the language, including its rhythmic class, and prosodic information (Nespor et al, 2003; Sharp, Scott, Cutler & Wise, 2005; Van Ooijen, 1996). For example, it was found that adult French listeners utilized transitional nonadjacent probabilities between consonants but not between vowels for word segmentation from continuous speech (Bonatti, Peña, Nespor & Mehler, 2005). It has also been found that when Spanish and Dutch adult speakers had to change non-words into words they tended to change the vowels and not the consonants, suggesting that vowels constrain lexical selection less tightly than consonants (Cutler, Sebastian-Galles, Soler-Vilageliu, & Van Ooijen, 2000). Studies with French and English toddlers also suggest some advantage for consonants over vowels in making words more distinct during word learning. French-learning 20-month-old toddlers showed reduced ability to learn new words when the words differ by a vowel (e.g., /*duk*/-/*dok*/) as compared to when the words differ by a consonant (e.g., /*pize*/-/*tize*/) (Nazzi, 2005; Nazzi & New, 2007). Thirty-month-old French- and English-learning infants preferred to match a target object (e.g., /*duk*/) to an object labeled with a changed or ‘mispronounced’ vowel (e.g., /*dok*/) over an object labeled with a mispronounced consonant (e.g., /*guk*/). In other words, toddlers disregarded a change in the vowel but not in the consonant (Nazzi, Floccia, Moquet & Butler, 2009).

These findings suggest that vowels play a less important role than consonants in lexical learning and recognition. Yet in situations that do not involve segmenting or recognizing individual word forms but instead require making generalizations about word structure, infants and adults appear to rely more on vowels (e.g., Hochmann, Benavides-Varela, Nespor & Mehler, 2011; Pons & Toro, 2010). For example, when 11-month-old infants learning Spanish were presented with a series of CVCVCV nonsense words in which all vowels were arranged according to an AAB rule (first and second vowels the same, third vowel different), they showed a listening preference for this pattern in novel nonsense words in the test phase, suggesting that they had learned the rule. When a change in consonants was involved, however, infants did not learn the rule (Pons & Toro, 2010). In summary, although there is some evidence to suggest that infants can learn structural rules based on vocalic sequences, it is unknown whether infants learning Semitic languages actually make use of this ability in naturalistic learning situations outside the lab; such learning would allow them to recognize more versus less common vocalic patterns.

*The role of vowel patterns in Hebrew morphology*

Word-internal vowel sequences do not play a phonological role in Germanic and Romance languages (although vowel harmony is reported for some dialects and for other European languages, such as Finnish, Hungarian and Turkish). However, in Semitic languages such as Hebrew the lexicon is made up of several groups of mainly disyllabic words characterized by a set sequence of vowels separated by consonants (Berman, 1978, 1987; Glinert, 1989). This unique lexical structure, which stems from the organization of Hebrew morphology, provides an opportunity to test whether pre-linguistic Hebrew-learning infants recognize common sequences of nonadjacent vowels.

Hebrew morphology includes two main types of word formation: root-and-pattern Semitic forms and concatenated linear structures. These two types have been termed ‘non-linear morphology’ and ‘linear morphology’, respectively (Berman, 1987; Blau 1971, Bolozky 1997). Non-linear morphology is exclusive to the Semitic languages, including the Arabic languages, Amharic, Tigrinya, Aramaic and Modern Israeli Hebrew, to mention some of the languages spoken today. It is based on the combination of root and phonological template (pattern) in a word. The root usually consists of three consonants, which express the semantic core of the word. The pattern is a phonological template, which includes both a vowel sequence and stress, and in some cases additional non-root consonantal affixes (Berman, 1987). For example, the root ʃ-l-t ‘control, rule’ is associated with /ʃalat/ ‘rule/control-3rd-person-sg-past’, /ʃlitá/ ‘control’ (verbal noun or gerund), /ʃilton/ ‘rule, government’, /ʃtaltan/ ‘domineering, bossy’, /ʃlat raxok/ ‘remote control’. While all the words in the above examples share the consonantal skeleton ʃ-l-t, they differ in their pattern (vowel sequence and position of stress as well as affixes). The phonological template or pattern serves as a primary lexical word-formation device (Berman, 1987, Ravid, 1990). The meaning of the core root (e.g., ʃ-l-t) is expanded and changed through combination with the phonological vocalic patterns, creating various words related through their shared core meaning but which differ in degree of abstraction and metaphoric associations.

While a root may be intertwined with different patterns, a single pattern may also extend to different roots. Thus, different words built around the same phonological template or pattern will differ only in their root consonants. For example, the words /kéʃer/ 'knot', /séfer/ 'book' /dérex/ 'road' /régel/ 'foot', /bérex/ 'knee', /béten/ 'belly' are all formed with the phonological template CéCeC, a highly frequent form for masculine nouns. Similarly, the words /koʃér/ ‘tie-masc-sg-pres’, /sofér/ 'count-masc-sg-pres', /doréx/ 'step on-masc-sg-pres' share the phonological template CoCéC, a frequent form for verbs inflected in the masculine singular present tense as well as for some types of nouns (e.g. /sofér/ 'writer'). Specifically, there are a set number of vowel-and-stress patterns for nouns and adjectives (termed *mishkalim*)and a set number of vowel-and-stress patterns for verbs (*binyanim*). These phonological patterns create the surface forms of the morphological system (Blau 1971, Bolozky, 1978, 1982, 1997; Ravid, 2006; Ravid & Malenky, 2001; Ravid & Schiff, 2006). It should be noted, however, that neither root nor pattern is pronounceable on its own, nor does either have a specific meaning or lexical status as a word.

