The Influence of Context and Form on 12-Month-Olds’ Sound-Object Associations

by

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Abstract

In this dissertation, I examine whether infants’ experience with their native language guides their developing expectations about the nature of an appropriate label for an object and the context in which these biases constrain their associative word learning ability.

Chapter 2 examines whether infants’ preference for words as object labels is impacted by native-language phonotactics and/or the phonetic realizations of native language sound categories (phonemes). Across two studies, 12-month-olds’ acquisition of novel English word-object pairings were compared to their acquisition of forms that violate native-language phonotactics (Czech) or forms that violate the low-level phonetic realization of phonemes (Japanese). Results indicate that infants are beginning to apply their language-specific knowledge to their acceptance of word forms and thus, will not map words that violate the phonotactics of their native language to objects.

Chapter 3 examines whether 12-month-olds will treat content versus function word forms differently in a sound-object associative task. Results indicate that 12-month-olds distinguish between different types of word forms on the basis of their phonological and acoustic properties and use this knowledge to guide their expectations about the appropriate word form for an object label.

Chapter 4 examines whether infants will override their bias for specific words as object labels when provided with a training phase that clarifies the referential role of these labels. Infants’ mappings of three different types of forms to objects in a modified referential Switch task were compared: phonotactically illegal CCVC words, consonantal sounds, and novel function-like words. Results indicate that infants will demonstrate
flexibility in the types of linguistic forms they will map to objects, however, this flexibility appears to be constrained to structural well-formed words that share the structural properties of noun-like words, even when the referential role of these labels are clarified.

These findings demonstrate that infants rely on the sound properties of the to-be-learned label to determine whether it is an appropriate label for an object, namely, a phonotactically legal content-like word. Furthermore, when provided with an additional cue that clarifies the purpose of the Switch task, infants can weigh this information along with the linguistic properties of the label to help guide their word-object mappings.
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Chapter One: Introduction

The acquisition of language is one of the most remarkable milestones in early childhood. By the end of the first year of life, infants have begun to develop into proficient word learners; understanding dozen of words and even producing some of their own (e.g., Fenson, et al. 1994). Children’s great success at word learning is particularly impressive given the complexity of the language learning task: children must first isolate the appropriate sound in the speech stream, identify the appropriate entity within ongoing activity, and then map that sound onto the entity that it represents. In order for a child to successfully map a novel word to its meaning; infants must also appreciate the referential nature of language, that is, words are symbols that refer to entities in the world. In this dissertation, I examine one aspect of the word-learning equation, namely, infants’ ability to form associations between a word and an entity. Across three chapters, I examine 12-month-olds’ associative word learning ability and ask whether this mechanism is constrained to particular sound forms over others. More specifically, I examine whether infants’ experience with their native language guides their developing expectations about the nature of an appropriate label for an object and the context in which these biases constrain this associative mechanism.

Learning word-object associations

Evidence for word learning has been found by 6-9 months of age (Bergelson & Swingley, 2012; Benedict, 1979; Fenson et al., 1994). By 12-14 months of age, infants can acquire a new word-object mapping without contextual and intentional support (Curtin, 2009; MacKenzie, Graham & Curtin, 2011; Hollich et al., 2001; Schafer & Plunkett, 1999; Werker, Cohen, Lloyd, Casasola & Stager, 1998). This type of associative word learning is typically examined using the Switch task, a task first used by Werker et al., (1998). In this first set of studies using the Switch
task, Werker and colleagues (Werker et al., 1998) demonstrated that 14-month-olds will rapidly associate two dissimilar sounding words with two different objects. In this procedure, infants were habituated to two word-object pairings (Object A paired with Word A; Object B paired with Word B). Following habituation, infants were presented with two types of test trials. On the Same trial, the familiar word and object were presented in a familiar combination (e.g. Object A paired with Word A). On the Switch trial, the familiar word and object were presented in a new combination (e.g., Object A paired with Word B). If infants have learned the link between the object and the word, they should be surprised when this link is violated, as evidenced by longer looking on the Switch than the Same trial.

Since 1997, the Switch task has been used to examine how different aspects of words including phonetic realization, lexical stress, acoustic saliency, and distributional information impact infants’ word-object associations (e.g., Archer, 2012; Archer, Ference & Curtin, accepted; Fennell & Werker, 2003; Stager & Werker, 1997; Thiessen, 2007). For example, a series of studies conducted by Werker and colleagues investigated whether the phonetic knowledge that infants accumulate during their first year of life impacts their mapping of novel words to objects (Stager & Werker, 1997; Werker et al., 2002; Fennell & Werker, 2003). The results of these studies have demonstrated that, although 14-month-olds can discriminate phonetically similar words from one another (i.e., bih versus dih; bin versus din), they fail to access and use this phonetic detail to detect mismatches in the word-object mappings. To account for these findings, Stager and Werker (1997) proposed a resource limitation hypothesis. This hypothesis proposes that the computational demands involved in learning new words, learning about new objects, and linking these words to objects are too great for 14-month-olds, who are at the early stages of word learning. These demands thus interfere with the ability to
attend to and access the phonetic detail in the words. In support of this hypothesis, Werker et al. (2002) demonstrated that 17- and 20-month-olds, who are more experienced word learners, will learn phonetically similar words in the Switch task. Furthermore, when the Switch task is sufficiently simplified or when the purpose of the task is highlighted by a training phase, 14-month-olds can successfully map similar sounding words to objects (Fennell & Werker, 2003; Yoshida, Fennell, Swingley & Werker, 2009; Fennell & Waxman, 2010).

Fourteen month-olds will also successfully map minimal contrasting words to objects when provided with distributional information (Thiessen, 2007). Using the Switch task, Thiessen (2007) found that when target contrastive syllables are presented in isolation (e.g., daw, taw), and as the first syllable of a bisyllabic non-word where the second syllable is maximally different, providing distributional context (e.g., daw, dawbow, tawgoo), 14-month olds successfully detect the switch at test.

Switch task studies have also demonstrated that infants will map distinct word forms that differ on multiple dimensions. In one such study, Curtin (2011) presented 12-month-old infants with novel objects paired with trisyllabic words that differed in segmental and lexical stress information (i.e., BEdoka and tiPEgu). Using the Switch task, infants recognized a violation in a mapping as demonstrated by longer looking time during the Switch trial. Furthermore, when 12-month-olds were habituated to a single trisyllabic string (i.e., BEdoka) and then presented with a switch in only the stress information (i.e., BEdoka versus beDOka), during test, infants looked longer during the Switch trial than the Same trial, indicating successful word-object mapping (Curtin, 2011). Infants of this age can also learn two novel word-object pairings that differ solely in their stress pattern. That is, when habituated to trisyllabic words containing the same segments but different stress patterns (i.e. BEdoka and beDOka) and then tested on a mismatch in the
word-object pairings, infants looked longer during the Switch trial (Curtin, 2009). Further support for the influence of lexical stress on infants’ word-object associative ability comes from recent work by Curtin, Campbell & Hufnagle (2012). In this study, 16-month-olds were presented with two novel words with either verb-like iambic stress or noun-like trochaic stress. During habituation, each word was paired with a single novel object performing one of two path actions and infants were tested using path-switch trials. Results indicated that only infants in the iambic stress condition learned the association between the novel words and the path actions. Furthermore, when infants were given a word-object Switch task using trochaic labels, infants successfully associated the trochaic labels with the objects. These results suggest that infants use lexical stress to guide label-referent associations and by 16-months of age, have developed a bias to expect disyllabic action labels to have iambic stress patterns, consistent with native language stress a patterns.

Finally, recent work has demonstrated how acoustic salience can impact infants’ word-object associations. Archer, Ference, and Curtin (accepted) found that 14-month-olds can detect a minimal pair (i.e., leDOna versus leBOna) when it is couched in a medially stressed syllable suggesting stronger place cues can enhance an otherwise difficult contrast. Some contrasts may also be inherently salient. To test this, Archer (2012) investigated 14-month-olds’ mapping of acoustically salient contrasts to objects (e.g., leet versus reet). Results from this study demonstrated that when two minimally different words have acoustically salient liquid onsets, 14-month-olds will successfully map access this information in the Switch task.

Overall, these findings demonstrate how the Switch task has been used to examine infants’ word learning ability and the influence that different properties of speech can have on infants’ word-object associations.
Developing Phonological Knowledge

Although the previously described research illustrates that infants can access and use different properties of the native language, depending on the task and the salience of the contrast, in word-object associative learning tasks, it is unclear, however, whether infants’ knowledge of their native language sound patterns constrains the types of forms infants will map to objects. During the first year of life, infants become attuned to the unique sounds of their native language and begin to refine their perceptual sensitivity to speech sounds found within this language system (Kuhl et al., 2006; Werker & Tees, 1984). For example, infants begin by discriminating both native and non-native phonetic contrasts, however, by 6-12 months of age, they show a decline in discrimination of many non-native distinctions and an enhancement of sensitivity to native ones (Kuhl et al., 1996; Polka et al., 2001; Saffran et al., 2006; Werker & Curtin, 2005; Werker & Yeung, 2005). These changes in perceptual sensitivity that occur in the first year of life can be viewed as a functional reorganization in that infants shift their attention to language-specific properties of their native language. This shift in attention is considered an advantage rather than a loss, in that infants’ increased sensitivity to properties of their native language may facilitate their ability to effectively segment words from fluent speech and eventually map sound sequences to meaning (Mattys & Jusczyk, 2001; Pelucchi, Hay & Saffran, 2009; Saffran, Aslin, & Newport, 1996). However, as demonstrated above, infants still have difficulty detecting minimal contrasts (e.g., bih versus dih) in a word-object associative learning task suggesting that while more focused discrimination of native-language speech sound categories is emerging over the first year of life, this information may not be used in the early stages of word learning. During the first year of life, infants are also becoming increasingly sensitive to many other phonological properties of the native language. By 9-10 months of age, monolingual infants can
discriminate between words composed of phoneme sequences with high transitional probabilities versus words that contain either illegal or low probability sequences (Jusczyk, Friederici, Wessels, Svenkerud & Jusczyk, 1993; Jusczyk, Luce & Charles-Luce, 1994). In artificial language learning studies, infants can also use the distributional statistics to learn about the speech sound combinations (phonotactics) of their native language (Chambers et al., 2003; Saffran & Thiessen, 2003). For example, Saffran & Thiessen (2003) found that when 9-month-olds were given the opportunity to induce specific phonological patterns through a pattern induction phase (i.e., syllable structure, consonant voicing position, and segmental position), infants were able to extract new phonological regularities when tested on these patterns during a word segmentation task. Indeed, by 9-months of age infants are also sensitive to type frequency of onset clusters in their native language (Archer & Curtin, 2011).

Infants’ increased sensitivity to statistical regularities of their native language supports their ability to recognize and segment words from fluent speech on the basis of their distributional and phonological properties (Lany & Saffran, 2011; Mattys & Jusczyk, 2001; Pelucchi, Hay & Saffran, 2009; Saffran, Aslin & Newport, 1996). For example, infants from an early age can differentiate word classes on the basis of their unique phonological, and distributional properties (Shi, Werker, & Cutler, 2006; Shi & Gauthier, 2006; Shi & Lepage, 2008). That is, newborns can discriminate between function words and content words, which differ on a number of phonological dimensions such as the type of vowel and word stress (Shi & Werker, 2001). By 9-months of age, infants can distinguish words based on their length, stress patterns and phonotactic properties and by 12-months, can track the distributional properties of words (Hohle, Weissenborn, Kiefer, Schulz & Schmitz, 2004; Jusczyk, Cutler & Redanz, 1993; Mintz, 2006; Spring & Dale, 1977). Furthermore, by 12-months of age, infants can form
rudimentary word categories when they are marked by correlated distributional and phonological cues (Gomez & Lakusta, 2004; Lany & Gomez, 2008; Lany & Saffran, 2011). Taken together, these findings suggest that infants may possess a distributional mechanism that can track the different phonological, prosodic, and distributional cues of different categorical word classes in their native language. If this is the case, this ability may be beneficial in the acquisition of language, whereby infants are able to attend to and recognize word forms in the speech stream that carry meaning and are used to make word-object mappings (i.e., noun-like words).

**Early constraints on word-object associations**

By their first birthday, infants can recognize and track the unique characteristics of the native language including the phonological, phonotactic and distributional properties of different word classes. Given infants’ knowledge about the properties of their native language, it may be the case that infants’ word learning ability is shaped by their experiences with speech. That is, infants’ emergent phonological knowledge about their native language may guide or constrain that types of words infants are willing to map to objects.

Recently, the investigation of early-emerging constraints on infants’ word learning has become a topic of interest. For example, work by Graf-Estes, Edwards & Saffran (2011) demonstrated that by 18-months of age, infants’ acquired knowledge of their native language constrains the types of words infants are willing to map to objects. That is, 18-month-olds will only map phonotactically legal, and not phonotactically illegal word forms, to objects when presented in a looking while listening paradigm. May & Werker (submitted) recently demonstrated that 14-month-olds, but not 20-month-olds will map unassimilable clicks to objects when provided with a referential training phase. These findings suggest that when young infants are provided with an additional cue that clarifies the nature of the Switch task, 14-month-olds
will demonstrate a shift in mapping labels that contain an illegal phoneme to novel objects. Interestingly however, 20-month-olds failed to map the clicks regardless of whether the referential training phase was provided, suggesting that a developmental narrowing is occurring between 14- and 20-months of age in infants’ awareness of what an appropriate label may be in their native language and their willingness to accept forms that contain illegal sounds as labels for objects. Recently, the impact of infants’ understanding of the distributional and phonological features of lexical versus grammatical word forms on early word learning has also been investigated (Hochmann, Endress, & Mehler, 2011). Hochmann et al. demonstrated that 17-month-olds recruited their knowledge of grammatical class when in a word learning context and relied on the distributional properties of word forms (i.e., frequency of occurrence during a familiarization phase) to guide their ability to map content words to objects. Finally, further support for constraints on early word learning comes from recent work by MacKenzie, Graham & Curtin (2011) who investigated 12-month-old infants’ mappings of a variety of linguistic sounds to objects when presented within an associative word-learning context. Using the Switch task procedure, MacKenzie et al. demonstrated that infants mapped CVC words (e.g., /fep/) but not communicative sounds (e.g., /mmm/) or consonantal sounds (e.g., /ll/) to objects. That is, in an associative learning context, infants as young as 12-months of age demonstrate a preference for words and not other linguistic sounds as labels for objects.

Overall, these studies provide evidence that by 12-months of age, infants’ word-object mappings are constrained to words over other linguistic forms, and by 17-18-months of age, infants’ knowledge about the phonotactic, phonological and distributional properties of their language can guide their word learning ability. It is unclear however, to what degree infants’ knowledge of their native language influences their understanding of what an appropriate label is
by 12-months of age. Recall, recent work by MacKenzie and colleagues (2011) demonstrated that by 12-months of age, infants show a preference for well-formed words over other linguistic sounds as object labels. Although these findings provide evidence for a preference for mapping words over other linguistic sounds as object labels, it is unclear whether 12-month-olds’ bias for word forms as object labels is guided by their acquired knowledge of their native sound system. Furthermore, if it is the case that infants’ knowledge of their native language constrains their word learning ability, under which word-learning contexts will this bias be activated?

