Children's Early Associations Between Segments of Words and Referents: Precursors of Morphology Acquisition

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Introduction

The comprehension of syntactic and morphological constructions is a very complex task in which several abilities must be coordinately deployed. For instance, to comprehend the simplest sentence, the hearer must deploy speech perceptual abilities, segmentation abilities (e.g., to segment the continuous stream of speech into discrete units), lexical and semantic abilities (e.g., to deploy vocabulary and their adequate word-meaning mappings), categorical abilities, etc. The ability to map referents to words lags behind perceptual abilities. Infants begin to link meanings to words at around eight to ten months (Bates, Dale, & Thal, 1995). Infants also can segment words from the speech stream using phonotactic patterns (Mattys & Jusczyk, 2001), stress patterns within words (Jusczyk, Houston, & Newsome, 1999), and patterns in allophonic variations (Jusczyk, Hohne, & Bauman, 1999), among other cues.

Most research on segmentation has focused on the process by which discourse is segmented, based on distributional evidence, into word-sized segments (e.g., Jusczyk & Aslin, 1995; Jusczyk, Houston, & Newsome, 1999; Morgan, Shi, & Allopenna, 1996; Newsome & Jusczyk, 1995; Peters, 1985; Saffran et al., 1996), which are therefore learned in their complete form. Fewer studies focus on how some morphemes, as grammatical elements (e.g., inflections), are used as keys to the segmentation of words (Christophe et al., 1997; Gout et al., 2004; Höhle & Weissenborn, 2003).

In the few studies on smaller units, the theoretical import is commonly attributed to the relation that these abilities could have to learning to read and write (e.g., Bryant, 2002; Hayes, Slater, & Brown, 2000; Jusczyk, Goodman, & Baumann, 1999; Treiman &

Zukowski, 1996), and the ways in which the ability to segment rhymes facilitates reading and the learning of new words (e.g., Goswami, 1988) and thus regard school or preschool stages of development. According to one of these studies (Treiman & Zukowski, 1996), infants first develop the ability to segment speech into words, then syllables, intrasyllabic units, and finally phonemes. The critical aspect of this segmentation is the linguistic status of the segmented unit (Treiman & Zukowski, 1996). This hypothesis assumes that syllables have an advantage over intrasyllabic units, which in turn have an advantage over phonemes (Treiman & Zukowski, 1996), which may apply to English.

However, and returning the issue to language acquisition, it should also be considered that in a relatively morphologically extensive language as Spanish, not only beginnings but also endings of words, and specifically the morphemes from which they are made, may take on an important linguistic status. Alternatively, the status of morphemes (as well as the ability to segment them) may potentially surpass that of syllables and phonemes, in the first months of infancy, as a consequence of a prevalent association between these segments and their meanings (or referents).

When referring to the ability to segment linguistic information and associate these segments to referents, it has been shown that 17-month-old infants can map meaning to newly segmented words (Estes et al., 2007). In their experiment, the authors showed that when infants previously segmented words from speech, these segments were easier to associate to novel objects, compared with novel sequences of familiar sounds, even when controlling total exposure to words.

Most of the previously described results show that infants are able to analyze words and learn suffixing patterns with no semantic information involved (e.g., Falcón, Canto, & Franco, 2013; Gout et al., 2004; Jusczyk, Goodman, et al., 1999). Some differences observed in the comparison of the processing of distinct languages suggest that sensitivity and attention to word segments shown by language learners may depend on phonological properties of those languages, likely as well on their morphological properties (e.g., Falcón et al., 2013; Hallé & de Boysson-Bardies, 1994; Jusczyk, Goodman, et al., 1999; Swingley, 2005). This is relevant considering that child directed speech in some languages includes a high prevalence of variant inflected forms (e.g., diminutives and verbs), which may suppose a very early development of abilities related with its processing.

Spanish learners may manifest a different process of acquisition of the segmentation and mapping abilities that support syntax and morphology. For example, based solely on morphological cues, Spanish learners have been shown capable of understanding the meaning to the plural morpheme (-s) at an earlier age than English learners (Arias-Trejo et al., 2014). This early acquisition may be facilitated by the morphosyntactic characteristics of Spanish, which exhibits a highly redundant morphology. For example, in Spanish it is obligatory to mark agreement in number and gender (see for example, Mariscal, 2008). Moreover, marking is required not only on nouns and adjectives but also on determiners and quantifiers. For example, in *todas las pelotas rojas* (all the red balls) the morpheme "-as", which marks feminine gender and plural number, appears four times. Spanish learners are thus more redundantly exposed to the same instance of particle-referent mapping, even in short utterances.