Taking into consideration the fact that infants recognize common accentual and phonotactic patterns of their native language (e.g., in English, Spanish, Dutch), as well as common sequences of nonadjacent consonants (in French), might Hebrew-learning infants recognize common vocalic patterns? If so, this would suggest that infants are able to recognize the recurring sequences of a vocalic template within a stress unit while disregarding the varied consonants of the root. Answering this question will shed light on the potential role of vowels in speech processing.

*Selection of vowel patterns for testing*

The purpose of the present study is to assess, in two experiments, whether Hebrew-learning infants recognize common phonological templates, as compared to non-existent or less common ones. The choice of common and less common patterns to test was based on detailed analysis of Berman’s large corpus of Hebrew Child Directed Speech (CDS): 228,948 word tokens (68,006 bi-syllabic) over a total of 392 sessions recorded longitudinally one hour per week at the homes of four middle-class families, addressed to four children aged 1;5-3 years (3 girls) (CHILDES, MacWhinney, 2000; Hebrew1 in Appendix 3).

Two common phonological templates were chosen: (a) CaCóC, the most widespread phonological template in Hebrew disyllabic words (9% of all such words, including open- and closed-class items, and 30.9% of all CVCVC tokens, with 90 different word types in the dataset analysed), and b) CéCeC, a widespread phonological template in Hebrew disyllabic words (3.43% of all such words and 11.32% of all CVCVC tokens, with 77 different word types), primarily nouns (about 14% of all disyllabic nouns).[[1]](#footnote-1) In addition, to test recognition of existing vocalic patterns versus non-existing or less common vocalic patterns we chose one vocalic template that does not occur in Hebrew words, CóCoC, and one vocalic pattern which does occur but which is less frequent, CaCéC (about 1% of all Hebrew disyllabic words in terms of tokens, with 41 different word types). Thus, the choice of the four templates (CéCeC, CaCóC, CóCoC, CaCéC) was guided by the intention to include a) vocalic templates with both trochaic (CéCeC, CóCoC) and iambic (CaCóC, CaCéC) stress patterns, b) templates with repeated vowels (CéCeC, CóCoC) as well as with different vowels (CaCóC, CaCéC), c) vowels with similar vowel height (/e/, /o/), and d) templates in which the vowels (but not the vowel sequence) have similar distribution in CDS. The trochaic templates 'CéCeC' and 'CóCoC' were tested in the first experiment, the iambic templates 'CaCóC' and 'CaCéC' in the second experiment.

The distribution of Hebrew vowels in CDS is presented in Table 1. Here it can be seen that, taking vowel height and backness as well as frequency into consideration, the most suitable pair of vowels for comparison is /e/ and /o/.[[2]](#footnote-2) However, because the frequency of /e/ is somewhat higher than that of /o/ it was important to test not only CéCeC vs. CóCoC templates, with a single repeated vowel, but also CaCóC and CaCéC templates: This allowed us to control for vowel frequency. We argued that if infants recognize the more frequently occurring template in each of the pairs (CéCeC in the first pair, CaCóC in the second), then they must be basing their recognition on the nonadjacent vowel sequence regardless of the frequency of the individual vowels (/o/ vs. /e/), because in the first pair the common template also contains the more frequently occurring vowel /e/, whereas in the second, iambic pair, the more frequently occurring template contains the less frequently occurring vowel (/o/).

Table 1. Frequency of occurrence of vowels (and % of total) in Hebrew CDS, based on 228,948 word tokens (including open class words, names, affective expressions) and 412,132 vowels.

|  |  |  |  |
| --- | --- | --- | --- |
| Vowel  | Frequency in strong syllables | Frequency in weak syllables | Total frequency  |
| /a/ | 48887 (11.86) | 126094 (30.59) | 174981 (42.45) |
| /e/ | 26771 (6.49) | 67747 (16.43) | 94518 (22.93) |
| /i/ | 23757 (5.76) | 41542 (10.07) | 65299 (15.85) |
| /o/  | 21781 (5.28) | 39453 (9.57) | 61234 (14.85) |
| /u/ | 4931 (1.19) | 11169 (2.71) | 16100 (3.90) |

In summary, the four templates chosen for the present study included two pairs: a) a common template in Hebrew nouns vs. a template that does not occur in Hebrew words (CéCeC vs. CóCoC, respectively) and b) a common vs. a less common template in Hebrew open class words (CaCóC and CaCéC, respectively).

Experiment 1 tested whether 8-11-month-old Hebrew-learning infants show a greater attentional response to the common trochaic phonological template CéCeC than to a phonological template that does not occur in Hebrew words, CóCoC (although the /o/ is frequent in other sequences: see Table 1). Experiment 2 tested whether 9-11-month-old Hebrew learning infants show a greater attentional response to the common iambic template CaCóC than to the less common template CaCéC.

**Experiment 1**

**Method**

**Participants**

Twenty full-term monolingual infants were included in the study; an additional four infants were excluded from the study because of restlessness. The ages of the 20 infants ranged from 8;10 (months: days) to 10;27 (*M* = 10;03; *SD* = 0.76). All infants (12 girls) were native Hebrew language learners, and Hebrew was the only language spoken regularly by their primary caregivers. Inclusion criteria for the infants were: (1) full-term, (2) normal development and hearing as reported by a developmental questionnaire and well-baby clinics, (3) score within 2 standard error (*SE*) of normal auditory and production functioning on the Infant Toddler Meaningful Auditory Integration Scale (ITMAIS) (Robbins, Koch, Osberger, Zimmerman-Phillips, & Kishon-Rabin, 2004) and Production Infant Scale Evaluation (PRISE) (Kishon-Rabin, Taitelbaum-Swead, Ezrati-Vinacour, & Hildesheimer, 2005; Kishon-Rabin, Taitelbaum-Swead, & Segal, 2009), and (4) parents reporting no more than two ear infections during the last 6 months and no upper respiratory infections (including ear infection) on day of testing. Infants were recruited via advertisements on the internet and families were paid for their participation.