**Introduction to Dissertation Chapters**

In the following three Chapters, I examine 12-month-olds’ association of novel words with novel objects with specific focus on the following questions: 1) Does 12-month-olds’ phonological knowledge (i.e., knowledge of native-language phonotactics and native-language phonetic realizations of phonemes) influence their tendency to map sound forms to objects; 2) Does the organization of word forms based on their phonological and acoustic shape (i.e., content versus function words) constrain 12-month-olds word-object mappings and 3) Does 12-month-olds’ established preference for well-formed, phonotactically legal words as object labels act as a default bias that can be overridden when provided with referential cues that highlights the purpose of the Switch task.

In Chapter 2, I examine whether infants’ sensitivity to the linguistic properties that correspond to their native language extends to the types of words infants are willing to accept as labels for objects. More specifically, I pursue the question of whether infants’ preference for words as object labels is impacted by native-language phonotactics and/or the phonetic realizations of native language sound categories (phonemes). Across two studies, I compare 12-month-olds’ acquisition of novel English word-object pairings to their acquisition of forms that
violate native-language phonotactics (Czech) or forms that violate the low-level phonetic realization of phonemes (Japanese). Results from this chapter indicate that by 12-months of age, infants are beginning to apply their language-specific knowledge to their acceptance of word forms and thus, will not map words that violate the phonotactics of their native language to objects.

In Chapter 3, I examine whether 12-month-olds’ acquired knowledge about the types of sound patterns that accompany an object label influence their expectations of what an appropriate label should be for a referent. More specifically, I examine whether infants will treat content versus function word forms differently in a sound-object associative task. Across two studies, I compared 12-month-olds’ ability to map novel word forms that are representative of English function words and English noun labels to objects. Results from this chapter indicate that 12-month-olds distinguish between different types of word forms on the basis of their phonological and acoustic properties and use this knowledge to guide their expectations as to what an appropriate word is for an object label.

In Chapter 4, I examine the parameters of 12-month-olds’ preference for well-formed phonotactically legal word forms. In particular, I examine whether infants will override their bias for specific words as object labels when provided with a training phase that clarifies the referential role of these labels. To address this question, I contrasted 12-month-olds’ mappings of three different types of forms to objects in a modified referential Switch task (Fennell & Waxman, 2010): phonotactically illegal CCVC words, consonantal sounds, and novel function-like words. Results from this chapter indicate that infants will demonstrate flexibility in the types of linguistic forms they will map to objects, however, this flexibility appears to be constrained to
structural well-formed words that share the structural properties of noun-like words, even when the referential role of these labels are clarified.

In the final Chapter, I discuss how infants’ developing perceptual systems of their native language guides their understanding of what an appropriate word is for an object label, the mechanisms that may be driving this established preference for specific word forms and what impact these early preferences has on infants’ developing lexicon. Limitations to the research included within these chapters and a future direction for research in this area is also addressed.
The following chapter is a reproduction of a published work, for which permission has been granted by the publishers, John Wiley and Sons (License # 3014540200013), for the use in this dissertation, The influence of context and form on 12-month-olds’ sound-object associations. I was the primary investigator and main contributor for the publication entitled, 12-month olds’ phonotactic knowledge guides their word-object mappings, in the journal Child Development, and was responsible for the conception, design, data collection and analysis with Dr. Suzanne Curtin and Dr. Susan A. Graham serving as my supervisors. A portion of the data from Experiment 1 in this manuscript was presented in my Masters of Science thesis.

Chapter Two: 12-month-olds’ phonotactic knowledge guides their word-object mappings

Infants approach language learning with relatively open systems that gradually become more specified over time (Waxman & Lidz, 2006). Here, we ask whether 12-month-old infants have acquired knowledge about what constitutes an appropriate phonological form for an object label. That is, we examine whether infants will accept words that differ phonologically and phonetically from their native language as object labels in an associative learning task.

During the first year of life, infants begin to hone in on the characteristics of speech found within their native language. This movement from a ‘language general’ to ‘language specific’ shift in the processing of linguistic stimuli has been clearly illustrated in the change in abilities that occurs as infants become specialized in processing their native language (e.g., Werker & Tees, 1984; Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992). Seminal research has demonstrated that 6- to 8-month-olds can discriminate between consonant contrasts that are used within their native language and in unfamiliar foreign languages. Around 10-months of age, however, infants only distinguish contrasts that occur in their native language (Werker & Tees, 1984). This pattern of experience-based winnowing has been found to occur earlier for the acquisition of vowels (Bosch & Sebastian-Galles, 2003; Kuhl et al., 1992). This shift from language-general to language-specific perception reflects a functional reorganization, rather than a loss (Werker, 1995), as infants attend to language-specific properties of their native language, allowing them to effectively discover word and phrase boundaries.

In addition to tuning into the ambient language’s speech sound categories, infants must determine their language’s legal speech sound co-occurrences. By 9-months of age, infants can discriminate between legal and illegal sound combinations (Jusczyk, Friederici, Wessels,
Svenkerud, & Jusczyk, 1993). They also recognize more probable speech sound combinations and positions (Jusczyk, Luce, & Charles-Luce, 1994), and prefer listening to legal sound combinations in legal positions (Friederici & Wessels, 1993). This awareness of phonotactic probabilities by 9-month-olds extends to positions within and across word-boundaries (Mattys, Jusczyk, Luce & Morgan, 1999). Thus, by 9-months infants have developed sensitivity to legal sound combinations and to positional constraints on sound combinations at word beginnings and endings for their native language.

Although the research described above provides compelling evidence that infants begin to narrow their sensitivity to linguistic properties that correspond to their native language by the end of their first year, it is unclear whether this knowledge is recruited when learning new words. Indeed, there is evidence that 14-month-olds do not use their native-language sound categories when engaged in a word-object associative learning task (Stager & Werker, 1997). Even at 15-months, infants only form mappings between novel words and objects with a subset of native-language vowel categories (Curtin, Fennell, & Escudero, 2009), and results from interactive object categorization tasks demonstrate that 20-month-olds confuse novel words that minimally differ in their vowel, while succeeding in distinguishing words that minimally differ in consonants (Nazzi, 2005; Nazzi & New, 2007). Further evidence that infants’ knowledge about their native language is not necessarily recruited into word learning comes from studies demonstrating that young infants are flexible in the range of forms that they will accept as object labels when these forms are presented in an interactive naming task (e.g., Namy & Waxman, 1998; Woodward & Hoyne, 1999). For example, 12-month-olds will map nonverbal mouth noises (e.g., “psst”) to objects using an interactive preferential looking paradigm (Hollich, Hirsh-Pasek, & Golinkoff, 2000). This general symbolic openness begins to narrow towards the end of
the second year when infants begin to accept only words as object names (e.g., Graham & Kilbreath, 2007; Namy & Waxman, 1998). Together, these findings suggest that while a great deal of language learning, including knowledge about native-language phonology, has taken place over the first 2-years, this information is not always accessible or used when learning new words.

In these experiments, we pursued the question of whether infants’ sensitivity to the linguistic properties that correspond to their native language extends to the types of words infants are willing to accept as labels for objects. We ask what kinds of constraints on word forms, if any, do infants possess at the onset of their productive language? Specifically, we examine whether such constraints are limited solely by native-language phonotactics or whether the phonetic realizations of phonemes also impact word learning. To this end, we compare 12-month-olds’ acquisition of novel English word-object pairings to their acquisition of forms that violate native-language phonotactics (Czech) or forms that violate the low-level phonetic realization of phonemes (Japanese).

Experiment 1

We examined whether 12-month-olds accept words that differ phonologically and phonetically from their native language as object labels in an associative learning task. We contrasted different types of ‘noun-like’ forms that vary in their phonological similarity to English content-type words. To directly compare infants’ mappings of illegal CCVC words versus legal CCVC words, we used CCVC Czech words that contain sound combinations that are illegal in English (i.e. violate English phonotactics) and legal CCVC English words. To compare infants’ mapping of phonologically legal sequences that differ phonetically from English, we presented novel phonologically legal CVCV English words and CVCV Japanese
words. That is, we used Japanese words containing a high vowel (/i/), which devoices when not contiguous with a voiced sound (Comrie, 1990).

If infants are open in what they consider to be an appropriate label for an object, then they should learn the word-object pairings for all types of word forms. However, if infants have refined their preferences for object labels to words that parallel their established expectations for a well-formed object label in English, then there are two possible outcomes. Infants may only accept the novel English forms and reject the Czech words and the Japanese words. However, it is possible that infants only focus on the legality of sound sequences and do not consider lower-level phonetic cues. If this is the case, they will accept the Japanese forms, but not the Czech words.

Method

Participants

Sixty 12-month-old infants from English-speaking homes were included in the final sample. An additional 16 infants were excluded from the sample for the following reasons: did not complete (n = 2), failure to habituate (n = 6), technical error (n = 3), excessive fussiness (n = 4), and parental interference (n = 1). Infants were randomly assigned to one of four between-subjects groups: the CVCV English, the CVCV Japanese, the CCVC Czech, or the CCVC English word group. See Table 1 for demographics. Infants did not differ significantly in age (p = .33) or productive vocabulary size across groups (p = .70).
Table 1

*Mean Ages, Mean Productive Vocabulary Size, and Gender Distribution by Group*

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean Age (SD)</th>
<th>Age Range</th>
<th>CDI production (SD)</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVCV English</td>
<td>15</td>
<td>12.43 (.27)</td>
<td>12.03-12.95</td>
<td>2.33 (2.69)</td>
<td>6 girls</td>
</tr>
<tr>
<td>CVCV Japanese</td>
<td>15</td>
<td>12.61 (.35)</td>
<td>12.07-12.95</td>
<td>2.93 (2.98)</td>
<td>8 girls</td>
</tr>
<tr>
<td>CCVC Czech</td>
<td>15</td>
<td>12.60 (.27)</td>
<td>12.03-12.95</td>
<td>3.6 (2.97)</td>
<td>8 girls</td>
</tr>
<tr>
<td>CCVC English</td>
<td>15</td>
<td>12.49 (.33)</td>
<td>12.06-12.95</td>
<td>3.13 (3.25)</td>
<td>6 girls</td>
</tr>
</tbody>
</table>

*Stimuli*

The visual stimuli were videotapes of three novel objects (See Table 2). The auditory stimuli presented during habituation and test trials consisted of eight exemplars of each of the following words: two novel CVCV English words: *mido* [maɪdoʊ] and *panu* [pænu]; two CVCV Japanese words: *sika* [ʃɪkə] (deer), and *hashi* [haʃi] (chopsticks); two CCVC Czech words: *ptak* [ptɑk] (bird) and *svet* [svɛt] (world); and two novel CCVC English words: *snet* [snɛt] and *plok* [plɑk]. The pre- and post-test trials words were: *tega* [teɪɡa] (CVCV English word group), *tega* [tega] (CVCV Japanese word group), *dluh* [dluɦɪ] (CCVC Czech word group) and *frim* [frɪm] (CCVC English word group). Using infant-directed speech, female native speakers recorded the English, Japanese, and Czech words (see Table 3 for acoustic measurements of the stimuli).
Table 2

*Outline of Switch Task Design*

<table>
<thead>
<tr>
<th>Pre-test Trial</th>
<th>Habituation Trials</th>
<th>Test-Trials</th>
<th>Post-test Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterwheel/ Word C</td>
<td>Object A/Word A</td>
<td>Same Trial</td>
<td>Waterwheel/ Word C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Object A/ Word A</td>
<td></td>
</tr>
<tr>
<td>Object B/ Word B</td>
<td>Switch Trial</td>
<td>Object B/ Word A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3

*Fundamental Frequency (F0) and Duration (sec) for Stimuli*

<table>
<thead>
<tr>
<th>Language/Syllable Structure</th>
<th>Word</th>
<th>F0 (SD)</th>
<th>Duration (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English/CVCV</td>
<td>mido</td>
<td>299.75 (18.09)</td>
<td>1.34 (.06)</td>
</tr>
<tr>
<td></td>
<td>panu</td>
<td>302.5 (11.6)</td>
<td>1.19 (.08)</td>
</tr>
<tr>
<td>Japanese/CVCV</td>
<td>hashi</td>
<td>256 (66.15)</td>
<td>.65 (.07)</td>
</tr>
<tr>
<td>(differ phonetically)</td>
<td>sika</td>
<td>263.12 (46.29)</td>
<td>.66 (.06)</td>
</tr>
<tr>
<td>English/CCVC</td>
<td>plok</td>
<td>291.62 (21.24)</td>
<td>.85 (.04)</td>
</tr>
<tr>
<td></td>
<td>snet</td>
<td>322.12 (18.7)</td>
<td>.86 (.03)</td>
</tr>
<tr>
<td>Czech/CCVC</td>
<td>ptak</td>
<td>318.75 (8.13)</td>
<td>.80 (.05)</td>
</tr>
<tr>
<td>(illegal phonotactics)</td>
<td>svet</td>
<td>325.75 (29.2)</td>
<td>.96 (.05)</td>
</tr>
<tr>
<td><strong>Experiment 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English/CVCV</td>
<td>mido</td>
<td>247.33 (6.47)</td>
<td>.65 (.04)</td>
</tr>
<tr>
<td></td>
<td>panu</td>
<td>286 (21.08)</td>
<td>.74 (.03)</td>
</tr>
<tr>
<td>Japanese/CVCV</td>
<td>hashi</td>
<td>303 (20.68)</td>
<td>.71 (.07)</td>
</tr>
<tr>
<td></td>
<td>sika</td>
<td>368.5 (15.08)</td>
<td>.65 (.06)</td>
</tr>
</tbody>
</table>

In order to ensure that non-native words were sufficiently different from English, we asked 27 adults to rate the words on a Likert-type scale (1 = Sounds like a possible English word to 7 = Does not sound like a possible English word). Raters heard the words in randomized orders with the sound of piano keys inserted between the words to control for carryover or
contrast effects. Adults rated the Japanese ($M = 6.03, SD = 1.01$), and Czech ($M = 4.91, SD = 1.05$) words as significantly different from the CCVC English ($M = 2.91, SD = 0.79$), and CVCV English ($M = 3.24, SD = 1.34$) words in the expected direction ($ps < .001$). There were no significant differences in the ratings of the CCVC English ($M = 2.91, SD = 0.79$) and CVCV ($M = 3.24, SD = 1.34$) English words ($p > .20$).

**Apparatus**

Testing took place in a dimly light sound-proof room. While sitting on their parent’s lap or in a high chair, infants faced a 122 cm x 91.5 cm video monitor. During testing, each parent wore headphones and listened to masking music. All words were presented at a consistent volume (65 dB, $+/-$ 5 dB) across groups from a speaker located directly below the monitor. Infants were recorded and video was used for frame-by-frame coding and primary coding. The experiment was run using the Habit X 1.0 program (Cohen, Atkinson, & Chaput, 2004).

**Procedure**

Infants were tested using a modified habituation paradigm known as the Switch task (Werker et al., 1998; See Table 2). The procedure followed for all four groups was identical – all that varied across groups were the words presented. Each infant was shown the same sequence of trials, which were each 20 seconds in duration. The pre-test and post-test trials, which consisted of a novel word-object pairing, were included to control for fatigue or disinterest.