Furthermore, Spanish has specific semantic demands associated to its morphosyntactic system. Thus in a typical instance of child directed speech, important semantic information is available only through the meaning encoded on the verb's morphemes. Words like *juego*, *juegas*, *juegan* (*I play*, *you play*, *they play*), carry their main meaning in the recurrent beginning (the lexeme), but the subject is encoded in second morpheme of the word (grammeme). Moreover, the ending of the verb not only encodes information about the subject, but also about tense (e.g. *juego vs. jugaba vs. jugué*; all different tenses of *I play*) and mood (e.g., *no juegues vs. no juegas*; don't play *vs.* you don't play). Also, words like *carrito*, *caballito*, *perrito* (diminutive forms of *cart*, *horse*, *dog*), vary in their initial segment and thus their main meaning is also different but share common ending that relates them as diminutive versions of those nouns.

Accordingly, Spanish's distributional characteristics may facilitate the acquisition of the abilities that support the comprehension of its syntax and morphology. Mastering the inflectional morphology of a language requires the ability to segment words into morphemes (Manning & Schütze, 1999) and the ability to recognize morphological regularities even in different words (Bedore & Leonard, 2000). The ultimate aim of these perceptual abilities is to associate these segments (morphemes) to referents, be they concepts or grammatical functions. It is this capacity for segmentation and categorization, and association to a referent, that is essential for understanding the meaning of inflections and roots of words, and that allows a person to dominate the morphological system of a language. These demands may force the infant to develop, not necessarily morphosyntactic knowledge, but perhaps at least the minimal abilities to later support that knowledge.

The present study highlights the necessity for further studies that evaluate segmentation abilities in a word level and its association to a referent, under consideration that these abilities may be the basis for the acquisition of the morphological system of a language. Our study intends to evaluate the abilities that allow infants to segment and categorize the recurring parts of several words. Most importantly, unlike other studies which have focused on assessing phonological parsing of artificial or natural morphemes on adults as well as on babies (i.e., Finley & Newport, 2010; Marquis & Shi, 2012), our study intends to evaluate a supposedly more complex ability: association of a referent (object) to an artificial morphological category (constructed through different novel words, with a common novel "inflection"). This latter ability, it is suggested, represents a key precursor for learning the meaning (or function) of inflections in the morphological system of a language.

We designed an experiment that partially resembles common situations infants face when hearing different variations of a word. For example, a common verb such as *jugar* (play) can be presented as *juega [conmigo]* (play with me) when uttered from an older sibling asking the infant to join him to play or as *¿…jugamos?,* having virtually the same meaning in spite of the varying ending. Regularity in morphemes also appears at the end of different words. For example, diminutives are highly pervasive in infant directed speech so infants frequently hear words such as *carrito, perrito or hermanito* (diminutive forms of cart, dog and brother).

To replicate these characteristics of Spanish morphosyntax, infants were presented to one of two novel objects (being the referent) while hearing two different nonwords in each trial. Words coincided in one of two segments, either the beginning (e.g., /*ˈsabo/, /ˈsade/*) or the ending (e.g., */taˈbi/, /seˈbi/*). The onset of each word was separated by 2500 ms allowing words to be processed as two different units and not just a single speech stream. Thus trying to make our artificial language more similar to the segmentation of parts from a word than to the segmentation of words from a speech stream. Also, in order to test segmentation and not just word learning we had taken care that nonwords presented during test trials were different than those presented during the training phase.

Method

An experiment was carried out using the Intermodal Preferential Looking Paradigm (IPLP), adapted by Golinkoff et al., (1987) for studies of language comprehension. Modifications were made for the purpose of evaluating the ability of infants aged 9 to 12 months to categorize alliterative (i.e., words that share the initial syllable) and rhyming words (i.e., words that share the ending syllable), and to evaluate in particular their ability to associate these categories to a referent, in this case a new object. This target age was chosen according to previous studies, which show children's sensitivity to sound similarities in words from 9 months of age (Jusczyk, Goodman, et al., 1999) and also according to the hypothesis that precursory abilities of processing morphemes may develop around this age.