 **Stimuli**

 Twenty-eight disyllabic nonwords were constructed for the present experiment. The words were based on 14 consonantal roots that do not exist in Hebrew. Each root included 3 consonants. For each root two nonwords were constructed, one with the CéCeC template (e.g., *bédet*), and one with the CóCoC template (e.g., *bódot*). Overall, the stimuli included 14 nonwords with the morphophonological template CéCeC and 14 matched nonwords with the morphophonological template CóCoC (see Appendix 1). The nonwords were judged as unfamiliar by five native Hebrew speakers.

 Stimuli were digitally recorded in a soundproof room via a JVC MV 40 microphone using Sound-Forge software (version 4.5a) and stereo channels, at a sampling rate of 48,000Hz and 16-bit quantization level. In order to prevent intensity differences between words, amplitudes were normalized. The mean length of the 14 CéCeC nonwords was 751.71 ms (*SD* = 75.37) and that of the 14 CóCoC nonwords was 792.57 (*SD* = 76.62) (difference *ns*, p =0.83). From the 28 different tokens 16 files were created: eight files with the 14 CéCeC words and eight with the 14 CóCoC words, with differing internal word orders and 500-ms silent inter-token intervals. The mean duration of the final audio files was 18.16 sec, *SD* = 0.16 (range 17.98 to 18.49) for the CéCeC files and 18.29 sec, *SD* = 0.22 (range 18.00 to 18.47) for the CóCoC files (the difference in duration between the two types of lists was not significant, p = 0.78).

**Apparatus**

The central fixation preference procedure (Cooper & Aslin, 1990; Houston, Pisoni, Kirk, Ying & Miyamoto, 2003) took place in a sound-proof booth adjacent to a control room. The booth had a large 50" wide-aspect TV monitor with two loudspeakers and a video camera mounted above the monitor. The camera recorded the orientation of the infant’s eyes and the experimenter viewed the session via a video monitor outside the booth. Gray curtains hung from the ceiling to block the infant’s view of the rest of the room and reduce distractions. The control room included a 23" monitor for observing the infant’s responses and a Macintosh G5 personal computer that presented the auditory stimuli to the loudspeakers through an amplifier. The experiments were controlled by the computer (including order of presentationand recording of the infant's response, which was keyed in by the experimenter), using HABIT (Cohen, Atkinson, & Chaput, 2000).

**Procedure**

The infant sat on the caregiver's lap in front of the monitor. The experimenter sat outside the booth in the control room. Both caregiver and experimenter listened to music with masking babble noise over headphones and were therefore unaware of the nature of the stimulus on any particular trial. All trials began by drawing the infant's attention to the TV monitor, using an attention getter (e.g., a small dynamic video display of a laughing baby’s face: see Houston et al, 2003; Segal & Rabin, 2011).

Experimental sessions consisted of 16 trials: 8 trials presented CéCeC nonwords and 8 presented CóCoC nonwords. Each infant first completed a four-trial familiarization phase. This phase consisted of two trials of each type (CéCeC, CóCoC). The purpose of the familiarization trials was to acquaint the infants with the procedure. After the familiarization phase, a 12-trial test phase was conducted. The order of presentations was quasi-random with no more than two trials in a row of the same type of phonological template.

During the trials a visual display (red and white static checkerboard) was presented on the TV monitor. The trials continued until the infant looked away for 2s or more or until the end of the trial. If the infants looked away for less than 2s, the trial continued but the looking-away time was not included in the length of look. The experimenter observed the infant via the footage transmitted from the video camera to the control-room monitor and coded the duration of the infants’ gaze towards the visual display by pressing keys on the computer keyboard. The duration of the infant’s gaze toward the checkerboard was measured for each trial. Stimuli were presented to the infants via loudspeakers at a comfortable level (65 dB SPL). It was predicted that if infants recognised the CéCeC template, they would look longer to the visual display during the CéCeC trials than during the CóCoC trials.

All infant responses were videotaped for later validation (offline) by a second experimenter. Offline measures for each test trial were conducted by a graduate student from the Communication Disorders Department at Tel-Aviv University, who evaluated infant looking times on the basis of frame-by-frame observation using the digitized video software Supercoder (frame rate = 1/30 sec). She could not hear the stimuli and was naïve to the purpose of the study. Persuasive agreement was found between the online and offline evaluations for both the CéCeC (*r* = 0.94) and the CóCoC (*r* = 0.95) trials. The procedure was approved by the Helsinki ethical committee, Ministry of Health, Israel.

**Results and Discussion**

The average looking times on the CéCeC and CóCoC trials are shown in Figure 1. The infants looked significantly longer in response to CéCeC nonwords (*M* = 5.37 sec, *SD* = 1.63) than to CóCoC nonwords (*M* = 4.73 sec, *SD* = 1.30), based on a two-tailed paired t-test [*t* (19) = 3.18, *p* = 0.005; *d* = 0.72][[3]](#footnote-3). Closer observation of the individual data showed a preference for CéCeC words for 16 of the 20 infants (p = .012, binomial two-tailed test).The differences in looking time between CéCeC and CóCoC nonwords for each infant are shown in Figure 2.