Testing began with a pre-test trial followed by the habituation phase, during which infants were presented with two sets of word-object pairings. Infants in the CVCV English word group were presented with two CVCV English word-object combinations presented alternatively (e.g.: *mido* paired with Object A and *panu* paired with Object B). Infants in the CVCV Japanese
word group were presented with two CVCV Japanese word-object combinations presented alternately (e.g., hashi paired with Object A and sika paired with Object B). Infants in the CCVC Czech word-object group were presented with two Czech word-object combinations presented alternately (e.g., svet paired with Object A and ptak paired with Object B). Finally, infants in the CCVC English word group were presented with two sets of novel CCVC English word-object pairings presented alternatively (e.g., snet paired with Object A; and plok paired with Object B). For each group, the particular word that was associated with a particular object was counterbalanced. All groups were presented with these word-object pairings in a semi-random order until looking time decreased to a set criterion (65%) or until a maximum of 24 trials were completed. The habituation criterion was met if an infant decreased their looking time by at least 65% (a 35% decrement) of that of the first block of four trials during any of the following five blocks. If the infant reached the habituation criterion before the sixth block of four trials, then the test phase would begin. Infants that did not reach the habituation criterion were excluded from the final analyses.

Following habituation, infants were presented with two test trials in counterbalanced order: the Same trial and the Switch trial. During the Same trial, infants were presented with a familiar object-word (e.g.: mido paired with Object A). During the Switch trial, infants were presented with a familiar object and word but with the familiar pairing violated (e.g., mido paired with Object B). These trials were followed by the post-test trial.

**Coding**

Online coding was only used to determine if infants habituated to the word-object pairings. For the critical trials (i.e., pretest trial, last four habituation trials, two test trials and the posttest trial), infants’ looking times were coded on a frame-by-frame basis. To measure inter-
rater reliability, 20% of the data \((n = 12)\) was coded by a second coder. Intraclass correlations (ICCs) coefficients for looking time responses were .99 \((ps < .001)\).

Results

To ensure that infants regained attention at the end of the task, we examined looking time during the pre-test, post-test, and last habituation block. See Table 4. Results of a 4 (Group) x 3 (Trial: Pre-test, Post-test, Last Habituation Block) ANOVA yielded only a main effect of trial \((p < .001)\). Infants’ looking times did not differ significantly between the pre-test trial and the post-test trial \((p > .99)\) but they did look significantly longer to the pretest compared to the last block of habituation trials and to the post-test compared to the last block of habituation trials \((ps < .001)\). A comparison of the number of habituation trials revealed no significant differences across groups \((p = .19)\). Together, these analyses indicate that infants in all groups recovered from habituation and did not differ in the number of trials required to habituate.

Table 4

*Mean Looking Times and Number of Habituation Trials by Group for Pre-Test, Post-Test and Last Habituation Block*

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Last Habituation block</th>
<th>Average No. of Habituation Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVCV English</td>
<td>15.09 (3.86)</td>
<td>15.45 (4.52)</td>
<td>6.78 (2.39)</td>
<td>13.87</td>
</tr>
<tr>
<td>CCVC Japanese</td>
<td>16.19 (3.41)</td>
<td>17.40 (2.67)</td>
<td>6.53 (1.37)</td>
<td>16.00</td>
</tr>
<tr>
<td>CCVC Czech</td>
<td>15.99 (3.25)</td>
<td>15.28 (4.03)</td>
<td>6.83 (2.06)</td>
<td>12.53</td>
</tr>
<tr>
<td>CCVC English</td>
<td>18.47 (1.79)</td>
<td>17.61 (2.45)</td>
<td>6.67 (2.10)</td>
<td>15.73</td>
</tr>
</tbody>
</table>

*Note.* Standard deviations in parentheses
The primary analyses compared infants’ performance during the Same and Switch test trials across groups. See Figure 1 for mean looking times by test trial and group. Recall that if infants have associated the words with the novel objects, their looking times should be significantly longer during the Switch trial than during the Same trial. A 4 (Group) x 2 (Trial Type: Same, Switch) mixed factor ANOVA yielded a significant main effect of trial type, \( F(1, 56) = 37.90, \eta_p^2 = .40, p < .0001 \), and a group by trial type interaction \( F(1, 56) = 3.28, \eta_p^2 = .15, p = .03 \). To understand the source of this interaction, pairwise comparisons were used to compare looking times during the Switch and Same trials for each group. Results indicated that infants looked significantly longer during the Switch trial versus the Same trial in the English CVCV word group, \( t(14) = 3.53, d = .733, p < .01 \); the English CCVC word group \( t(14) = 5.17, d = 1.78, p < .001 \) and the Japanese CVCV word group, \( t(14) = 2.86, d = .88, p < .05 \). The majority of infants in the English CVCV group (13/15), in the English CCVC group (14/15) and in the Japanese CVCV group (11/15) looked longer to the Switch trial than the Same trial. In contrast, infants in the CCVC Czech word group did not look significantly longer during the Switch trial versus the Same trial, \( p > .43 \), indicating that 12-month-olds did not map Czech words to objects. Here, only 7 of 15 infants looked longer to the Switch trial than the Same trial.
Figure 1. Differences in mean looking time for the Same and Switch Trials by group

Note. Significant differences (i.e., $p < .05$) between Same and Switch Trials are indicated by *

Discussion

These results demonstrate 12-month-olds accept CVCV English, CCVC English, and CVCV Japanese words, but not CCVC Czech words which are phonotactically illegal in English, as labels for objects. This pattern likely reflects infants’ sensitivity to the phonotactic properties of their native language and indicates that they will not map illegal word forms to objects in an associative task. However, the finding that infants will accept Japanese words as labels suggests that their word learning is not constrained by phonetic differences on the realization of
phonemes. It is possible, however, that infants were simply not sensitive to the differences in the English and Japanese CVCV forms, even though adults rated the Japanese forms used in this study as not native-like. To address this possibility, we next asked whether infants prefer CVCV English over CVCV Japanese word forms.

Experiment 2

Method

Participants

Sixteen infants were included in the final sample (9 female; mean age: 12.51, SD = .31).

Stimuli

Six tokens of each of the two CVCV English words (i.e., *mido* and *panu*), and six tokens of each of the two CVCV Japanese words (i.e., *sika* and *hashi*) used in Experiment 1 were presented. To control for any influence of voice quality, both sets of words were recorded by a Japanese-English bilingual female speaker (see Table 2 for F0 and durations).

Apparatus and Procedure

The apparatus used for testing was identical to Experiment 1. Infants were tested using an infant-controlled sequential looking preference (SLP) procedure (Cooper & Aslin, 1990, 1994; Vouloumanos & Werker, 2004). Each trial took the following form: Infants first were presented with a flashing colored ball to attract their attention to the screen. Once the infant fixated on the screen, the trial began. On each trial, a static black and white checkerboard was displayed while one set of words was played from a speaker below the screen. Stimulus presentation on each trial was infant-controlled. That is, the sound and checkerboard were presented for as long as the infant looked at the screen. When the infant looked away continuously for longer than 1 second, the stimulus presentation terminated and the next trial began.
Each infant was presented with a total of 10 trials, five English word trials alternated with five Japanese word trials. A full trial consisted of 14 tokens chosen randomly from the set of 12 tokens, separated by 300 to 500 ms silence, for a maximum length of 20 seconds per trial. For any given trial, tokens were ordered in a semi-random order so that every fixed window of four tokens included at least two of each word (i.e., two mido exemplars and two panu exemplars and two sika exemplars and two hashi exemplars). For half the infants (N = 8), trial order was reversed.

Infants’ looking times were coded on a frame-by-frame basis. Inter-rater reliability for 20% of the data (n = 3) was high (ICCs = .99, ps < .001).

Results and Discussion

As is standard with the SLP procedure, the first trial was excluded from the analysis (Cooper & Aslin, 1994). Since order of presentation was counterbalanced, an equal number of English and Japanese trials were excluded. Using the remaining nine trials, we calculated each infant’s total looking time for each type of word, English or Japanese. We then compared looking time during the English versus Japanese trials. Results indicated that infants looked significantly longer during the English trials (M = 5.62, SD = 2.98) than the Japanese trials (M = 3.67, SD = 1.73), t(15) = 3.82, d = 0.80, p < .01.

The results demonstrate that 12-month-olds are sensitive to the phonetic distinction between CVCV English words and CVCV Japanese words and show a preference for listening to CVCV English words over CVCV Japanese words.

General Discussion

Infants’ shift from language-general to language-specific processing has been well-documented during the first year of life. The results of these experiments offer insight into
whether this attunement to the properties of their native language is reflected in infants’ willingness to attach words from different languages to objects in an associative learning task. When presented with a variety of word forms, 12-month-olds will attach novel CVCV English, CVCV Japanese (even though these are phonetically different from English), novel CCVC English words, but not CCVC Czech words (which are phonotactically illegal in English), to objects when presented in an associative learning paradigm. These results demonstrate that by 12-months of age, infants are beginning to apply their language-specific phonotactic knowledge to their acceptance of word forms. That is, they will not map words that violate the phonotactics of their native language to objects.

Infants treated the English and Japanese words similarly in that they mapped both types of words to the objects. This similarity in performance suggest that that infants recognized both words as object labels that parallel their established expectations of what constitutes as a word. That is, although the Japanese words are phonetically different from English, they did not differ enough from infants’ native language to be dismissed as a potential label. This finding is impressive, given that same-aged infants prefer listening to English forms over Japanese words and adults rated the Japanese words as different from English. In contrast, the CCVC Czech words violated English phonotactics with illegal consonant cluster onsets (i.e., /pt/ and /sv/). The finding that infants mapped both CVCV English and CCVC English words to objects, suggests that it is the illegal consonant clusters, not the syllable structure of the Czech words, that influenced infants’ willingness to map these words to objects.

Given that infants have honed in on native-language sound combinations (phonotactics), it is quite possible that their failure to map these illegal forms to objects stems from a lack of similarly structured forms in their lexicon. That is, since these forms violate English phonotactics
and no such forms exist in the infants’ lexicon, they are resistant to mapping the Czech words to objects. An alternative, yet compatible, explanation is that lexical neighborhood density (Bailey & Hahn, 2001) is driving English infants’ resistance to map Czech words onto novel objects. Here, a neighborhood is determined by the addition, subtraction, or substitution of a sound (e.g. Charles-Luce & Luce, 1990; Vitevitch & Luce, 1998). Words that have less dense neighborhoods, in this case the Czech forms, will be unlikely word candidates. While both possibilities can help to explain why infants do not map the Czech forms, given the size of a 12-month-old lexicon (expressive CDI < 4 words; receptive CDI mean = 19.95), all neighborhoods at this stage of development may be sparse. However, further research is required to determine if this is indeed the case.

Our findings demonstrate that while phonotactics do constrain infants’ word-object mappings, differences in the phonetic realization of the forms do not. The phonetic realization of the Japanese words used in our study differs only in subtle ways from English. Infants’ acceptance of these forms is consistent with findings demonstrating that 9-month-olds are tolerant of novel words produced in accented speech (Schmale & Seidl, 2009). Thus, 12-month-olds may not have fully refined their preferences to focus exclusively on English phonology.

It remains to be determined whether infants would ever fully narrow their focus or whether some phonological variation from their native language would remain acceptable. Studies examining recognition of familiar words suggest that older infants rely on their abstract sound categories (phonemes) when confronted with words that vary in their pronunciation (phonology constancy; Best, Tyler, Gooding, Orlando, & Quann, 2009). This reliance on phonemes helps to explain the minimal pair findings where 17-month-olds, but not 14-month-olds, detect a mismatch in the word-object label (e.g. bih and dih; Stager & Werker, 1997). That
is, as the lexicon develops, infants can use phonemes to direct attention to the relevant information in a word-object associative task (Werker & Curtin, 2005). Thus, the changing system itself might obscure sensitivity to phonetic information in word learning.

In sum, we demonstrate that infants have acquired a significant amount of knowledge about their native language sound system by the end of the first year of life. This knowledge is reflected in their willingness to attach novel words to novel objects. Indeed, if a form is phonotactically illegal in the language, infants will not map this form to a novel object. This suggests that experience with the native language influences what is considered an acceptable label.
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The following chapter is a reproduction of a published work, for which permission has been granted by the publishers, John Wiley and Sons (License # 3036271149110), for the use in this dissertation, *The influence of context and form on 12-month-olds' sound-object associations*. I was the primary investigator and main contributor for the publication entitled, *Class matters: 12-month-olds’ word object associations privilege content over function words*, in the journal *Developmental Science*, and was responsible for the conception, design, data collection and analysis with Dr. Suzanne Curtin and Dr. Susan A. Graham serving as my supervisors.

Chapter Three: Class Matters: 12-month-olds’ word-object associations

Privilege content over function words

Word learning is at once seemingly effortless yet spectacularly complex. To learn a new word, infants must identify the relevant sound pattern in the speech stream and encode a phonological representation of that pattern. Next, they must establish a linkage between that sound pattern and an element in the environment. Once this linkage is formed, infants must appreciate that the new word can refer to entities that are beyond those immediately present, drawing upon their well-developed conceptual abilities (Waxman & Gelman, 2009). Here, we focus on one aspect of the word learning equation, namely, the development of an association between a word and an entity. In particular, we explore the nature of the associative mechanism in 12-month-olds, examining whether it is a broad associative ability or whether it is constrained to privilege particular word forms over others.

In natural languages, words can be classified broadly into two categories that serve critically different functions. Open class words are the content items of a language, such as nouns, verbs, and adjectives. Closed-class words are the functional elements that provide information about the grammatical relationships between words (i.e., articles, prepositions). These two word classes (i.e., content-like versus function-like words) can be reliably differentiated from one another based on a number of perceptual dimensions in English (Monaghan, Christiansen, & Chater, 2007), Mandarin, and Turkish (Shi, Morgan, & Allopenna, 1998). Compared to content words, function words tend to have short vowel duration, weak amplitude, and a simplified syllable structure (Monaghan, Christiansen, & Chater, 2007; Shi, Morgan, & Allopenna, 1998). On the basis of these acoustic and phonological differences,
human neonates can discriminate function words from content words (Shi, Werker, & Morgan, 1999).

Function words and content words also can be differentiated based on the frequency in which they occur in the speech stream. That is, there are typically far fewer function word types in any given language; however, each type generally occurs with high frequency. In contrast, content words, which tend to have a large number of word types, occur far less frequently. Recent work has demonstrated that infants will use the frequency cue of function words to recognize and store specific function words and to segment other words, in preparation for language acquisition (Shi, Cutler, Werker & Cruickshank, 2006a; Shi & Lepage, 2008). More specifically, both English and French preverbal infants use frequent function words (such as ‘the’), but not infrequent ones, to segment adjacent nouns. French-learning infants recognize and use familiar functors to segment potential vocabulary items somewhat earlier than English-learning infants, that is, by 8-months (Shi & Lepage, 2008). This earlier sensitivity to function words may be due to the specific prosodic and distributional properties of French functors, which may allow French infants to more easily encode specific forms. Overall, these findings suggest that infants are able to recognize the most frequent words of their language and use them as a cue to segment the continuous speech stream, which in turn, may assist in other aspects of language acquisition such as learning of word meanings. In support of this proposal, recent work by Hochmann, Endress & Mehler (2010) demonstrated that when 17-month-old infants were exposed to a foreign language (e.g., French), infants relied on differing distributional cues (i.e., frequency of occurrence during a familiarization phase) for function words and content words to determine which word in a two-word phrase should be mapped to an object (i.e., the content words). Interestingly, when these distributional cues were absent from the word-object mapping
task, infants did not use prosodic differences between the two classes of words to bias word learning. These results suggest, that when considering an unfamiliar language, infants’ preference to associate content-like words with objects results from distributional properties in the input, rather than from the specific acoustic or phonological properties of the words themselves.