Participants. The final sample included 38 infants who were aged 9 to 12 months (mean: 10.25, range: 9.1 to 12.13). Nine infants were previously excluded who did not complete a minimum of 4 of the 10 testing trials to be included in the statistical analysis. All of the infants were born at term, were from homes speaking exclusively Spanish, and where parents reported no diagnosis or suspicion of hearing, visual, perinatal, or neurological impairments. Informed consent from caretakers on the behalf of the children participants was obtained. The protocol was conducted according to the corresponding ethics for these kinds of studies.

Stimuli

Novel words. Forty CVCV words were prepared, divided into two categories: alliteratives (20) and rhymes (20). Alliterations were defined by regularity in the first syllable (e.g., */ˈsato/, /ˈsame/, /ˈsaru/*), and rhymes by the second syllable (e.g., */taˈbi/, /seˈbi/, /doˈbi/*). Novel words were formed from phonemes with a high frequency in Spanish, as well as a high phonetic contrast, based on the International Phonetic Alphabet.

Which syllable (*bi* or *sa*) was used in the initial or final segment was counterbalanced across participants. It is very important to note that the novel words presented in the testing phase, including those that belonged to the same category, were distinct from those used in the training phase. The auditory stimuli were recorded by a female speaker who was instructed to read each novel word in a phrase with the following form: *¡Mira, /ˊsame/, /ˊsado/!* ("Look, /*ˊsame*/, /*ˊsado*/!") using infant directed speech.

Table 1. Examples of novel words presented in the experiment. Syllables (*bi* or *sa*) used in the initial or final segment was counterbalanced across participants.

Initial	Ending
sato	*tabi*
same	*babi*
saru	*ribi*
sagu	*gobi*
sane	*nabi*
sasi	*sobi*

Visual stimuli. Two distinct, novel, colorful, three-dimensional objects were created, using the 3-D computer design program *MilkShape 3D*, version 1.8.1. The visual stimuli were associated with words during the experiments. Two versions of each object were created: an animated one used in the training phase and a static version used in the testing phase (as in Ballem & Plunkett, 2005). In order to avoid any effect caused by the type of movement, both objects in the animated version were projected rotating around their vertical axes. Both stimuli were created using the same number of pixels and were projected on a black background. The assignment of categories and the order of presentation were counterbalanced.

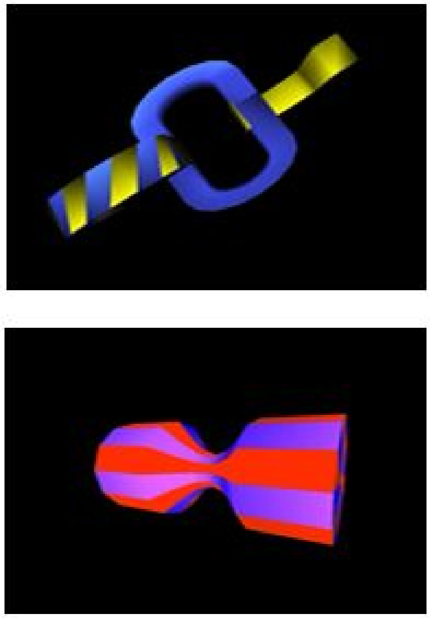

Fig. 1. Novel objects used in the experiment. Objects' association to each category of novel words was counterbalanced across participants.

Procedure

The evaluation of infants' performance was carried out on an individual basis using the Intermodal Preferential Looking Paradigm (IPLP), which evaluated their ability to categorize alliterative and rhyming words and associate each category with a distinct object. Infantswere seated on the laps of their mother or other caregiver in a cubicle, with a 50-inch screen in the center, in front of the infant. The infant's gaze was monitored by three video cameras installed behind the cubicle wall, facing the infant. A monitor and computer for the projection of the experiment and recording of the session were located outside the cubicle.

The experiment consisted of a total of 20 trials, 10 for training and 10 for testing, divided into two blocks of training and two of testing. The training and testing trials were alternated: eight training trials, six testing trials, two more training trials, and four more testing trials.

Training Phase. Five training trials, divided into two blocks, were performed for each category: four in the first block and one in the second. Each trial associated a new object with two pseudowords corresponding to one of the two lists (e.g., *Look, /ˈbime/, /ˈbiro/!*). It is important noticing that the two words presented in the training trials were ‘clearly’ (at least from an adult’s perspective) separated by a 500 ms pause whilst no pause was included in word segments (i.e., syllables within words). Unlike other experiments that test word segmentation from a continuous speech stream this design intended to test for intra-word segmentation.