**[**INSERT FIGURES 1 AND 2 ABOUT HERE]

The results of Experiment 1 suggest that 8- to 11-month-old infants learning Hebrew show a preference for the more common vocalic template in Hebrew words (CéCeC) compared to a non-occurring vocalic template (CóCoC). However, it remains unclear whether the preference shown by infants for CéCeC over CóCoC nonwords is the result of a bias toward the more common vocalic template CéCeC or, alternatively, a reflection of the infants’ preference for the more frequently occurring /e/ vowel compared to the less frequently occurring /o/ vowel (See Table 1). Thus, the results of the first study could result from infants attending to only one vowel in the sequence. Accordingly, the second study was designed to further examine these issues using the vocalic templates CaCóC and CaCéC. If infants' preference is based on the first vowel, then we assume that they would show no preference for one template over the other in this case because CaCóC and CaCéC have the same initial vowel. Alternatively, if infants' preference is based on the second vowel, they might prefer the CaCéC template over the CaCóC template because the vowel /e/ is more frequent in Hebrew words overall. However, if infants' preference is based on recognizing more frequently occurring vowel *sequences* within words, then they will prefer the more frequently occurring vocalic sequence in CaCóC over the less frequently occurring one in CaCéC. Note that these predictions, all of which assume that longer looks will be elicited by the familiar stimuli, rest on the results of Experiment 1, which show a clear preference for the familiar over the unfamiliar pattern (or vowel).

**Experiment 2**

**Method**

**Participants**

Twenty full-term monolingual infants were included in the study. Five additional infants were excluded because of restlessness (n = 3) or crying (n = 2). The infants’ ages ranged from 9;10 to 11;05 (*M* = 10;09, *SD* = 0.72). All infants (9 girls) were learning Hebrew, the only language spoken regularly by their caregivers. Inclusion criteria, recruitment methods and payments to participants were the same as for Experiment 1.

**Stimuli**

 Twenty-eight disyllabic nonwords were constructed for the present experiment, based on the same 14 consonantal roots as in Experiment 1. For each root two nonwords were constructed, one with the CaCóC template (e.g., *badót*), one with the CaCéC template (e.g., *badét*). Overall, the stimuli included 14 nonwords with the morphophonological template CaCóC and 14 matched nonwords with the morphophonological template CaCéC (see Appendix 1). The words were judged as unfamiliar by 5 native Hebrew speakers.

 Stimuli were digitally recorded and normalized as described for Experiment1.

 The mean length of the 14 CaCóC nonwords was 713.21 ms (*SD* = 65.08), which was not significantly different (*p* = 0.81) from that of the 14 CaCéC nonwords, 717.50 ms (SD = 69.00). From the 28 different tokens 16 files were created, eight with the 14 CaCóC nonwords and eight with the 14 CaCéC nonwords. The nonwords in each file had a different order. The mean duration of the final audio files was 17.43 sec, *SD* = 0.16 (range 17.3 to 17.5), for CaCóC files and 17.40 sec, *SD* = 0.21 (range 17.18 to 17.84), for CaCéC files (the difference was not significant, *p* = 0.76).

**Apparatus and Procedure**

The apparatus and procedure were identical to those of Experiment 1. The experimental sessions consisted of a four-trial familiarization phase followed by 12 randomly presented trials, eight for CaCóC nonwords and eight for CaCéC nonwords. High agreement was found between the online and offline evaluations for both the CaCóC (*r* = 0.95) and the CaCéC (*r* = 0.96, *p* = 0.01) trials.

**Results and Discussion**

The average looking times on the CaCóC and CaCéC trials are shown in Figure 3.The infants looked longer in response to CaCóC than to CaCéC nonwords. Paired t-tests confirmed that looking time for CaCóC sequences (*M* = 5.26 sec, *SD* = 1.66) was significantly longer than for CaCéC sequences (*M* = 3.90 sec, *SD* = 1.30) [*t* (19) = 3.23, *p* = 0.004; *d* = 0.72][[4]](#footnote-4). Closer observation of the individual data showed a preference for CaCóC words for 17 of the 20 infants (p = .003, binomial two-tailed test). The differences in looking times for each infant are shown in Figure 4.

**[**INSERT FIGURES 3 AND 4 ABOUT HERE]

The results of Experiment 2 show that 9- to 11-month-old infants learning Hebrew demonstrate a listening preference for the vocalic template that occurs more frequently in Hebrew words (CaCóC) compared to a vocalic template that occurs less frequently in words (CaCéC).

Together with the results of Experiment 1, then, the present results suggest that infants learning Hebrew are sensitive to the relative frequency of nonadjacent vocalic templates in Hebrew speech already within the first year of life. Furthermore, the findings of the two experiments suggest that infants did not base their preference on the more frequent vowel (/e/) compared with the less frequent vowel (/o/) but on the specific non-adjacent vowel sequences /é – e/ (Exp. 1) and /a – ó/ (Exp. 2).

**General Discussion**

The goal of the present study was to explore the recognition of nonadjacent vowel sequences in words in infants learning Hebrew. To this end we assessed 8- to 11-month-old infants on their listening preference for a) a common phonological template in Hebrew nouns (CéCeC) over a non-occurring phonological template (CóCoC), and b) a common phonological template in Hebrew open class words (CaCóC) over a less common phonological template (CaCéC). In addition, because in Hebrew the iambic template is more frequent than the trochaic one(Segal et al, 2009), it was important to test whether or not the recognition of vocalic templates is tied to a specific stress pattern, iambic or trochaic. The present study provides evidence that 8- to 11-month-old infants are able to recognize frequently occurring nonadjacent vowel sequences in both trochaic and iambic words, whether the nonadjacent vowels are identical or not.