Finally, function words and content words can also be differentiated based on their differing syntactic and semantic roles. For example, function words tend to precede or follow words with semantic properties (e.g., nouns in English are often preceded by determiners) and thus, provide particularly good distributional cues to word meaning (Lany & Saffran, 2011; Christophe, Millotte, Bernal, & Lidz, 2008). Recent work by Lany & Saffran (2011) demonstrated that 22-month-olds rely on both the phonological and distributional cues marking both these word categories to facilitate early word learning.

Thus, function words and content words can be differentiated based on their unique phonological, and distributional properties (i.e., including word frequency). As such, the initial recognition and processing of these two word classes may follow different developmental trajectories. In support of this proposal, studies with preverbal infants have shown differences in early processing of content words and function words (Shi, Werker, & Cutler, 2006; Shi & Gauthier, 2006; Shi & Lepage, 2008). For example, by 6-months of age, infants demonstrate a clear preference for listening to content words over function words (Shi & Werker, 2001) and by 7-8 months of age, infants begin recognizing and comprehending the meaning of familiar content words (Fenson, Dale, Reznick, Bates, Thal, & Pethick, 1994). English-learning infants from 10.5 to 13 months of age can discriminate real function words with varying frequencies from nonsense function words (Shady, 1996; Shafer, Shucard, Shucard, & Gerken, 1998), including
nonsense function words which are only minimally modified from real function words (Shi, Werker, & Cutler, 2006).

Overall, these findings suggest that by their first birthday, infants may possess a distributional mechanism that can track the different phonological, prosodic, and distributional cues of content-like and function-like word forms. Furthermore, by 17-months of age, infants’ discrimination of and preference for content word forms over function word forms guides their subsequent willingness to map particular word forms to objects (Hochman et al., 2010). In the following experiments, we investigate whether the organization of word forms based on their phonological and acoustic shape constrains the mechanism that associates novel words to their referents. In particular, we ask whether the ability to associate a sound pattern with an element in the environment represents a broad domain-general ability that is recruited to the word learning enterprise or whether this mechanism is refined to consider only particular sound patterns in the context of word learning. That is, when infants are presented with word forms that share similar phonological properties of function and content words, will infants treat these auditory stimuli differently when mapping them to objects? To answer this question, we focus on 12-month-old infants who are at the beginning stages of productive language. For infants at this stage of language acquisition, differentiating between word forms that map onto elements in the world and word forms that provide information about grammatical relationships would greatly restrict the pool of potential labels and thereby facilitate word learning. Indeed, recent literature has shown that by their first birthday, infants have begun to develop constraints on word-object associations. For example, 12-month-olds privilege consonantal information in word learning (Hochmann, Benavides-Varela, Nespor & Mehler, 2011) and demonstrate a preference for noun-
like words over other linguistic sounds as labels for objects (MacKenzie, Graham & Curtin, 2011).

To test whether infants will treat content word forms and function word forms differently in a sound-object associative task, we presented 12-month-olds with novel word forms that are representative of English function words and English noun labels (Expt. 1). We chose to compare infants’ ability to map function words and content words that were phonetically legal as opposed to forms outside of their native language (i.e., English) based on previous work demonstrating that 12-month-olds will not map novel content-like words to objects if they violate the phonotactics of their native language (MacKenzie, Curtin & Graham, in press). If the mechanism whereby infants associative novel words with objects is a broad associative mechanism, then infants will consider both types of words as possible labels for objects. If, however, the mechanism is attuned to particular forms, infants should map only those forms that have the properties of content words to objects.

In Experiment 2, we investigated whether infants’ willingness to map content versus function words was influenced by the way in which they are produced. That is, will 12-month-olds map co-articulated novel content words excised from a sentence to objects similarly as they map novel content words produced in isolation to objects? If infants’ preference for particular word forms as object labels is facilitated by the phonological properties of these lexical structures, then infants should map the excised novel content words to objects in the same way they map novel content words that are produced in isolation and therefore have no co-articulation with other words in the sentence.
Experiment 1

Method

Participants

Infants were randomly assigned to one of two groups: Function word (\(n = 16; \ M = 12.34\) months; \(SD = .29, 8\) girls) and Content word (\(n = 16; \ M = 12.46\) months; \(SD = .33, 8\) girls). Thirteen additional infants were tested but excluded from the final sample for the following reasons: (a) did not habituate (\(n = 4\)), (b) parental interference (\(n = 1\)), and (c) did not complete the task due to fussiness (\(n = 8\)). Infants in the content word and function word groups did not differ significantly in age (\(p = .11\)) or in productive vocabulary size (\(p = .38\)), as measured by the CDI short form. Finally, all infants were raised in monolingual English speaking households.

Stimuli

The words presented during the habituation and test trials consisted of nine exemplars of each of the following words: two novel function-like words: \(keh (/k\ /angle\) and \(iv (/v\ /angle\); and two novel CVC content-like words: \(fep (/f\ep/\) and \(wug (/w\ag/\). For presentation during the pre- and post-test trials: \(und (/\And/\ function word group), and \(dax (/d\æks/\ content word group) were recorded. A female native English speaker recorded all auditory stimuli. The average acoustic measurements and spectrograms of representative stimuli overlaid with the fundamental frequency (F0) are presented in Table 1.
Table 1. *Acoustic Measurements for Stimuli*

<table>
<thead>
<tr>
<th>Acoustic Measure</th>
<th>Function Words</th>
<th></th>
<th>Content Words</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre/Post Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>und</em></td>
<td><em>iv</em></td>
<td><em>keh</em></td>
<td><em>dax</em></td>
</tr>
<tr>
<td>Word Duration (sec)</td>
<td>.81 (.002)</td>
<td>.52 (.008)</td>
<td>.32 (.001)</td>
<td>.97 (.01)</td>
</tr>
<tr>
<td>Vowel Duration (sec)</td>
<td>.13 (.003)</td>
<td>.14 (.004)</td>
<td>.09 (.002)</td>
<td>.16 (.004)</td>
</tr>
<tr>
<td>Pitch (Hz)</td>
<td>197 (.05)</td>
<td>185 (2.2)</td>
<td>192 (2.61)</td>
<td>211 (5.86)</td>
</tr>
<tr>
<td>Segments</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Spectrogram</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: All items were produced in adult-directed speech (blue lines in spectrogram indicate pitch contour). Function words and content words in Expt. 2 were produced in carrier sentences in order to ensure appropriate phonetic realization. Amplitude was controlled. All items were presented between 65-70 dB.

The novel function-like words (i.e., *keh* and *iv*) were chosen for inclusion in this experiment because they are analogous to frequently used English function words, *the* and *is*. That is, these novel function words and their familiar counterparts (i.e., *iv/is* and *keh/the*) share similar vowel placement. This similarity allows our novel function-like words to capture key phonological characteristics of frequent function words. Furthermore, we produced these novel function-like words in sentences that captured the acoustic characteristics of frequent English function words (e.g., “*Keh* hog ran away” and “The stove *iv* hot to touch”). Each of the nine exemplars for the novel function-like words were approximately 0.32 - 0.52 seconds in duration, with a 1.4 - 1.6 second silent interval between exemplars, resulting in audio files of 20-seconds in duration. To ensure the acoustic characteristics of function words were captured by our function word stimuli (e.g., short vowel duration, weak amplitude); each novel function word
exemplar was spliced from a sentence (e.g., *keh hog ran away*) that was recorded in adult-directed speech. All stimuli were recorded in adult-directed speech to ensure we captured the prosodic and acoustic characteristics of natural sounding function words.

The novel content words (*fep* and *wug*) were chosen because they are representative of canonical English monosyllabic nouns and have been successfully used in other word learning studies using this paradigm (MacKenzie, Graham, Curtin, 2011). Each of the nine exemplars for the novel CVC content-like words were approximately 0.87-0.98 seconds in duration, with a 1.0-1.25 second silent interval between exemplars, resulting in audio files of 20-seconds in duration. Each of the CVC-content-like words was recorded in isolation as is typical of other word-object associative learning studies. To ensure that the exaggerated prosody typical of infant-directed speech was not responsible for engaging the infants and to make the content-like words more comparable to the function-like words, we recorded them using adult-directed speech.

The individual naturally produced tokens used in each condition varied in their overall duration (although not significantly). To ensure that each trial has the same number of repetitions of the tokens and a fixed length, the ISIs between tokens varied (although not significantly). Due to the between-subjects design of our study, infants were only exposed to either the function words or content words, which then controlled for any differences in the length of silent intervals provided between each word token in each 20-second trial.

The visual stimuli consisted of videotapes of three novel objects. Two of the novel objects, a black and blue molecule-shaped object (*Object A*) and a pink, yellow, and blue spiky-shaped object (*Object B*) were presented during the habituation and test trials. Following the procedures used in previous Switch task experiments (e.g., Werker, Cohen, Lloyd, Casasola, &
Stager, 1998), a white plastic water wheel was presented during the pre- and post-test trials. The auditory files containing the auditory stimuli were presented simultaneously with the video display to ensure that the infants were, in fact, mapping the word onto the object.

Apparatus

During testing, infants sat on their caregiver’s lap or in a high chair facing a video monitor in a sound-attenuated room. The words were delivered at 65 dB, +/- 5 dB from a speaker located directly below the monitor. Each trial had a fixed length of 20-seconds in duration and was initiated upon the infants’ fixation on the monitor. If the infant was looking away after a trial ended, a flashing light would be presented to attract the infants’ attention so that the next trial could begin. During the task, the caregiver wore headphones delivering music to mask the auditory stimuli. Looking time was monitored via a hidden digital video-camera which was then used for both frame-by-frame primary and reliability coding.

Procedure

Infants were tested using the Switch task (Werker et al., 1998). See Figure 1 for an outline of the task. During the habituation phase, infants were presented with two sets of word-object pairings. The presentation of the words was asynchronous with the movement of the objects. Infants in the content word group were presented with two content word-object combinations presented alternately (e.g., *fep* paired with Object A & *wug* paired with Object B). Infants in the function word group were presented with two function word-object combinations presented alternately (e.g., *iv* paired with Object A & *keh* paired with Object B). For both groups, the combination of each particular word (e.g., *fep* & *wug*) paired with a particular object (*Object A* or *Object B*) was counterbalanced across infants. For example, in the content word condition, half of the infants were habituated to *fep* paired with Object A and *wug* paired with Object B,
and the other half of infants were habituated to \textit{fep} paired with Object B and \textit{wug} paired with Object A. Similarly, in the function word condition, half of the infants were habituated to \textit{iv} paired with Object A and \textit{keh} paired with Object B, and the other half of infants were habituated to \textit{iv} paired with Object B and \textit{keh} paired with Object A. During habituation, multiple blocks of four habituation trials (a semi-random order of two tokens of each type per block) were presented until infant looking time decreased to at most 65\% of the longest looking block or until 24 trials were presented. After habituation, the program automatically shifted to the test phase. Infants that did not reach the habituation criterion were excluded from the analyses. The presentation orders were yoked across the two groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Habituation Phase</th>
<th>Test Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Same Trial</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>‘wug’</td>
<td>‘fep’</td>
</tr>
<tr>
<td>Function</td>
<td>‘iv’</td>
<td>‘keh’</td>
</tr>
</tbody>
</table>

\textit{Figure 1.} Schematic of testing conditions and phases.

In the test phase, each infant was presented with two counterbalanced trials: the \textit{Same} trial and the \textit{Switch} trial. During the \textit{Same} trial, infants were presented with a familiar word-object pairing (e.g.: \textit{fep}/Object A) heard during the habituation phase. During the \textit{Switch} trial, infants were presented with a familiar object and word but with the familiar pairing violated (e.g., \textit{fep}/Object B). Additionally, a novel word-object pairing was presented once as a pre-test
trial before the habituation phase and then again as the post-test trial, following the test phase to control for fatigue and/or disinterest in the test stimuli.

Coding

Online coding was used to determine if infants habituated to the word-object pairings during the habituation phase. For the critical trials (i.e., pre-test trial, last four habituation trials, two test trials, and the post-test trial), infants’ looking times to the object were coded on a frame-by-frame basis from videotapes. To measure inter-rater reliability, 20% of the data (n = 6 infants) was coded by a second coder. Intraclass correlations (ICCs) coefficients for looking time responses were .98 (all ps <.001).

Results

To ensure that any differences found on test trials were not a result of fatigue, we compared infants’ looking time during the pre- and post-test trial to determine if infants regained attention at the end of the task. See Table 2 for mean looking times by group for the pre-test, the post-test, the last habituation block as well as the average number of habituation trials. Results of a 2 (Group) x 2 (Trial: Pre-test vs. Post-test) ANOVA indicated that infants’ looking times on the pre-test and post-test trials did not differ significantly between groups (p =.17) or between the pre-test trial (M = 16.42, SD =3.25) and the post-test trial (M = 16.48, SD = 3.54), p = .95. Further analyses indicated that infants in both groups looked significantly longer during the post-test trial (M = 16.48, SD = 3.54) than during the last habituation block (M = 7.59, SD = 2.06), indicating that they recovered from habituation, p = .000. The average number of habituation trials did not differ significantly between the content word group (M = 14.50, SD = 4.82) and the function word group (M = 14.50, SD = 5.63) suggesting that attention to the word-object pairings during the habituation phase was similar across groups, p = .83.
Table 2

Mean Looking Times by Group for Pre-Test, Post-Test, Last Habituation Block and Average Number of Habituation Trials

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Last Habituation block</th>
<th>Average No. of Habituation Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Word</td>
<td>15.96 (3.86)</td>
<td>15.71 (3.87)</td>
<td>7.73 (2.15)</td>
<td>14.50 (4.82)</td>
</tr>
<tr>
<td>Function Word</td>
<td>16.89 (2.54)</td>
<td>17.24 (3.12)</td>
<td>7.46 (2.04)</td>
<td>14.50 (5.63)</td>
</tr>
<tr>
<td>Spliced-Content Word</td>
<td>16.79 (3.54)</td>
<td>17.18 (3.50)</td>
<td>7.27 (2.41)</td>
<td>14.93 (6.14)</td>
</tr>
</tbody>
</table>

Note. Standard deviations in parentheses

The primary analyses compared infants’ looking time during the Same and Switch test trials across groups. See Figure 2 for mean looking times by test trial and group. Recall that if infants have established word-object associations, their looking time should be significantly longer during the Switch trial than the Same trial. A 2 (Group) x 2 (Trial: Same, Switch) ANOVA yielded significant main effects of group, $F(1, 30) = 6.50, \eta^2_p = .18, p = .02$, and a group by trial interaction, $F(1, 30) = 4.41, \eta^2_p = .13, p = .04$. Pairwise comparisons indicated infants in the content word group looked significantly longer during the Switch trial ($M = 10.61, SD = 4.02$) than during the Same trial ($M = 7.72, SD = 3.32$), $t(15) = 2.71, d = .78, p = .02$. In contrast, infants in the function word group did not differ in their looking times during the Switch ($M = 6.68, SD = 3.00$) and Same trials ($M = 6.88, SD = 2.98$), $p = .85$. These results
demonstrate that 12-month-olds will only associate content-like words with novel objects, even though both groups of infants attended equally during habituation to the word-object pairings.