During the training phase, the objects were projected on the center of the screen. In some studies using the PLP it has been observed that children younger than 18 months of age are capable of associating a word with an object after just three repetitions of the word.

However, it is important to note that the task in this experiment did not seek a one-to-one word-object association, but rather the association of an entire category of several words to an object. Given this consideration as well as the fact that these infants were at most 12 months old, it was decided to include a larger number of training trials presented in two uneven blocks to try avoiding children's fatigue.

In the training trial, the first word was played at the same time that the object began its rotation, in accordance with previous results of (Gogate & Bahrick, 1998), who found that presenting the sound and the movement simultaneously facilitated the association between the two.

Testing Phase. Each category included three testing trials in the first block and two in the second one. In each trial, infants heard words from one of the two lists, repeated twice. The words used in the testing trials were different from those heard in the training trials; to insure that what was being evaluated was a categorization rather than merely recognition of the words.

In the test trials, the two images appeared simultaneously in static form to avoid any bias related to the effects of animation. Objects were presented for a total of 6000 ms. For the first 2000 ms they were presented without auditory stimulus, in order to measure the duration of the infants' attention toward each object in the absence of words (pre-naming). For the next 2000 ms (post-naming), one of the objects was referred to with a word from the category it was associated with during the training phase (e.g. /*bima*/), in the phrase *¡Mira, _____!* (Look, _____!). Post-naming phase initiated at the onset of the regular segment. Also, in order to replicate the form of the phrases used during the training phase, children heard a second instance of the category (e.g. /*bide*/) on the onset of the final 2000 ms. This additional window of 2000 ms allowed us to test a potential learning dependent only on the utterance of two words (as in the training phase).

Results

Evaluation of infants' learning was carried out off-line through analysis of the recorded videos. Using these videos, the trials were divided into frames of 33 ms (i.e., 30 frames per second) and the direction of the infants' gaze in each was coded. The coding was performed *blind*: an experienced researcher, unaware of the target word from each trial, coded whether the infants looked left or right. In addition, independent coding by another experimenter showed 96% reliability.

Frame-by-frame analysis was used to calculate total looking time at target (the named stimulus) and total looking time at distractor (the stimulus not named). From these data *Difference of Total Looking Time at Target vs. Distractor (DTLT), Proportion of Looking Time at Target vs. Distractor (PLT) and Difference of Longest Look at Target vs. Distractor (DLLk)* were calculated and these results were considered as the infants' preference, which were used to carry out a repeated-measures ANOVA: naming: pre-naming vs. post-naming (2) x segment: initial vs. ending (2). In this analysis significant main effects related with the *naming* factor were observed on all measures (see Table 2): *Difference of Total Looking Time at Target vs. Distractor* ($F_{1,37}$ = 7.138, p = .011), *Proportion of Looking Time at Target vs. Distractor* ($F_{1,37}$ = 4.910, p = .033) and *Difference of Longest Look at Target vs. Distractor* [$F_{1,37}$ = 6.944, p = .012]. No other significant main effect or interaction with other factor was observed.

Table 2. Results. Mean and standard deviation of looking preference pre and post naming in three measures (DTLT, PLT and DLLk). Looking times are presented in milliseconds.

Preference measure	Pre-naming M (SD)	Post-naming M (SD)
Difference of Total Looking at Target vs. Distractor	-48.33 (163.58)	113.68 (327.81)*
Proportion of Looking at Target vs. Distractor	.48 (.05)	.52 (.09)*
Difference of Longest Look at Target vs. Distractor	-48.22 (154.85)	108.14 (340.72)*

* indicates a significant difference between pre-naming and post-naming ($p < .05$)

Given that no effects were observed related to the segment of the word (i.e., initial vs. ending), subsequent analyses were collapsed into a single factor (naming: pre-naming vs. post-naming). The t-tests showed a statistically significant increase in infants' preference to the target from pre-naming to post-naming, in all three analyzed measures: DTLT (t_{37} = 2.853, p = .007, η^2=.66), PLT (t_{37} = 2.260 p = .030, η^2=.52), DLLk (t_{37} = 2.660, p = .011, η^2=.63). These differences are shown in Table 2. A representative result is illustrated in Figure 2 by showing the Difference of Total Looking time at Target vs. Distractor (i.e., increase from the pre-naming to the post-naming phase of the test trials). Figure 3 shows time course of toddlers' target looking during the first 4000 ms of the test trials. Results on the last window of the test trial (4000 to 6000 ms) were also computed and tested on similar statistical analyses, however no significant results were observed.