The evidence of infant preference for the vocalic sequences that occur more frequently in words raises the question whether this preference is based on learning (i) the vowel sequences in individual disyllabic words or (ii) frequent vowel sequences in running speech, whether these occur within or between words. In order to shed light on this issue we analyzed the distribution of the nonadjacent vowel sequences targeted in this study, with different stress positions, in 804 utterances (1019 word tokens) of child-directed speech taken from the Berman longitudinal corpus in CHILDES. MacWhinney, 2000: Hebrew2).[[5]](#footnote-5) The utterances were recorded over the course of five sessions (totaling four hours) with two children (one boy aged 17 to 19 months and one 19-month-old girl). The utterances were produced by eight different adults – two mothers, two fathers, two grandmothers, an aunt and a family friend – and were all addressed to the children. A total of 2359 Hebrew word tokens (3938 syllables) were analyzed. The results are summarized in Appendix 2a.

We found that the /e - e/ sequences are more frequent than the /o - o/ sequences (in both types and tokens), regardless of stress position, both within- and between words.[[6]](#footnote-6) Thus, it can be argued that the preference found for CéCeC over CóCoC does not necessarily support recognition of within-word sequences but only recognition of the more frequent nonadjacent sequence in the language in general. However, since infants are sensitive not only to vowel sequences but also to stress position (Jusczyk & Thompson, 1978; Sansavini, Bertocini & Giovanelli 1997; Spring & Dale, 1977), they might base their preference for CéCeC over CóCoC sequences on familiarity with the sequence /é - e/, with stress on the first syllable. Since this sequence appears much more often within than between words, recognition of the nonadjacent sequence /é – e/ in running speech would serve as an efficient cue for word segmentation.

For the second experiment we analyzed the distribution of nonadjacent /a - o/ and /a - e/ sequences within and between words. The results of this analysis are more complex. The analysis reveals that, taken together (within- plus between-word sequences, regardless of stress position), the frequency of /a - e/ and /a - o/ sequences is very similar, with /a - o/ sequences more frequent in terms of tokens but less frequent in terms of types. In addition, /a – e/ sequences are more common than /a – o/ between words (in both types and tokens), regardless of the position of stress, whereas within words the reverse is true: /a – o/ sequences are more common, regardless of stress (in tokens; in types the two patterns are more or less equal in frequency). Given the less obvious dominance of one pattern over the other in running speech in terms of types, the question arises as to what the source of the infants’ preference for /a – ó/ could be. In the exemplar literature it is type frequency that is generally thought to be conducive to morphological generalization (e.g., Bybee, 2001). We therefore looked at the distribution of these two vowel sequences in the *individual disyllabic words* addressed to infants (in Hebrew2; note that in the analysis of sequences in running speech, reported in Appendix 2a, we tallied the occurrence of those sequences within words of any length in syllables). The data is presented in Appendix 2b. Here it can be seen that within disyllabic words the vowel sequence /a – o/ is indeed more frequent than /a – e/, regardless of stress position, in either types or tokens. This suggests that infants’ increased familiarity with this phonological structure is based not on tallying the distribution in running speech but on its occurrence in word-sized units of the relevant length in syllables.

A further possibility is also worth considering, however. We have been looking only at Hebrew input to quantify the occurrences of the vowel patterns (or the phonological templates) that we tested. But it may be that these patterns are universally preferred; in other words, our findings may say nothing about infant sensitivity to Hebrew input but merely reflect what is commonly found in any language.[[7]](#footnote-7) In order to test this possibility we compared the input frequency of the vowel patterns of interest here in CDS for three additional languages. We also analysed 701 disyllabic word tokens from one additional Hebrew corpus (the Ravid corpus in CHILDES: Hebrew3), in order to sample a different set of speakers; these utterances were produced by three adults (mother, father, grandfather) and were addressed to a 9-month-old boy and a 23-month-old girl.

For the non-Hebrew corpora we made use of three CDS corpora that were available to us, focusing on just the relevant non-adjacent vowel sequences: instances of (trochaic) /é – e/, /ó – o/ in Italian and Swedish disyllabic words and (iambic) /a – é/, /a – ó/ in French, Italian and Swedish disyllables. We analysed 722 French and 832 Swedish disyllabic word-tokens produced by five mothers per language in the course of one 30-minute recorded interaction in the home with one child each, aged 12 (Swedish) or 13 months (French); for further details see Vihman, Kay, Boysson-Bardies, Durand & Sundberg (1994). (Note that Swedish words with front rounded vowels were excluded from the count of both types and tokens). For Italian we analysed 1424 disyllabic word-tokens produced by five mother-father dyads in the course of one 20-minute recording per family in the observational laboratory of the Department of Psychology, University of Parma, when the children were aged about 15 months (Majorano, Sóskuthy & Vihman, submitted).

We note, however, that a comparison with other languages immediately raises additional questions. Other languages naturally differ in accent type: Swedish disyllables have one of two pitch accents and French disyllables are exclusively ‘iambic’ (due to phrase-final accent), while Italian and Swedish are more variable, although both have stress far more often on the first than on the second syllable of disyllabic words. (Note that English stress, in comparison, involves vowel reduction, so that the relevant patterns are likely to occur only rarely, if at all). Furthermore, vowel systems as a whole differ, with French and Swedish having many more vowel types than Hebrew. This makes the decision as to what should count as equivalent to the Hebrew patterns particularly difficult: A language may have several vowels in the vicinity of the Hebrew /o/, for instance, none of which are phonetically quite like it. Inflectional marking is also an issue: Italian has many nouns ending in –o, a marker of masculine gender (and occasionally a feminine plural in –e), while –e appears in the plurals of nouns and adjectives in Swedish.