![Figure 2](image.png)

*Figure 2.* Mean looking times during Same and Switch Trials as a function of group.

**Discussion**

Our results demonstrate that infants’ willingness to associate sounds with objects is already constrained by 12-months of age. When presented with novel content and function word forms, 12-month-olds established associations between objects and novel content words, but not between objects and novel function words. Although these results suggest that 12-month-olds are
sensitive to differences between word forms when making word-object associations, it is possible that the difference in these word-object mappings may have been impacted by the way in which our stimuli were produced. That is, the function-like word forms were excised from sentences whereas the noun-like word forms were recorded in isolation. As a result, the stimuli that were excised from sentences (i.e., function-like words) were co-articulated with the adjacent words in the sentence, whereas the stimuli produced in isolation (i.e., content-type words) were not co-articulated with other words. Thus, infants’ differential mappings of content words versus function words may have resulted from the difference in stimuli preparation and not from infants’ sensitivity to the phonological differences between word classes. We address this possibility in Experiment 2.

Experiment 2

Here, we investigated 12-month-olds ability to establish linkages between objects and novel content-like word forms that are co-articulated and excised from continuous speech. If infants establish such mappings, they should look longer during the Switch trial than during the Same trial.

Method

Participants

Sixteen infants were included in the final sample ($M = 12.51$ months; $SD = .25$, 8 girls). Three additional infants were tested but excluded from the final sample as they failed to habituate. All infants were raised in monolingual English speaking households. Infants in
Experiment 2 did not differ significantly in age, \( p = .17 \), or in productive vocabulary size, \( p = .21 \), as measured by the CDI short form, from infants tested in Experiment 1.

**Apparatus and Procedure**

The apparatus and procedure were identical to Experiment 1; the only difference was the how content words were produced. See Table 1 for the average acoustic measurements and spectrograms of representative stimuli. The words used during the habituation and test trials consisted of nine exemplars of each of the following words: two novel CVC content-like words: \( fep \) (/fɛp/) and \( wug \) (/wʌg/) which were excised from the same sentence (i.e., “The \( fep \) has two legs” and “The \( wug \) has two legs”). This sentence context is comparable to that used in Experiment 1 for production of the function words. That is, the word that follows the production of the content words in Experiment 2 (and the function words in Experiment 1) begins with an \( h \), which is ‘placeless’ in English and has minimal articulatory effect on the preceding form. For presentation during the pre- and post-test trials, the word \( dax \) was recorded. All words were recorded by the same female native English speaker as in Experiment 1 and produced in adult-directed speech. Each of the nine exemplars for the novel content-like words were approximately 0.53 - 0.54 seconds in duration, with a 1.5 - 1.6 second silent interval between exemplars, resulting in audio files of 20-seconds in duration.

Infants’ looking times for the critical trials were coded on a frame-by-frame basis. Interrater reliability for 20% of the data (\( n = 3 \)) was high (ICCs = .99, \( ps < .001 \)).

**Results and Discussion**

To ensure differences found on test trials were not a result of fatigue, we compared infants’ looking time during the pre- and post-test trial. See Table 2 for mean looking times by group for the pre-test, the post-test, the last habituation block as well as the average number of
habitation trials. Analyses indicated that infants’ looking times on the pre-test and post-test trials did not differ significantly between the pre-test trial \((M = 16.93, SD = 3.47)\) and the post-test trial \((M = 16.78, SD = 3.73)\), \(p = .90\). Furthermore, infants looked significantly longer during the post-test trial \((M = 16.78, SD = 3.73)\) than during the last habituation block \((M = 7.11, SD = 2.42)\), indicating that they recovered from habituation, \(p = .000\). The average number of habituation trials for infants in the spliced-content word group \((M = 14.75, SD = 5.97)\) did not differ significantly from either the content word group \((M = 14.50, SD = 4.82)\) or function word group \((M = 14.50, SD = 5.63)\) in Experiment 1, \(p = .99\), suggesting that attention to the word-object pairings during the habituation phase was similar across groups.

The primary analyses compared infants’ looking time during the Same and Switch test trials. Results indicated that infants looked significant longer during the Switch trial \((M = 9.72, SD = 3.50)\) than during the Same trial \((M = 6.42, SD = 3.23)\), \(t (15) = 5.03, d = .98, p = .000\) (See Figure 2). Next, we compared infants’ looking time on the test trials to that of the content-word group and function word group in Experiment 1, using a 3(Group) x 2(Same vs. Switch) ANOVA. This analysis yielded a significant main effect of trial, \(F(1, 31) = 23.48, \eta^2_p = .13, p = .001\), a significant group by trial interaction, \(F(1, 45) = 4.25, \eta^2_p = .16 p = .02\), and no significant main effect of group \((p = .07)\). Follow up analyses comparing infants’ looking times on the Same trial revealed no significant differences across groups, \((p = .51)\). In contrast, infants’ looking times during the Switch trial differed significantly across groups, \(F (2, 47) = 5.43, \eta^2_p = .19, p = 0.01\). Follow up comparisons using Tukey HSD tests indicated that infants’ looking time on the Switch trial did not differ between the spliced-content word group and the content-word group from Expt. 1, \(p = 0.76\). Infants in both content-word groups, however, looked significantly
longer during the Switch trial than infants in the function word group, (i.e., content versus function, \( p = 0.01 \); spliced-content versus function, \( p = 0.049 \)).

These results demonstrate that when content-like words were either excised from continuous speech or produced in isolation, 12-month-olds mapped these word forms to objects in an associative learning task. This result serves to benchmark the findings of Experiment 1 by suggesting that infants’ differential mapping of content versus function words was not due to differences in co-articulatory cues.

General Discussion

The results of these experiments offer insight into whether the organization of word forms based on their phonological shape constrains the mechanism that associates novel words to their referents. We demonstrated that by the end of the first year of life, infants’ associative learning mechanism is attuned to differences between word forms and thus, they will map only words that possess the acoustic and phonotactic properties of content words to objects. These results demonstrate that mere associative pairings are not sufficient to form mappings. Rather infants require well-formed noun-like words to co-occur with objects in order for the linkages to arise.

We propose that the limiting of the potential mapping space for specific word forms for objects reflects a refinement of the system that begins from birth. Infants’ detection of the acoustic differences between content and function words (Shi et al., 1999) and their emergent preference for content forms by 6-months (Shi & Werker, 2001) suggests that infants are sensitive to differences in the phonological and acoustic forms of these items and may use this information to categorically discriminate sets of lexical and grammatical words from one another. It is important to emphasize, however, that this early differentiation of word forms does
not imply that infants have inferred the syntactic properties or appreciate the semantic roles accompanying these word classes, let alone formed these categories themselves (Shi et al., 1999). Instead, these findings suggest that infants sort words on the basis of their surface acoustic and phonological cues and through this differentiation, develop a preference for word forms that share the acoustic and phonological properties of content words (Shi & Werker, 2001). Infants’ ability to attend preferentially to content words may then serve to highlight those words in the speech stream that a child will first understand and eventually map to meaning. This broad-based organization of word forms may then subsequently constrain possible labels infants are willing to map to objects. That is, as infants progress in their lexical development, they may begin to develop expectations regarding which word forms constitute as an appropriate label for an object, based on the phonological and acoustic properties.

It is possible that salience alone may have made the content words more interesting to infants in these experiments and this differential salience may have driven infants’ differential mappings, as opposed to infants’ established expectations about the appropriate word form for an object label. Indeed, infants find content words more salient and interesting than function words (Shi & Werker, 2001). Content words tend to have longer and full vowels, have a more complex syllable structure, and they are more likely to have the presence of stress in the word form than function words. Even our adult-directed stimuli demonstrate these differences in both isolated and spliced contexts. However, if it were the case that content words were perceived as simply more interesting words forms than function words and thus infants were not attending to the function words, one would anticipate a difference found between the number of trials infants in each group required to reach habituation. That is, if infants perceived the content words as more interesting, they should look longer during each trial in the content word group and therefore
take longer to habituate. However, there were no group differences in the number of trials infants used to reach habituation or in the number of infants who did not reach habituation (i.e., did not reduce their looking time by 65% criterion). Thus, although the content words used in this study may have possessed certain acoustic and phonotactic properties which made them more salient to infants than the function words, this difference in salience cannot be solely responsible for infants’ differential mapping of content- versus function-words to objects.

Another possible explanation for the current findings is that the similarity between the novel function words used and well-known function words in English may have impacted infants’ ability to map these word forms to objects. As described earlier, we based our novel function word stimuli on forms that occur in English. Indeed, keh and iv are analogous to frequent English function words the and is, sharing similar syllable structures and vowels. Given this similarity, infants may have treated the novel function word forms as variants of known or familiar English function words. This possibility is unlikely, however, as research has shown that English-learning infants aged 11-13-months recognize function words and encode their phonetic detail in their lexical representations (Shi, Werker & Cutler, 2006). That is, infants prefer to listen to real functors over minimally segmentally modified nonsense functors (i.e., keh versus the). In contrast, 8-month-olds do not distinguish real from nonsense functors. In a similar vein, research with French-learning 8-month-olds has also demonstrated an early ability to recognize and differentiate real function words from minimally segmentally modified nonsense functors (Shi & Lepage, 2008). Together, these findings suggest that the recognition and representation of function words develops gradually in preverbal infants and by the end of the first year of life, infants are able to recognize phonetically similar function words from one another. This suggests that infants in our study were not simply assimilating the novel function-like words to their
familiar counterparts. To fully address this possibility, however, future research should investigate whether infants treat less familiar function-like words similarly to those used in our study when presented with a word-object mapping task (i.e., *ler*).

It is important to note however, that under specific word learning contexts, infants below 14-months of age fail to apply their well-honed phonetic sensitivities in word learning tasks (Stager & Werker, 1997). That is, when the demands of a word learning task are increased by the need to detect phonetic details of words (e.g., *bih* versus *dih*), infants do not map these words to objects. However, when the demands of a word learning task are reduced by eliminating the need to detect phonetic detail in words, 14-month-olds are able to map two phonetically different words to objects in an associative learning task (e.g., *lif* versus *neem*) (Werker, Cohen, Lloyd, Casasola & Stager, 1998; see also Curtin, 2009, Curtin, 2011; MacKenzie et al., 2011, MacKenzie et al., in press for similar results with 12-month-olds). In a similar vein, recent work has demonstrated that 14-month-olds will map similar-sounding labels when the demands of the testing phase are reduced or when the purpose of the task is highlighted by a training phase (Yoshida, Fennell, Swingley & Werker, 2009; Fennell & Waxman, 2010). Taking these findings into account, we chose to reduce the demands of our word learning task by presenting infants with two novel function words that were phonetically dissimilar from one another (i.e., *keh* versus *iv*). Thus, it is unlikely that the demands of detecting the phonetic details of our two novel function words is driving infants’ inability to map these word forms to objects.

Overall, our findings add to the growing literature on the existence of early-emerging constraints on word-object associations. In recent work, MacKenzie et al. (2011) have demonstrated that 12-month-olds will associate novel English words (e.g., *fep*) with novel objects at 12-months, but will not form mappings between communicative sounds (e.g., *ooh*;
ssh) or single consonantal sounds (e.g., /l/) and objects. In a subsequent study, these researchers demonstrated that 12-month-olds will not map content words to objects when these forms violate native phonotactics (e.g., ptak; MacKenzie, Curtin, & Graham, in press) providing further evidence that infants have begun to acquire knowledge about what an appropriate word form is in their native language. Another line of research has demonstrated that older infants will identify function words and content words on the basis of their unique distributional and phonological cues (Hochmann et al., 2010). In a series of experiments, these researchers investigated whether 17-month-old infants can use the high frequency of occurrence of function words as a cue to identify function word forms in a word learning paradigm. Results indicated that when word frequency was provided as a cue for function words during a familiarization phase, infants segmented a foreign determiner-noun sequence and mapped the noun to an object. These results suggest that word frequency plays an important role in identifying function words from content words in the speech stream. These researchers also suggest that word frequency is a universal cue that can be used to identify function words across languages. These findings parallel previous research that has demonstrated that English and French-learning infants can use frequent function words to segment potential vocabulary items from continuous speech (Shi, Lepage, 2008; Shi, Werker & Cutler, 2006). Interestingly, these results differ from our findings in that we demonstrated that infants at 12-months of age show preference for content-type word forms during word-object mapping on the basis of their phonological and prosodic cues. Indeed, there are several methodological differences between our study and Hochmann et al (2010) including testing procedures, stimuli, designs, as well as language background and age of the infants that may account for this difference in findings. In particular, it is likely that infants in our study used prosodic differences between the two word classes of words to bias word learning.
as the words presented were similar to words used in their native-language whereas Hochmann et al. used foreign language words.

The current findings extend the above research by demonstrating that 12-month-olds differentiate word forms on the basis of their surface acoustic and phonological cues and use this knowledge to guide their word-object associations. That is, when distributional cues associated with function words were not present (e.g., high frequency function words occurring in unit-initial positions), infants relied on the phonological and acoustic properties of specific word forms to guide their word-object associations. This suggests that the phonological and acoustic properties of function words may also serve an important role in the identification of grammatical versus lexical word forms in the speech stream and contribute to infants’ expectations regarding the appropriate word form for an object label. Although our results provide insight into infants’ use of phonological cues to word forms to guide word-object associations, our results do not address whether this ability is universal in nature. Future research is needed to clarify whether infants’ phonological differentiation of content versus function words informs the word-object associations of infants learning languages other than English.

Our findings also build on work in speech segmentation in which adults rely on a constraint that limits what a possible word might be (Norris, McQueen, Cutler, & Butterfield, 1997). That is, researchers have found that the operation of the Possible Word Constraint (PWC) is sensitive to cues such as silence, metrical structure, phonetic sequences, and most importantly, difference types of phonemes. Thus, consonants alone are not possible words. Rather, a possible word consists of any stretch of speech that contains at least one vowel (Norris et al., 1997), and this appears to be the case irrespective of one’s native language (Norris, McQueen, Cutler, Butterfield, & Kearns, 2001). Our findings reveal that the phonological shape of a word
constrains a possible object mapping such that CV and VC structures containing weak vowels are not well-formed object labels. This suggests that when learning a new object label, infant’s acquired knowledge of appropriate forms over the course of development conforms to something akin to a Minimal Word (Demuth, 1996). That is, open class items (nouns, verbs, adjectives, adverbs) must contain sufficient phonological information to be classified as a legitimate word (Demuth, 1996).

In summary, our findings demonstrate that the mechanism with which basic associations are formed in language is remarkably sophisticated by the onset of productive language. That is, infants distinguish between different types of word forms on the basis of their phonological and acoustic properties and use this knowledge to constrain the search space for possible labels for objects.
References


word-object associations by 14-month-old infants. *Developmental Psychology, 34*(6), 1289-1309.

The following chapter is a reproduction of a published work, for which permission has been granted by the publishers, American Psychological Association (License # 3203230357153), for the use in this dissertation, *The influence of context and form on 12-month-olds' sound-object associations*. I was the primary investigator and main contributor for the publication entitled, *The flexibility of 12-month-olds’ preferences for phonologically appropriate object labels*, in the journal *Developmental Psychology*, and was responsible for the conception, design, data collection and analysis with Dr. Suzanne Curtin and Dr. Susan A. Graham serving as my supervisors.