Discussion

Our evaluation of a task in an artificial language to assess the ability to identify segments and categorize them, a task focused on exploring the capacity to associate these segments to a referent, produced relevant findings toward tracking the early comprehension of morphology.

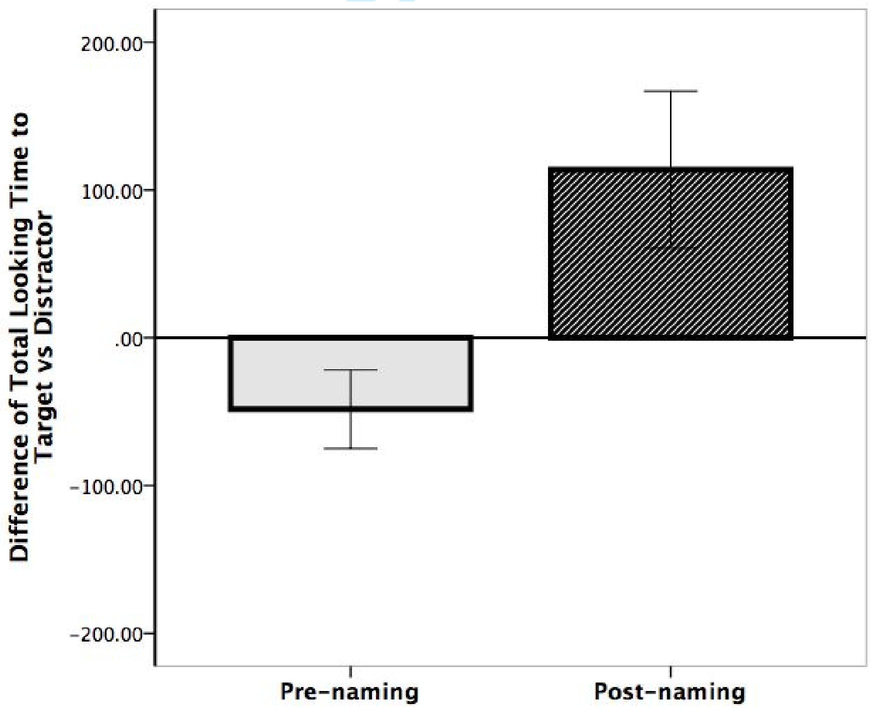

Figure 2. Mean (+/-1 standard error) Difference of Total Looking Time to Target vs Distractor. The horizontal line at 0.5 indicates looking at chance level.

The closest reference to our present results comes from the study by Jusczyk, Goodman, et al. (1999) (see also Hayes). With the aim of exploring 9 month-old children`s sensitivity to internal similarities in the beginning segment (alliteratives) or ending segment (rhymes) of CVC syllables, Jusczyk and cols. performed a Head-turn Preference Procedure, with which they found that English-learning infants show sensitivity to similarities within the initial segments of a word but not to their ending segments.

To tackle on infant's sensitivity to segments, but also to evaluate infant's ability to associate the regular segments to a referent in a Spanish-learning population, we performed an IPL procedure. Similarly to Jusczyk, Goodman, et al.'s results (1999), Spanish-learning infants showed an ability to segment and categorize the regular parts of a nonword. On the other hand, unlike English-learning infants, Spanish-learning infants did not show a differential sensitivity to any of the segments, that is, children where able to categorize the regular segment independently of its position (i.e., beginning or ending). Also, as part of our procedure, children were able to categorize and associate the regular segments to their corresponding novel object.

Differences in the abilities observed in English-learners (Jusczyk, Goodman, et al., 1999) and Spanish-learners (e.g., infants' symmetric sensitivity) can be directly explained by differences in procedures of each study (i.e., an auditory preference paradigm vs. an intermodal preference paradigm). However our initial hypothesis also took into consideration differences in English and Spanish morphological systems, which implies differences in infants` language experiences.