The results of the cross-linguistic analysis are summarized in Appendix 3. Here it can be seen that there are differences in the relative distribution of the relevant vocalic patterns in different languages. For example, the pattern **/**é - e**/** is much more frequent than /ó - o/ in Hebrew and Swedish but the opposite is the case in Italian. Similarly, the pattern /a - ó/ is much more frequent than /a - é/ in Hebrew but not in French or Swedish. Thus, the lexical distribution of vocalic patterns differs between languages. On this basis it is plausible to assume that the preference shown in the present study for the more frequent vocalic patterns of Hebrew is related to the distribution of these patterns in input speech rather than being the result of a more general or universal tendency. Note also that differences in stress systems and in vowel systems make a putative universal preference so difficult to define operationally that, in the end, such a preference would necessarily have to refer to language-internal categories or patterns. However, future cross-linguistic studies of infants’ preferences may elucidate to what extent it is specific experience with a given language rather than a universal preference for certain vowel sequences that drives infants' listening preferences.

The results of the present study suggest that the recognition of phonological templates may provide a valuable tool for word segmentation in infants learning Hebrew. Previous studies have already shown that infants recognize and use lexical stress for segmentation (e.g., Jusczyk et al, 1993a; Jusczyk, Houston & Newsome, 1999). Given the results obtained by Segal & Kishon-Rabin (2012), it is likely that Hebrew-learning infants would also be able to recognize and use lexical stress for segmentation. However, the findings of the present study make it clear that infants learning Hebrew recognize not only stress but also phonological patterns commonly found in words. Further studies may be able to show whether the recognition of these common patterns additionally supports segmentation.

The present findings are in agreement with previous studies of the recognition of legal or common phonotactic patterns versus illegal or uncommon phonotactic patterns in English, Dutch, Spanish and Catalan by 9-to-10-month-old infants, in both adjacent (Friederici & Wessels, 1993; Jusczyk et al, 1993b; Jusczyk et al, 1994; Mattys et al, 1999; Sebastián-Gallés & Bosch, 2002) and nonadjacent sequences (Gonzalez-Gomez & Nazzi, 2012, Gonzalez-Gomez, Poltrock, & Nazzi, 2013; van Kampen et al., 2008) and they also support previous findings with infants learning French or Turkish, showing that during the second half of their first year of life infants recognize non-adjacent phonological dependencies that characterize word forms in their native language.

Previous findings with Romance and Germanic languages have suggested that consonants are more informative than vowels for word segmentation and recognition for both adults (e.g., Bonatti, Peña, Cutler et al, 2000; Nespor, & Mehler, 2005) and children (Havy, Serres & Nazzi, 2013; Nazzi, 2005; Nazzi, Floccia, Moquet & Butler, 2009; Nazzi & New, 2007). However, it was also found that infants can generalize nonadjacent vocalic patterns more easily compared to consonantal patterns following training (Hochmann et al, 2011; Pons & Toro, 2010). Nespor and colleagues’ (2003) CV hypothesis suggests that while consonant sequences support the identification of specific lexical items, vowel sequences support generalizations regarding rhythm as well as morphosyntactic aspects of a given language. The present findings that 8-11-month-old infants learning Hebrew already recognize frequent non-adjacent vowel sequences in words support the importance of vowels for identifying phonological-morphological patterns in Semitic languages, although they do not address their role in word recognition tasks. Moreover, while previous findings showed the ability to learn vocalic templates in the lab during training (Hochmann et al, 2011; Pons & Toro, 2010), our findings suggest that infants learning Semitic languages actually make use of this ability in naturalistic learning situations outside the lab. It is possible that because vowels play an important role in word formation in Semitic languages, speakers of those languages are more attuned to them than speakers of Germanic or Romance languages. Further studies are needed to test this idea.

Finally, how abstract is the knowledge exhibited by the infants in this study? Is their response to the nonword stimuli based on an abstract representation of the relevant templatic patterns? Or do the nonwords belonging to the more frequent patterns simply remind the infants of familiar words? In order to investigate this issue we compared our nonword stimuli with words of the same CVCVC phonological pattern, based on an adaptation for Hebrew of the widely used Communicative Development Inventory (HCDI-WG: Gendler-Shalev, 2005), which is designed to assess word knowledge in 12-24 month-old children (see Appendix 4a).[[8]](#footnote-8)

We find that there are real-word neighbors for some nonwords in three of the four patterns we tested (see App. 4b). For both trochaic and iambic patterns we find more neighbors for the nonwords based on the more frequent template than for the contrasting set; this is not surprising, since more HCDI words belong to those more frequent patterns than to the less frequent ones. This leads us to make three observations. First, recognition (or mis-recognition) of familiar words might be taken to lie behind the responses observed in this study. However, children younger than 11 months (exposed to English or Welsh) have been found not to show reliable word-form recognition (in the absence of either training or meaning-based priming: Vihman, Nakai, DePaolis & Hallé, 2004; Vihman, Thierry, Lum, Keren-Portnoy & Martin, 2007), and even at 11 months changes to the onset consonant of the accented syllable consistently block recognition of familiar words in both English and French (Vihman et al., 2004). Studies are currently in preparation to test 11-month-old Hebrew-learning infants on word-form recognition, with and without changes to the onset-consonants in stressed and unstressed syllables.

Second, if the children’s responses to our nonword stimuli are in some sense based on mis-recognition of real words, we might expect more extreme results in Experiment 1 (in which the CéCeC list includes 4 neighbors whereas CóCoC includes none) than in Experiment 2 (in which the CaCóC list includes 5 nonwords with 7 different neighbors and the CaCéC list includes 3 nonwords with 3 neighbors). However, we actually observed an increased preference for the more frequent template in Experiment 2 in comparison with Experiment 1.