Chapter Four: The flexibility of 12-month-olds’ preferences for phonologically appropriate object labels

By the end of the first year of life, infants can proficiently identify and track those sound combinations that make up the word forms in their native language and map these forms onto different concepts (for reviews see Saffran, Werker, & Werner, 2006, Waxman & Lidz, 2006). Furthermore, infants’ refined sensitivity to the linguistic properties of their native language guides the types of word forms they are willing to accept as labels for objects (Graf-Estes, Edwards, & Saffran, 2011; Hochmann, Endress, & Mehler, 2011; MacKenzie, Curtin & Graham, 2012a; MacKenzie, Curtin & Graham, 2012b). Here, we investigate the parameters of 12-month-old infants’ established preferences for specific word forms as object labels. Across two experiments, we ask whether 12-month-old English learning infants’ preferences for specific word forms will be overridden in a sound-object association task, when provided with referential cues that indicate that a linguistic form is intended to be a label for an object.

Recent research has documented early-emerging constraints on word-object associations. That is, English-learning 12-month-olds will associate novel English words (i.e., words containing legal speech sounds, in allowable combinations (phonotactically legal), and syllable structures appropriate for English; e.g., /fep/) with novel objects. In contrast, 12-month-olds will not form mappings between communicative sounds (e.g., /ooh; ssh/) or single consonantal sounds (e.g., /l/) and objects (MacKenzie, Graham & Curtin, 2011). Furthermore, 12- and 18-month-olds will not map words to objects when these forms violate native phonotactics (e.g., /ptak/; Graf-Estes et al., 2011; MacKenzie et al., 2012a), providing further evidence that infants have begun to acquire knowledge about
what an appropriate word form is in their native language. Finally, studies have also
demonstrated that 12- and 17-month-olds will map content-like words (meaningful items,
such as nouns and verbs), but not function-like words (grammatical items, such as
determiners), to objects (Hochmann et al., 2010; MacKenzie et al., 2012b). That is, infants
do not map function-like words, which are forms that are marked by syllable reduction,
reduced vowels, and simplified syllable structure with minimal, if any, onsets and codas.
Also, these forms are highly subject to coarticulation (i.e., articulatory influence of one
segment on another segment) by adjacent words (Morgan, Shi & Allopenna, 1996).
Together, these results suggest that by their first birthday, infants have become attuned to
the specific characteristics of their native language and apply their knowledge about the
nature of appropriate object word sound forms when making word-object mappings.

The research described above provides compelling evidence that infants have
developed a bias for the types of word forms they will accept as labels for objects through
experience with their native language. At the same time, young infants can be flexible in
the range of symbolic forms that they will accept as naming objects when tested in
interactive contexts (e.g., Hollich, Hirsh-Pasek, & Golinkoff, 2000; Namy & Waxman,
1998; Namy, Campbell, & Tomasello, 2004; Woodward & Hoyne, 1999). In these studies,
researchers have demonstrated that younger infants are willing to accept both words and
nonlinguistic forms as labels for objects. For example, Namy (2001) demonstrated that
when 18-month-olds were presented with a range of different symbols (i.e., word, gesture,
non-verbal sounds & pictograms) paired with objects in an interactive word-learning task
(i.e., provided with attentional and social referential cues), infants successfully mapped
these symbols to the objects. Interestingly, however, this general symbolic openness begins
to narrow toward the end of the second year of life when infants begin to accept only words as object names (e.g., Graham & Kilbreath, 2007; Namy & Waxman, 1998; Woodward & Hoyne, 1999).

This seeming discrepancy between infants’ preference for particular word forms and their apparent symbolic openness raises the question of whether this symbolic flexibility may be contingent upon the presence of social-referential cues in the word learning task. In the typical interactive tasks used in the studies described above, the use of referential cues such as pointing and eye gaze highlight that the experimenter’s intention is to treat a specific non-linguistic symbol as an object name (e.g., Campbell & Namy, 2003; Woodward & Hoyne, 1999; Hollich et al., 2000). Thus, infants’ attention to these social-referential cues may lead them to override a bias to privilege specific word forms over other types of stimuli when establishing word-object mappings. When social-referential cues are stripped away, as in the word-object association tasks described above, infants’ default preferences about appropriate forms for object names become evident (MacKenzie et al., 2011; MacKenzie et al., 2012a; MacKenzie et al., 2012b).

In the present studies, we explore the possibility that referential cues will lead English learning infants to overlook their preferences for particular linguistic forms. Specifically, we ask whether infants’ knowledge about the form of linguistically appropriate object labels can be overridden with minimal referential cues or whether learned biases constrain their label-object mappings regardless of the cues provided. To address this question, we draw upon research demonstrating that infants’ performance in the word-object association task can be modified by providing the infant with information about the referential status of a to-be learned label (e.g., Fennell & Waxman, 2010). For
example, 14-month-olds’ inability to map phonetically similar words (i.e., minimal pairs such as *bin* and *din*; e.g., Pater, Stager, & Werker, 2004; Stager & Werker, 1997; Werker, Fennell, Corcoran, & Stager, 2002) to objects in a word-object association task is altered when the referential status of these words is highlighted by syntactic and pragmatic cues (Fennell & Waxman, 2010). When infants were habituated to a single novel word-object pairing (i.e., *bin* + Object A) embedded within a familiar naming phrase (e.g., “*Look. It’s the ___*”), or given a training phase in which they received three familiar word-object pairings (e.g., car, cat, shoe) prior to habituation to the single word-object pairing presented without a naming phrase, 14-month-olds were now able to detect a switch in the pairing (i.e., *din* + Object A) at test.

In the present experiments, we used the modified word-object association task to examine whether infants will accept linguistic forms that deviate from their preference for well-formed phonotactically legal word forms. Here, we examine sounds that are contained within the native language sound system, but that occur in illegal combinations (e.g., non-native phonotactics), occur in isolation (e.g., individual phonemes), or occur as grammatical elements (e.g., function-like words). Specifically, we ask whether English learning infants’ preference for word forms that possess the phonological properties of noun-like words of their native language can be overridden when provided with additional referential clarity for the task. To address this question, we contrasted 12-month-olds’ mappings of three different types of forms to objects in a modified referential Switch task (Fennell & Waxman, 2010): phonotactically illegal CCVC words (e.g. non-native phonotactics), consonantal sounds (e.g. individual phonemes), and novel function-like words. This age range was chosen as infants will only associate novel well-formed,
phonotactically legal words with objects in an associative learning task at 12 to 14 months of age (e.g., Curtin, 2011; MacKenzie et al., 2011; Werker et al., 1998) and infants around this age will associate a variety of symbols (e.g., gestures, non-linguistic sounds, pictograms) to objects when provided with contextual support (e.g., Hollich et al., 2000; Woodward & Hoyne, 1999).

Experiment 1

In Experiment 1, we examined whether 12-month-olds’ preference for well-formed, phonotactically legal words as object labels can be shifted when the goal of the word-object association task is clarified. That is, when English learning infants are provided with a training phase that highlights that this is a labeling task, will infants map phonotactically illegal word forms to objects? We decided to use CCVC Czech words that contain illegal sound combinations in English (i.e., violate English phonotactics) because previous research has demonstrated that 12-month-olds will not map these forms to objects in an associative learning task (MacKenzie et al., 2012a).

To examine the influence of referential cues on word-object associations, two groups of infants were tested with a modified Switch task (Werker et al., 1998) that included a training phase that either increased the referential clarity of the task (e.g., familiar objects paired with their labels) or maintained the lack of clarity in the task (e.g., familiar objects paired with exclamations). The two training phases were adapted from previous research (e.g., Namy & Waxman, 2000; Fennell & Waxman, 2010) demonstrating that infants will map novel words presented in isolation to novel objects when provided with a training phase that pairs familiar objects with their familiar basic level names. Following training, both groups of infants were habituated to two sets of CCVC Czech
word-object pairings (e.g., svet paired with Object A & ptak paired with Object B) and then were tested on these word-object mappings by comparing their looking time during the Same trial versus the Switch trial.

If 12-month-old infants’ bias for preferred word forms is flexible, then when presented with information about what the task entails, infants should broaden their acceptance of potential word forms. Thus, infants should successfully map the illegal word forms to the objects when provided with a training phase that increases the referential clarity of the task (i.e., Name-training group) and not when the task remains ambiguous (i.e., Exclaim-training group). The findings from this experiment will help clarify the contexts in which infants will apply their established preferences for specific word forms as object labels and the role that referential information has in shifting infants’ tendency to link phonotactically illegal word forms with objects in an associative learning context.

Method

Participants

Data from 32 English-learning 12-month-old infants (were included in the final sample. An additional 9 infants were tested but were excluded from the sample for the following reasons: did not complete the task (n = 4), failed to habituate (n = 2), excessive fussiness (n = 2), and parental interference (n =1). Infants were randomly assigned to one of two groups: the Name training group (n =16; Mean age = 12.68; range = 12.36-13.00; 7 girls), or the Exclaim training group (n = 16; Mean age = 12.56; range = 12.23-12.95; 8 girls). Infants were from homes in which English was the primary language spoken (i.e., exposure to English was 80% or greater) and were recruited through pamphlets at child-related trade shows and health clinics within the Calgary, Alberta area. Infants in the two
groups did not differ significantly in age \((F(1, 30) = 2.82, \eta_p^2 = .08, p = .10)\) or in productive vocabulary size \((F(1, 30) = .01, \eta_p^2 = .00, p = .91)\), as measured by the MacArthur-Bates Communicative Development Inventory (MCDI; Fenson, Pethick, Renda, Cox, Dale, & Reznick, 2000) short form. Information on ethnicity, race, cultural background and family socioeconomic status was not collected.

**Stimuli**

See Figure 1 for an overview of the design. A female, bilingual Czech-English speaker recorded all the auditory stimuli using infant-directed speech in a soundproof booth. The pre-test and post-test stimuli consisted of a white plastic waterwheel accompanied by the novel word (i.e., wug), similar to procedures used in previous switch-task experiments (e.g., Werker et al., 1998).
<table>
<thead>
<tr>
<th>Training Phase for Exp 1 &amp; 2&lt;sup&gt;a&lt;/sup&gt;</th>
<th><img src="70" alt="Image" /></th>
<th><img src="100" alt="Image" /></th>
<th><img src="207" alt="Image" /></th>
<th><img src="291" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name Training</td>
<td>“kitty”</td>
<td>“shoe”</td>
<td>“car”</td>
<td>“baby”</td>
</tr>
<tr>
<td>Exclaim Training</td>
<td>“wow”</td>
<td>“whee”</td>
<td>“yay”</td>
<td>“ooh”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Habituation Phase</th>
<th>Test Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name Training &amp; Exclaim Training (Exp 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘ptak’</td>
<td>‘svet’</td>
<td>‘ptak’</td>
</tr>
<tr>
<td>Consonantal Sound (Exp 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘/l/’</td>
<td>‘/ʒ/’</td>
<td>‘/l/’</td>
</tr>
<tr>
<td>Function Word (Exp 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘iv’</td>
<td>‘keh’</td>
<td>‘iv’</td>
</tr>
</tbody>
</table>

*Figure 1.* Schematic of testing conditions and phases.

During the training phase, infants in both groups were shown four stationary images of a car, cat, baby and shoe. The auditory stimuli presented during this phase, however, varied according to a group assignment. During the Name training phase, English basic-level names (i.e., *kitty, shoe, baby, car*) were paired with the corresponding familiar object. During the Exclaim training phase, familiar exclamations (i.e., *whee, wow, yay, ooh*) were paired with the familiar object.
During the habituation and test phases, all infants were presented with the same videotapes of two novel objects: a black and blue molecule-shaped object (Object A) and a pink, yellow and blue spiky-shaped object (Object B) and the same auditory stimuli: eight exemplars of each of two phonotactically illegal CCVC Czech words: /ptak/ and /svɛt/. The acoustic measurements of both the training and habituation auditory stimuli (i.e., duration and pitch mean) are available in the supplementary materials online.

**Apparatus**

Testing took place in a quiet and dimly lit sound-proof room. Infants sat on their parent’s lap or in a high chair facing a 122 cm high by 91.5 cm wide video monitor. Each parent wore headphones while listening to music. The auditory stimuli were delivered at 65 dB, +/- 5 dB from a speaker located directly above the monitor. Infants were recorded using a digital video camera with the lens peeking out of the cloth covering the electronic equipment. The video was used for frame-by-frame reliability coding and primary coding. The experiment was controlled by the Habit X 1.0 program (Cohen, Atkinson, & Chaput, 2004). The visual and audio stimuli were played from digitized files on a computer, which were transmitted to the monitor and speaker in the testing room.

**Procedure**

Infants were tested using a modified version of the habituation paradigm known as the Switch task (Werker et al., 1998). The procedure was identical for both groups – all that varied were the auditory stimuli presented during the training phase. Each trial was 20 s in duration. To begin, infants were presented with one of two training phases: 1) **Name training phase:** which included four familiar objects (i.e., a car, a cat, a baby, a shoe), presented sequentially, each paired with its appropriate basic-level name (e.g., “car!”),
“kitty!”); or 2) *Exclaim training phase:* which included four familiar objects (i.e., a car, a cat, a baby, a shoe), presented sequentially, each paired with familiar exclamations (e.g., “whee”, “wow”, “yay”). During the habituation phase, infants were presented with two sets of phonotactically illegal Czech word-object combinations presented alternately (e.g.: *ptak* paired with Object A & *svet* paired with Object B). Both groups were presented with these auditory stimuli-object pairings in a semi-random order until looking time decreased to a set criterion (65%) or until a maximum of 24 trials were completed (see below).

Following the habituation phase, infants were presented with two test trials in counterbalanced order: the *Same* trial and the *Switch* trial. During the *Same* trial, infants were presented with a familiar object-sound pairing (e.g.: Object A/*ptak*). During the *Switch* trial, infants were presented with a familiar object and sound but with the familiar pairing violated (e.g., Object B/*ptak*). To control for whether the infant became fatigued or uninterested in the test stimuli, a novel auditory stimuli-object pairing was presented once as a pre-test trial before the habituation phase and then again as the post-test trial, following the test phase (i.e., Waterwheel/*wug*).

The particular auditory stimulus (e.g.: *ptak* & *svet*) that was associated with a particular object (*Object A* or *Object B*) and the order of the switch and same trials was counterbalanced across children in all groups. The habituation criterion was met if an infant decreased his/her looking time to at least 65% (a 35% decrement) of that of the first block of four trials during any of the following five blocks of four trials. If the infant reached the habituation criterion before the sixth block of four trials, then the test phase would begin. Infants who did not reach the habituation criterion were excluded from the final analyses (*n* = 2).
After completion of the task, all parents completed the MCDI short form (Fenson et al., 2000). All infants comprehended the basic-level name for at least one training object, as measured by the MCDI short form.

**Coding**

Online coding was used only to determine if infants were habituating to the word-object pairings. For the critical trials (i.e., pretest, four training trials, last four habituation trials, two test trials and the post-test), infants’ looking times to the object were coded on a frame-by-frame basis from the videotapes. To establish inter-rater reliability, 20% of the data (n = 6 infants) was coded by a second coder. Intra-class correlations (ICCs) coefficients for looking time responses were .98 (all ps < .001).