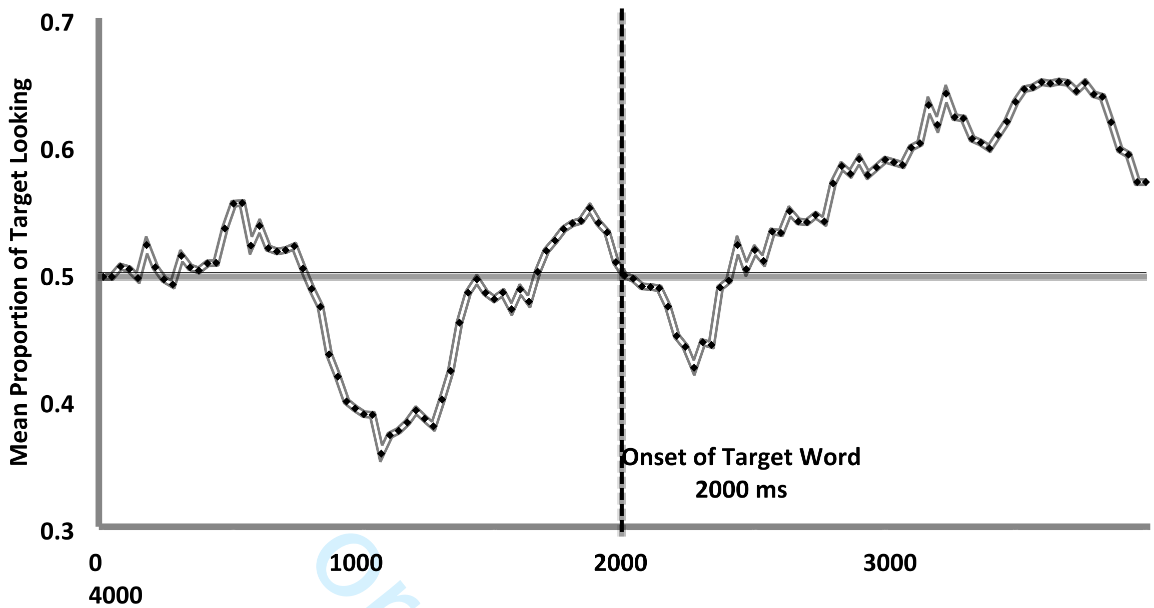

Figure 3. Time course of looking preference during a 4000 ms window of trial presentation. The vertical line marks the onset of the target word. Scores higher than 0.5 denote a preference to the target object whilst scores under 0.5 indicate a preference to the distractor.

A possible explanation of these differences in the acquisition processes, as we mentioned in the introduction, is that Spanish learners are more frequently exposed to the distributional characteristics and semantic demands of the Spanish morphosyntax. As we have mentioned, similar results has been documented experimentally (e.g., Arias-Trejo et al., 2014; Arias-Trejo & Alva, 2013). From an early age, Spanish-learning infants are more frequently exposed to and are demanded to process the semantics of Spanish morphosyntax. This may lead to an incipient exercise of the cognitive abilities suggested by Peters (Peters, 1985) as necessary for the learning of morphemes: phonological identification, location of the recurring segment or morpheme, and ultimately mapping the segment or morpheme to its function (grammatical or semantic). The characteristics of the Spanish language may promote the development of the ability to distinguish and categorize words on the basis of meaningful segments. The characteristics of Spanish lend greater importance to the segments that have a linguistic function.

Based on the fact that frequency and other characteristics of an infant's linguistic experience are known to determine many aspects of language acquisition in the first 12 months (Beckman & Edwards, 2000; Plunkett, 1993; Werker & Curtin, 2005; Werker & Yeung, 2005) we suggest that the early manifestation of the perceptual-lexical abilities found in the present study may be the result of the specific experience Spanish learners have. Moreover, other studies have reached similar conclusions: characteristics such as the redundancy of morphological cues in Spanish (West, 2010) seem to facilitate the comprehension number marking in Spanish, based solely on morphological cues (Arias-Trejo, Cantrell, Smith, & Canto, 2014).

One contribution of the present study is to advance our comprehension of the cognitive abilities that support the acquisition process of the morphosyntax of language (Kempe & Brooks, 2001; Laalo, 1998; Marquis & Shi, 2012; Plunkett & Nakisa, 1997). Mastery of the morphosyntax of a language involves more complex abilities and knowledge, such as knowledge of the function of all of the morphemes that make up a word, as well as knowledge of the degree to which the function of such morphemes is generalizable. The comprehension and use of the morphosyntactic system of language are not evident until the age of 17 months (Hernández-Pina, 1984), and are not consistent until the age of 24 months (e.g., Arias-Trejo, Falcón, & Alva-Canto, 2013) However, the simple associations observed in the present study are an essential initial step in reaching more advances stages in the acquisition of morphosyntax.

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