Lastly, it is possible that the recognition of frequent vowel sequences and the preference that arises from it develop through neighbors activating one another. This suggests that phonological templates can emerge out of systems consisting of few and dense neighborhoods. The level of abstraction of the representation of templates is not a question we can address in this study. However, the idea that a template system may arise out of such neighborhoods fits in well with exemplar models of phonology (see also Deutscher’s 2005 speculative account of the possible origins of the Semitic root and pattern structure). This last interpretation is intriguing but it too will have to wait to be tested in future investigations.

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**Figures**



**Figure 1:** Mean looking times (in ms) and standard errors for 'CéCeC' and 'CóCoC' nonsense words.

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**Figure 2:** Individual looking time (in ms) for 'CéCeC' and 'CóCoC' nonsense words.

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**Figure 3:** Mean looking times (in ms) and standard errors for 'CaCóC' and 'CaCéC' nonsense words.

**Figure 4:** Individual looking time (in ms) for 'CaCóC' and 'CaCéC' nonsense words.

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Appendix 1.

1. Lists of nonwords

|  |  |  |  |
| --- | --- | --- | --- |
| CéCeC  | CóCoC  | CaCóC  | CaCéC  |
| bédet | bódot | badót | badét |
| géles | gólos | galós | galés |
| géfel | gófol | gafól | gafél |
| déken | dókon | dakón | dakén |
| télen | tólon | talón | talén |
| gémen | gómon | gamón | gamén |
| méteʃ | mótoʃ | matóʃ | matéʃ |
| kédef | kódof | kadóf | kadéf |
| bémek | bómok | bamók | bamék |
| xésev | xósov | xasóv | xasév |
| dével | dóvol | davól | davél |
| dékef | dókof | dakóf | dakéf |
| kéʃen | kóʃon | kaʃón | kaʃén |
| xéfel | xófol | xafól | xafél |

Appendix 2a. Distribution of nonadjacent /e - e/, /o - o/, /a - o/ and /a - e/ sequences with different stress positions in running speech in Hebrew (Hebrew2)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| within/betweenword syllabic sequences | Forms of/e - e/ sequences | # of occurrences intypes (tokens) | Forms of/o - o/ sequences | # of occurrences in types (tokens) | Forms of/a - o/ sequences  | # of occurrences intypes (tokens) | Forms of/a - e/ sequences | # of occurrences intypes (tokens) |
| Within words | **/é -** e/ |  40 (60)  | **/ó -** o/ | 1 (1) | **/á -** o/ | 1 (5) | **/á -** e/ | 1 (1) |
| /e **-** e/ | 4 (9) | /o **-** o/ | 2 (4) | /a - o/ | 1 (2) | /a **-** e/ | 1 (1) |
| /e **- é/** |  5 (8)  | /o **- ó/** | 2 (9) | /a - **ó/** | 31 (129) | /a **- é/** | 29 (41) |
| /**é - é**/ | 0 (0) | /**ó - ó**/ | 0 (0) | **/á - ó**/ | 0 (0) | /**á - é/** | 0 (0) |
| **Total** | **49 (77)** |  | **5 (14)** |  | **33 (136)** |  | **31 (43)** |
| Between words | **/é -** e/ | 6 (8) | **/ó -** o/ | 2 (2) | **/á -** o/ | 5 (5) | **/á -** e/ | 15 (23) |
| /e **-** e/ | 23 (49) | /o **-** o/ | 12 (24) | /a - o/ | 17 (95) | /a **-** e/ | 46 (121) |
| /e **- é**/ | 5 (7) | **/**o **- ó**/ | 1 (2) | /a - **ó/** | 4 (4) | /a **- é/** | 14 (21) |
| /**é - é**/ | 0 (0) | /**ó - ó**/ | 0 (0) | **/á - ó**/ | 0 (0) | /**á - é/** | 0 (0) |
| **Total** | **34 (64)**  |  | **15 (28)** |  | **26 (104)** |  |  **75 (165)** |
| Within plus between words | **/é -** e/ | 46 (68) | **/ó -** o/ | 3 (3) | **/á** -o/ | 6 (10) | **/á -** e/ | 16 (24) |
| /e **-** e/ | 27 (58) | /o **-** o/ | 14 (28) | /a - o/ | 18 (97) | /a **-** e/ | 47 (122) |
| /e **- é/** | 10 (15) | /o **- ó/** | 3 (11) | /a - **ó/** | 35 (133) | /a **- é/** | 43 (62) |
| /**é - é**/ | 0 (0) | /**ó - ó**/ | 0 (0) | **/á - ó**/ | 0 (0) | /**á - é/** | 0 (0) |
| Grand total |  | **83 (141)** |  | **20 (42)** |  | **59 (240)** |  | **106 (208)** |

 Tokens = number of nonadjacent vocalic sequences, types = number of nonadjacent vocalic sequences from

 different syllables (within or between words).

Appendix 2b. Distribution of nonadjacent /e - e/, /o - o/, /a - o/ and /a - e/ sequences with different stress positions *in disyllables* in Hebrew2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| syllabic sequences | Forms of/a - o/ sequences  | # of occurrences intypes (tokens) | Forms of/a - e/ sequences | # of occurrences intypes (tokens) |
| Within disyllabic words | **/á -** o/ | 1 (5) | **/á -** e/ | 1 (1) |
| /a - o/ | 0 (0) | /a **-** e/ | 0 (0) |
| /a - **ó/** | 17 (110) | /a **- é/** | 5 (13) |
| **/á - ó**/ | 0 (0) | /**á - é/** | 0 (0) |
| Grand total |  | **18 (115)** |  | **6 (14)** |