**Results**

To ensure that any differences found on test trials were not a result of fatigue, we compared infants’ looking time during the pre- and post-test trial to determine if infants regained attention at the end of the task. See Table 1 for mean looking times by group for the pre-test, the post-test, the last habituation block, as well as the average number of habituation trials. Results of a 2 (Group) x 2 (Trial: Pre-test vs. Post-test) ANOVA indicated that infants’ looking times on the pre-test and post-test trials did not differ significantly between groups ($F(1, 30) = .11$, $\eta_p^2 = .00$, $p = .75$) or between the pre-test trial ($M = 17.11$, $SD = .20$) and the post-test trial ($M = 16.62$, $SD = .88$), $F(1, 30) = .31$, $\eta_p^2 = .01$, $p = .58$. Further analyses indicated that infants in both groups looked significantly longer during the post-test trial ($M = 16.62$, $SD = 3.88$) than during the last habituation block ($M = 7.66$, $SD = 2.69$), indicating that they recovered from habituation, $t(31) = 7.16$, $d = 2.70$, $p < .0001$. The average number of habituation trials did not differ significantly
between the Name training group and the Exclaim training group, $F (1, 30) = .35$, $\eta_p^2 = .01$, $p = .56$. Furthermore, the amount of looking time during the habituation phase did not differ significantly between the Name training group and the Exclaim training group, $F (1, 30) = .06$, $\eta_p^2 = .00$, $p = .80$. These latter analyses indicated that attention to the word-object pairings during the habituation phase was similar across groups.
Table 1

Mean Looking Time by Group for Pre-Test, Post-Test, Last Habituation Block and Average Number of Habituation Trials

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Last Habituation Block</th>
<th>Average Number of Habituation Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>English-training (Exp 1)</td>
<td>16.92 (3.68)</td>
<td>17.11 (3.60)</td>
<td>7.94 (2.35)</td>
<td>10.50 (3.54)</td>
</tr>
<tr>
<td>Exclaim-training (Exp 1)</td>
<td>17.30 (2.75)</td>
<td>16.14 (4.23)</td>
<td>7.38 (3.06)</td>
<td>11.25 (3.64)</td>
</tr>
<tr>
<td>Function word (Exp 2)</td>
<td>17.19 (2.58)</td>
<td>15.69 (3.73)</td>
<td>8.21 (2.84)</td>
<td>9.75 (2.52)</td>
</tr>
<tr>
<td>Consonantal sound (Exp 2)</td>
<td>16.82 (3.27)</td>
<td>12.70 (5.19)</td>
<td>7.94 (3.35)</td>
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</table>

Note. Stand deviations in parentheses

The primary analyses compared infants’ looking times during the Same and Switch test trials across groups. See Figure 2 for mean looking times by test trial and group. Recall that if infants have established word-object associations, their looking time should be significantly longer during the Switch trial than the Same trial. A 2 (Group) x 2 (Trial: Same, Switch) ANOVA yielded a significant group by trial interaction, $F (1, 30) = 9.65, \eta_p^2 = .24, p = .004$. Pairwise comparisons indicated infants in the Name training group looked
significantly longer during the Switch trial ($M = 9.27$, $SD = 3.67$) than during the Same trial ($M = 6.04$, $SD = 3.48$), $t(15) = 3.56, d = .90, p = .003$. In contrast, infants in the Exclaim training group did not differ in their looking times during the Switch ($M = 5.83$, $SD = 2.71$) and Same trials ($M = 6.79$, $SD = 2.72$), $t(15) = .97, d = .35, p = .34$. These results demonstrate that when the referential status of phonotactically illegal words was highlighted by the use of an English word-referent training phase, 12-month-olds did associate Czech words with novel objects in an associative learning task.

![Figure 2](image_url)

**Note.** *indicates $p < .05$.

*Figure 2.* Mean looking times during Same and Switch Trials as a function of group in Experiment 1.

To investigate whether infants’ performance on the Switch task was related to their knowledge of the names of the objects presented during the training phase, we tallied the number of training words comprehended by each infant (0-4) and correlated this measure
with infants’ success on the Switch task (i.e., difference score that represented looking time to the Switch trial minus looking time to the Same trial). Results indicated that infants’ knowledge of the names of objects in the training phase did not correlate with success in the English Name-training condition, $r (14) = .20, p = .46$, nor performance in the exclaim-training condition, $r (14) = -.05, p = .85$. These findings suggest that increased comprehension of training words did not directly relate to infants’ performance in the Name training condition, suggesting that knowledge of at least one training word (i.e., minimum requirement) was sufficient to understand the purpose of the Switch task.

In the final analysis, we examined whether infants responded similarly to the two Czech words. Note that the ‘pt’ cluster in ptak is illegal only in onset position in English. It surfaces in word final position in forms such as ‘kept’. In contrast, the ‘sv’ cluster is illegal in both onset and coda positions. To ensure that infants’ success in the English Name training group was not influenced by a preference for one of the two Czech words, we compared the performance of infants who received a switch trial with each Czech word (i.e., ptak or svet name switch) using a Same-Switch difference score. Results indicated that infants who received the ptak switch ($M =2.53, SD = 3.50$) did not differ significantly from those infants who received the svet switch ($M =3.94, SD = 2.65$), $F (1, 15) = 2.2, \eta^2_p = .13, p = .16$. As demonstrated by the positive difference scores, infants looked longer at the Switch trial than at the Same trial, regardless of the word presented.

Discussion

Our results demonstrate that English-learning infants will associate word forms that violate the phonotactics of their native language to objects when the referential role of these to-be-learned novel words is clarified. However, when the referential role of these
phonotactically illegal words remains ambiguous (i.e., Exclaim training group), infants fail to make these word-object mappings. These findings suggest that when infants are presented only with the linguistic information from a to-be-learned label in the word-learning task, their language-specific preferences guide their word-object mapping. However, when infants are provided with additional information that clarifies the referential nature of the Switch task, 12-month-old infants’ bias for phonologically appropriate object labels is overridden.

The findings from Experiment 1 demonstrate that infants will map phonotactically illegal words to objects when provided with a short training phase. These word forms, however, are well-formed nouns. While the onsets are phonotactically illegal in English, the individual sounds and the CCVC syllable structure (e.g., play, sleep) are both legal in English. In the next experiment, we further examine infants’ acceptance of various word forms in the modified Switch task. That is, we ask whether infants’ flexibility is limited to well-formed noun-like words or whether it extends to other types of sound forms.

Experiment 2

Here, we investigated 12-month-olds’ ability to establish linkages between objects and either consonantal sounds or novel function-like words when the referential clarity of these labels is highlighted by a Name-training phase. Previous work has demonstrated that 12-month-olds will not map these forms to objects in the traditional Switch task (e.g., MacKenzie et al., 2012a; MacKenzie et al., 2012b). If infants are flexible in the types of linguistic forms they will accept as object labels when provided with information that clarifies the referential nature of the task, infants should successfully establish these mappings, as they did with the illegal word forms in Experiment 1. That is, infants in
Experiment 2 should demonstrate similar performance to infants in the Name-training group in Experiment 1. If, however, infants fail to map these forms to objects, this would suggest that even when the referential role of these labels is highlighted by additional cues provided in the word-learning task, infants’ understanding of what an appropriate label is for an object is limited to well-formed words that share the appropriate phonological properties of noun-like words.

Method

Participants

Thirty-two English-learning 12-month old infants were included in the final sample. An additional 11 infants were tested but were excluded from the sample for the following reasons: did not complete the task (n = 6), and failure to habituate (n = 5). Infants were randomly assigned to two conditions: consonantal sound group (n= 16; Mean age = 12.42 months, range = 11.97- 12.95; 8 girls) and function word group (n = 16; Mean age = 12.58, range = 12.10- 13.00; 8 girls). Infants were from homes in which English was the primary language spoken (i.e., exposure to English was 80% or greater) and were recruited as described in Experiment 1. Information on ethnicity, race, cultural background and family socioeconomic status was not collected. Infants in both groups did not differ significantly in age ($F (1, 30) = 1.45, \eta_p^2 = .05, p = .24$) or in productive vocabulary size ($F (1, 30) = 0.19, \eta_p^2 = .00, p = .94$), as measured by the MCDI short form (Fenson et al., 2000). Infants also did not differ in age ($F (3, 60) = 2.23, \eta_p^2 = .00, p = .09$) or vocabulary size ($F (3, 60) = 1.03, \eta_p^2 = .05, p = .70$) from those tested in Experiment 1.

Stimuli
The auditory and visual stimuli presented to both groups of infants in the training phase were identical to those presented in the Name training group in Experiment 1. The visual stimuli presented during the habituation and test phases were also identical to those used in Experiment 1. The auditory stimuli presented during the habituation and test trials, however, varied according to group (i.e., consonantal sound or function word). Within each group, the same native English female speaker recorded the Name training words and the test stimuli. These auditory stimuli were the same auditory stimuli used in previous Switch task studies (MacKenzie et al., 2012a; MacKenzie et al., 2012b). Acoustic measurements of auditory stimuli are available in the supplementary materials online.

Infants in the consonantal sound group were presented with exemplars of each of the following linguistic sounds: /l/ and /ʒ/, paired with an object (i.e., Object A or Object B). These consonantal sounds were chosen as they are phonetically distinct from one another (i.e., /l/ is a voiced, alveolar, lateral approximant and whereas /ʒ/ is a voiceless, post-alveolar fricative), and can be produced without a vowel (in contrast to a stop consonant). This allowed us to assess infants’ potential mappings of single sounds to objects. Previous research has demonstrated that infants will not map these sounds to objects in a Switch task (MacKenzie et al., 2011).

Infants in the function word group were presented with exemplars of each of the following words: two novel function-like words: keh (/kə/ ) and iv (/ɪv/), paired with an object (i.e., Object A or Object B). The novel function-like words (i.e., keh and iv) were chosen for inclusion in this experiment because they are analogous to frequently used English function words, the and is. That is, these novel function words and their familiar counterparts (i.e., iv/is and keh/the) share similar vowel placement. This similarity allows
our novel function-like words to capture key phonological characteristics of frequent function words. Furthermore, we produced these novel function-like words in sentences that captured the acoustic characteristics of frequent English function words (e.g., “Keh hog ran away” and “The stove iv hot to touch”) and spliced them out to create the individual tokens. All stimuli were recorded in adult-directed speech to ensure we captured the prosodic and acoustic characteristics of natural sounding function words. Previous research has demonstrated that infants will not map these function-like words to objects in a Switch task (MacKenzie et al., 2012b).

For presentation during the pre- and post-test trials: und (/And/ function word group), and /n/ (consonantal sound group) were recorded.

Apparatus and Procedure

The apparatus and procedure used were identical to that of the Name training group in Experiment 1; the only difference was the auditory stimuli presented during the habituation and test phases. All infants comprehended the basic-level name for at least one training object, as measured by the MCDI.

Infants’ looking times for the critical trials were coded on a frame-by-frame basis. Inter-rater reliability for 20% of the data ($n = 6$) was high (ICCs = .98, $ps < .001$).

Results and Discussion

To ensure that infants were not fatigued or generally disinterested in the task, we compared infants’ looking time during the pre- and post-test trial. See Table 1 for mean looking times by group for the pre-test, the post-test, the last habituation block as well as the average number of habituation trials. Results of a 2 (Group) x 2 (Trial: Pre-test vs. Post-test) ANOVA indicated that infants looked significantly longer during the pre-test trial ($M$
= 17.00, \( SD = 2.91 \), compared to the post-test trial, \( (M = 14.20,\ SD = 4.70) \), \( F(1,\ 30) = 13.43, \eta_p^2 = .31, p = .001 \). These results suggest that infants may have become disinterested or fatigued in the task, which could have in turn impacted their willingness to map these forms to objects. However, results of a 2 (Group) x 2 (Trial: Last Habituation Block vs. Post-test Trial) ANOVA indicated that infants looked significantly longer during the post-test trial (\( M = 16.78,\ SD = 3.73 \)) compared to the habituation block (\( M = 7.11,\ SD = 2.42 \)), \( F(1,\ 30) = 77.35, \eta_p^2 = .72, p = .0001 \). Overall, these results confirm that infants in both groups recovered from habituation, which suggest that infants decreased looking time from pre-test to post-test most likely did not affect their performance on the task. Finally, the average number of habituation trials for infants in the consonantal sound group did not differ significantly from infants either in the function word group in Experiment 2 or the Name training group or Exclaim training group, in Experiment 1, \( F(3,\ 60) = .85, \eta_p^2 = .04, p = .47 \). Furthermore, infants’ proportion of looking time during the habituation trials did not differ across groups, \( F(3,\ 60) = 0.32, \eta_p^2 = .04, p = .81 \). These findings suggest that that attention to the word-object pairings during the habituation phase was similar across groups.

The primary analyses compared the looking times on the test trials for infants in the function word and consonantal sound group to that of infants in the Name training group in Experiment 1, who were presented with phonotactically illegal word forms during the mapping phase. A 3 (Group) x 2 (Same vs. Switch) ANOVA yielded a significant group by trial interaction, \( F(2,\ 45) = 4.64, \eta_p^2 = .17 p = .02 \). Follow-up comparisons indicated that only infants in the Name training group from Experiment 1 looked significantly longer during the Switch trial (\( M = 9.27,\ SD = 3.67 \)) than during the Same trial (\( M = 6.04,\ SD = 2.91 \)).
3.48), $t(15) = 3.56, d = .90, p = .003$. Infants in the consonantal sound and function word group did not look significantly longer during the Switch trial ($M = 7.93, SD = 4.91; M = 7.12, SD = 4.25$) than during the Same trial ($M = 7.97, SD = 3.27; M = 8.02, SD = 3.49$), $t(15) = .04, d = .01, p = .97, t(15) = .96, d = .23, p = .35$, respectively (See Figure 3). These results demonstrate that when provided with a word-referent training phase, infants successfully mapped phonotactically illegal words to objects; however, they did not map consonantal sounds or function-like words to objects.

![Figure 3. Mean looking time during Same and Switch Trials as a Function of group in Experiment 2.](image)

*Note.* *indicates $p < .05$.

*Figure 3.* Mean looking time during Same and Switch Trials as a Function of group in Experiment 2.

Finally, we tallied the number of training words comprehended by each infant (0-4) in Experiment 2. This measure was not significantly correlated with performance in the consonantal sound condition, $r(14) = .15, p = .59$, nor performance in the function word condition, $r(14) = -.05, p = .86$. 
Overall, these results demonstrate that when infants are provided with the same word-referent training phase as in Experiment 1, 12-month-olds will not map isolated consonantal sounds or function-like words to objects in an associative learning task.

General Discussion

Together, these findings clarify English learning infants’ flexibility in linguistic form-object mappings in an associative learning context. In particular, our findings demonstrate that by 12 months of age, English learning infants will limit their word-object mappings to words that share the phonological properties of content-like words, even when provided with referential training that adds clarity to the task.

In Experiment 1, 12-month-olds were flexible in accepting word forms that violated the phonotactics of their native language when the referential role of these to-be-learned novel words was clarified with a word-referent training phase. That is, infants in the Name training condition, who were provided with contextual evidence that object labeling was the goal of the task, mapped words that contained illegal sound combinations to objects. Infants’ failure to map these phonotactically illegal words to objects in the Exclaim training condition provides critical evidence that simply presenting infants with familiar attention-directing words is not sufficient to promote these word-object mappings. Thus, in order for infants to map words that contain illegal sound combinations to objects, infants require contextual cues in the Switch task that indicate that the unusual sounding label is meant to refer to an object.