Appendix 3. Hebrew child-directed speech (CDS) and Adult Directed Speech (ADS) as well as cross-linguistic analysis of the occurrence in child-directed speech of the Hebrew vowel patterns tested in this study.[[9]](#footnote-9)

|  |
| --- |
| I. Trochaic |
|  | types (tokens) |
|  | e - e | o - o |
| Words that fit the CVCVC template |
| Hebrew1  | 77 (2335) | 0 (0) |
| Hebrew2  |  10 (16) | 0 (0) |
| Hebrew3  | 8 (28) | 0 (0) |
| Hebrew ADS | 39 (180) | 0 (0) |
| All disyllables with trochaic stress |
| Hebrew2 | 11 (24) | 1 (1) |
| Hebrew3 | 11 (37) | 1 (7) |
| Swedish | 14 (50) | 5 (21) |
| Italian | 14 (46) | 29 (116) |
|  |  |  |
| II. Iambic |
|  | types (tokens) |
|  | a - o | a - e |
| Words that fit the CVCVC template |
| Hebrew1 | 90 (6386) | 41 (737) |
| Hebrew2 |  12 (101) | 1 (1) |
| Hebrew3 |  10 (68) | 0 (0) |
| Hebrew ADS |  45 (319) |  20 (81) |
| All disyllables with iambic stress |
| Hebrew2 | 17 (110) | 5 (13) |
| Hebrew3 | 15 (82) | 9 (19) |
| French  | 14 (58) | 22 (63) |
| Swedish | 2 (11) | 1 (1) |
| Italian | 1 (2) | 2 (40) |

Appendix 4.

1. Words on the HCDI-WG that fit the templates tested in the study

|  |  |  |  |
| --- | --- | --- | --- |
| CéCeC | CóCoC | CaCóC | CaCéC |
| bérex | = | balón | jaʃén |
| bérez |  | gadól | javéʃ |
| béten |  | hajóm | latét |
| délet |  | hakól | laʦét |
| géʃem |  | hamón | mahér |
| gézer |  | laʃón | namér |
| jéled |  | matók | ʃamén |
| kélev |  | matós | ʃaxén |
| késef |  | ratóv | xaʦér |
| léxem |  | raxók | xavér |
| réfet |  | sabón | zakén |
| régel |  | ʃalóm |  |
| séfel |  | xalón |  |
| séfer |  | xamór |  |
| ʃémeʃ |  |  |  |
| zével |  |  |  |

Words with clusters or words lacking consonants initially, finally or medially are not included; glottal-stop is not treated as a consonant.

1. Real word neighbors of the nonword stimuli and their glosses

|  |  |
| --- | --- |
| Non-words | Real words |
| CéCeC |  |
| dével | zével ‘garbage’ |
| géfel | séfel ‘mug’ |
| kédef | késef ‘money’ |
| xéfel | séfel ‘mug’ |
| CóCoC |  |
| = | = |
|  CaCóC |  |
| gafól | gadól ‘big’ |
| gamón | hamón ‘lots (of) |
| kaʃón | laʃón ‘tongue’ |
| matóʃ | matók ‘sweet’, matós ‘airplane’ |
| talón | xalón ‘window’, balón ‘baloon’ |
| CaCéC |  |
| dakén | zakén ‘old (man)’ |
| kaʃén | jaʃén ‘asleep’ |
| gamén | ʃamén ‘fat’ |

1. In order to assess whether the pattern of distribution of the phonological templates 'CéCeC', 'CaCóC', 'CóCoC', 'CaCéC' also characterizes Adult Directed Speech (ADS), 53,644 tokens from the 'Spoken Israeli Hebrew' corpus (Esti) (MILA, Knowledge center for processing Hebrew, Itay & Winter, 2008), were analyzed and found to show the same distribution as is observed in CDS (see Appendix 3, Hebrew ADS). [↑](#footnote-ref-1)
2. Note that /i/ and /o/ are closer in frequency, but neither of those is frequent in a pattern with a repeated vowel, and they differ not only in backness but also in height. The front vowels /i/ and /e/, also close in frequency, do not provide a good contrast due to their proximity in acoustic and articulatory space. [↑](#footnote-ref-2)
3. The mean looking time difference was 0.64 and the SD was 0.9. Only participant # 12 showed a difference in looking time greater than 2 standard deviations (preference for CéCeC vs. CóCoC words). However, even when taking this participant out, the t-test revealed a significant difference in looking time for CéCeC vs. CóCoC words [t (18) = 3.15, *p* = .005]. [↑](#footnote-ref-3)
4. The mean looking time difference was 1.36 sec and the SD was 1.88 sec. Only one participant showed a difference in looking time (preference for CaCóC over CaCéC words) more than 2 standard deviations above the mean. However, even when this participant is removed the t-test reveals a significant difference in looking time for CaCóC vs. CaCéC words [*t* (18) = 2.94, *p* = .009]. [↑](#footnote-ref-4)
5. Note that here we looked at vowel sequences rather than at word shapes (or phonological templates). Therefore a word with the shape of, e.g., CaCé, would count towards the vowel sequence /a - é/ in this analysis, but would not have been counted as belonging to the CaCéC pattern in our analysis of the distribution of phonological templates in Hebrew (see p. 10). [↑](#footnote-ref-5)
6. Vowel sequences across utterances or major prosodic boundaries, as indicated by punctuation, were not included in the ‘between-word sequence’ count. The ‘within word’ count includes words with more than two syllables in which the sequence in question appears. [↑](#footnote-ref-6)
7. We thank an anonymous reviewer for this suggestion. [↑](#footnote-ref-7)
8. We thank another anonymous reviewer for suggesting that we consider neighborhood density. [↑](#footnote-ref-8)
9. Note that all names of children directly addressed in the recordings have been omitted from the pattern count, to avoid local frequency biases. [↑](#footnote-ref-9)