Our findings extend previous work that has demonstrated that clarifying the ambiguous referential status of words leads infants to map words to objects in isolation (Fennell & Waxman, 2010; Fulkerson & Waxman, 2007; May & Werker, 2012; Namy &
Waxman, 2000). Our findings are also consistent with recent research by May and Werker (submitted) who investigated how the presence of a referential training phase influenced English-learning 14- and 20-month-olds’ mapping of non-native speech sounds (i.e., clicks) to objects. These sounds fall well outside of any native-English sound categories and therefore cannot be assimilated into any native speech sound category. Results indicated that when infants were provided with a referential training phase, 14-month-olds, but not 20-month-olds, mapped the unassimilable clicks to objects. These findings suggest that when young infants are provided with an additional cue that clarifies the nature of the Switch task, 14-month-olds will map labels that contain an illegal phoneme to novel objects. Interestingly however, 20-month-olds failed to map the clicks regardless of whether the referential training phase was provided, suggesting that a developmental narrowing is occurring between 14- and 20-months of age in infants’ awareness of what an appropriate label may be in their native language and their willingness to accept forms that contain illegal sounds as labels for objects. While our findings are consistent, we have found that forms which are legal in the native language (i.e., function words) are not acceptable object labels, suggesting that some lexical knowledge about the phonological structures specific to object labels exists at 12 months. This is further supported by the finding that our infants also rejected individual legal sounds (i.e. phonemes) as potential labels. Accepting both illegal sound combinations (Exp. 1) and non-native sounds (May & Werker, submitted) when provided with additional support to the task is potentially very useful. That is, it suggests a certain degree of willingness to learn about sound patterns that have not been experienced in appropriate contexts.
These results raise the question as to whether older infants would fully narrow their acceptance of word forms that contain illegal onset sound combinations as object labels? Given previous work demonstrating that by 20 months of age, infants begin to narrow their acceptance of a variety of symbolic forms as labels (e.g., non-native sounds, non-linguistic sound and gestures), we would predict that infants would demonstrate a similar decrease in flexibility in accepting phonotactically illegal word forms around 20 months of age even when provided with referential support (e.g., Graham & Kilbreath, 2007; May & Werker, submitted, Namy & Waxman, 1998; Woodward & Hoyne, 1999). This, of course, remains an empirical question.

In Experiment 2, infants demonstrated a limited flexibility in mapping ill-formed words to objects. That is, infants did not map consonantal sounds or function-like words to objects even when the referential intention of these labels was clarified through a Name training phase. Of course, it remains to be seen whether additional contextual or referential cues may lead infants to accept even the poor forms as labels for objects. Why will infants capitalize on the referential training provided in the Switch task to map phonotactically illegal words to objects, yet fail to apply this cue when mapping ill-formed words to objects? We propose that although the Czech words contained an onset sound cluster that is illegal in the English language (i.e., /pt/ or /sv/), the structural shape of these words may share more similar characteristics to words that infants typically learn as labels for objects early in the acquisition of language; namely noun-like words. The illegal Czech words were comprised of four sound segments, as opposed to the consonantal sounds and function-like words, which were comprised of a single sound and two-sound segments, respectively. The simplified structure of the function-like words can be viewed as sharing similar sound
structures commonly found in frequent function words in English (i.e., CV, VC, V structure), whereas the Czech words have a complex sound structure that is commonly found in frequent English content words (e.g., CVC, CCVC). Thus, when infants are provided with information that indicates that the to-be learned linguistic form is intended to be a label, infants may weigh aspects of what an appropriate word form is differently and thus, be less flexible with accepting word forms that are structurally poor (i.e., C, CV or VC structure) as compared to word forms that contain illegal sound combinations.

In support of this argument, research has demonstrated that young infants are sensitive to not only the structural shape of words but also their phonological properties, which in turn, permit them to distinguish between grammatical and lexical word forms (Shi & Werker, 2001; Shi, Werker & Morgan, 1999). Thus, it may be the case that infants’ developing sensitivity to the structural shape of words may then subsequently constrain possible labels infants are willing to map to objects. That is, as infants begin to further develop their lexicon, expectations form regarding which word forms constitute an appropriate label for an object, based on several linguistic cues, including the sound structure of word forms. Consequently, even when infants are presented with cues within a word-learning context that indicate that an ill-formed word is intended to be an object label (i.e., word-referent training), infants may be less flexible in mapping these linguistic forms to objects. When precisely this preference for well-formed words develops is unclear.

Infants younger than 12 months of age may be willing to accept function words and consonantal sounds as labels for objects. However, given neonates’ ability to discriminate content and function words on the basis of their phonological and acoustic cues (Shi, Werker, & Morgan, 1999) and 6-month-olds’ preference for listening to content words over
function words (Shi & Werker, 2001), infants between 6 and 12 months of age may have already begun establishing preferences about the particular shape of an object label.

Why do infants in our experiment fail to map function words when previous work has demonstrated that 17-month-olds will map word forms with similar properties to function words (e.g., short vowel, open syllable) to objects (e.g., Werker, Fennell, Corcoran & Stager, 2002)? Werker and colleagues demonstrated that 17-month-olds mapped minimally different words with short vowels and an open syllable structure to objects in the Switch task (e.g., *bih* and *dih*). This study however, differs in several ways methodologically from our study. First, the infants tested were significantly older which may account for this difference in performance in that the computational demands involved in learning new words, learning about new objects and linking these words to objects may be more strenuous for young 12-month-olds who are in the early stages of word learning. This argument parallels previous work by Werker and Stager (1997) who found that unlike 17-month-olds, 14-month-olds failed to map minimally different words with short vowels and an open syllable structure to objects in the Switch task. Second, differences in how the auditory stimuli were produced may account for the difference in findings. That is, unlike our function words, which were spliced from a sentence to ensure the forms weren’t stressed in production, the word forms used in Werker et al.’s study were produced in isolation and with infant-directed speech. Thus, although the stimuli from both studies shared an open syllable structure, the difference in speech style may account for the way in which the infants processed these different word forms. Future research investigating older infants’ acceptance of function words as object labels would help clarify the extent to
which 12-month-olds’ inability to map these forms to objects is impacted by the structure of these word forms or by their stage in development (i.e., age).

Overall, our findings demonstrate that infants are sensitive to both the linguistic properties of potential labels as well the context in which the labels are presented. That is, infants’ language system allows for a certain degree of flexibility in that they will use information that clarifies the Switch task to guide their mapping of unusual sound patterns to objects. This flexibility, however, is tempered by the phonological shape of these labels. More specifically, if the forms do not structurally conform to what is considered to be a reasonable syllable pattern (CVC, CCVC) for a label, infants will not accept these labels. It remains an open question whether providing additional contextual or referential information will lead infants to accept these “poor” forms.

These results parallel previous work demonstrating that infants will demonstrate a limited flexibility in the types of auditory stimuli they will accept as labels for objects depending on the cues, which are presented in the word learning task (Hollich et al., 2000; Namy & Campbell, 2001). For example, Hollich and colleagues (2000) investigated the context in which 12-month-olds will accept linguistic sounds (e.g., mouth sounds) and non-linguistic sounds as object labels. Results indicated that when infants were provided with attentional cues including a naming phrase and eye gaze, they accepted the mouth noises but not the non-linguistic sounds as labels for objects. When perceptual salience of the target object was added as an additional cue in the task, infants accepted the non-linguistic sound as a label for an object. Further support for the influence of referential cues on word learning comes from work by Campbell and Namy (2003) who demonstrated that both 13- and 18-month-olds will map both verbal (e.g., foppick) and nonverbal symbols (e.g., two-
tone beep) to object categories when presented within a referential context, but not when
the referential context is absent (i.e., when the word or the nonverbal sound was emitted
from a baby monitor when the infants looked at the object). Together, these findings
suggest that when infants are presented within a rich social interactive task with several
referential cues indicating the intent of the speaker, infants will demonstrate a symbolic
openness regarding the types of labels they will map to objects (e.g., Campbell & Namy
2003; Namy 2001; Namy & Waxman, 1998; Woodward & Hoyne, 1999). However, when
referential cues are limited or absent from the word learning task, infants will constrain the
types of forms they will map to objects (e.g., Graf-Estes et al., 2011; Hollich et al., 2000;
MacKenzie et al., 2011; MacKenzie et al., 2012a; MacKenzie et al., 2012b). Together these
findings suggest that infants have emergent preferences for what constitutes an object label,
but also a certain degree of flexibility within the system, which allows for these preferences
to be overridden by other factors, such as referential information.

In summary, our findings add to the growing body of literature on infants’ acquired
knowledge about their native language sound system and their willingness to apply this
knowledge when making word-object mappings (Fennell & Waxman, 2010; Hochmann et
al., 2011; MacKenzie, et al., 2011; MacKenzie et al., 2012a; MacKenzie et al., 2012b;
Werker & Fennell, 2004). Indeed, we have shown that English learning infants will exhibit
flexibility in the types of linguistic forms they will map to objects, however, this flexibility
appears to be constrained to structurally well-formed words that share the syllabic
properties of noun-like words, even when the referential role of these labels are clarified.
Thus, our results demonstrate that by their first birthday, infants’ ability to make word-
object mappings is sophisticated in that, infants will weigh the relevance of the linguistic
properties of potential labels and contextual information provided in the task to determine what an appropriate word is for an object label.
References


Chapter 5: Conclusion

The chapters of this dissertation explored 12-month-olds’ associative word learning ability with specific focus on: 1) how infants’ experience with their native language guides their developing expectations about the appropriate sound form for an object label; and 2) the flexibility of these expectations across different sound-object associative contexts.

In Chapter 2, I examined how native-language phonotactics and realization of phonemes influences the types of words 12-month-olds were willing to map to objects. Results from this set of experiments indicated that infants’ language-specific phonotactic knowledge constrains their word-object mappings. In contrast, variations in the phonetic realization of particular forms do not. In Chapter 3, I explored whether the organization of word forms based on their phonological shape constrains the types of words infants are willing to map to objects. Across two studies, results demonstrated that 12-month-old infants have accumulated knowledge about the acoustic properties of function words versus content words that differentiate them and will privilege noun-like forms as labels for objects. Finally, in Chapter 4, I examined whether infants will override their established preferences for particular forms as labels for objects when provided with a training phase that highlights the goal of the task. The results of two studies indicated that 12-month-olds are flexible in the types of linguistic forms they will map to objects when provided with a training phase that clarified the referential nature of the task, however, this flexibility appears to be limited to structurally well-formed words that share the phonological properties of noun-like words.

There are a number of broader implications for the findings in this dissertation. First, these findings illustrate the important influence experience with the native-language
sound system has on 12-month-olds’ associative word learning ability. Indeed, over the first year of life, infants are honing in on their native language sound system (Werker & Tees, 1984). During this period of development, infants are also learning about the distributional patterns of phonotactic combinations present in their native language. Infants’ sensitivity to statistical regularities of their native language also supports their ability to recognize and segment words from fluent speech on the basis of their distributional and phonological properties (Lany & Saffran, 2011; Mattys & Jusczyk, 2001; Pelucchi, Hay & Saffran, 2009; Saffran, Aslin & Newport, 1996). It can be suggested then that infants’ experience with statistical regularities in the speech stream supports vocabulary development by facilitating more in-depth processing and rapid learning of sound sequences that carry meaning and are mapped to referents (Lany & Saffran, 2011). For example, infants at 6-months of age can differentiate word classes on the basis of their unique phonological, and distributional properties and demonstrate a preference for listening to content words over function words (Shi, Werker, & Cutler, 2006; Shi & Werker, 2001; Shi & Gauthier, 2006; Shi & Lepage, 2008). Infants’ preference for attuning to content words may be influenced by the unique phonological and acoustic characteristics they hold (i.e., receive greater stress, and have more melodic contours; Hohle, Weissenborn, Kiefer, Schulz & Schmitz, 2004; Jusczyk, Cutler & Redanz, 1993; Mintz, 2006; Spring & Dale, 1977). Overall, these findings suggest infants’ ability to identify and attend preferentially to content words may be beneficial in that it leads them to attend to words in the speech stream that have rich conceptual content and will first appear in their productive lexicon.

The findings that 12-month-olds will not map words that violate the phonotactics of
their native language to objects is consistent with research demonstrating that 18-month-olds rely on their phonotactic knowledge of their native sound system to guide their word learning ability. For example, when 18-month-olds were presented with two phonotactically legal object labels (containing sound sequences that occur frequently in English) or two phonotactically illegal object labels (containing sound sequences that never occur in English), paired with novel objects, infants looked at the correct objects after hearing the legal labels, but not the illegal labels during a looking while listening procedure (Graf-Estes, Edwards & Saffran, 2011). Our results provide new evidence that infants by 12-months of age, will use their acquired knowledge about the sound system of their native language to constrain the types of words they identify as appropriate labels for objects. Interestingly, infants’ acceptance of both English and Japanese words suggests that both the English and Japanese auditory stimuli parallel their established expectations of what constitutes an appropriate word. That is, even though the Japanese words differed phonetically from English, this did not impact infants’ willingness to map these word forms to objects. These findings suggest that 12-month-olds may be directing more attention to the phonotactic information of potential labels compared to the phonetic realization of phonemes when mapping words to objects. At the same time, infants in Experiment 2 demonstrated a preference for the English words over the Japanese words, illustrating that infants do indeed detect the subtle differences between the words used in this study, however did not use this knowledge to constrain their word-object mappings.

These findings add to the growing body of literature investigating infants’ phonetic realization of phonemes and their ability to apply this knowledge in early word learning (e.g., Best et al., 2009; Stager & Werker, 1997; Fennell & Werker, 2003). For example,
research on phonological distinctiveness has shown that infants discriminate minimal pairs (e.g., “vaby” for “baby”) more readily and consistently by 18-19 months of age than between 11-17 months of age (Halle & de Boysson-Bardies, 1996; Stager & Werker, 1997). These findings suggest that as infants further progress in their lexical development, their use of phonemes to direct attention to relevant information in word learning may be available (Werker & Curtin, 2005). It remains to be seen whether infants will completely narrow their preference or whether acceptance of phonologically varied words outside their native language remain open. Future research is needed to clarify the degree to which phonetic realization of phonemes impacts word learning over the course of development.

Chapter 3 provides evidence that 12-month-olds can sort words on the basis of their surface acoustic and phonological properties and use this knowledge to guide their word-object associations. That is, infants will map words that share the phonological and acoustic properties of content-like words and not function-like words to objects. These findings suggest that infants’ developed sensitivities for phonological properties of their native sound system, along with repeated exposure to certain forms as referential labels (i.e., content-type words), may lead infants to develop expectations as to what an appropriate phonological form is for an object label. These findings add to the growing body of literature investigating how infants’ sensitivity to phonological and distributional properties of grammatical versus lexical word forms influences their word learning ability (e.g., Hochmann et al., 2010; Lany & Saffran, 2011). Indeed, previous work has demonstrated that 17-month-olds can rely on statistical cues such as frequency to identify function words from content words in a word learning paradigm. That is, when word frequency is provided as a cue for function words during a familiarization phase, infants can segment a foreign
determiner-noun sequence and map the noun to the object (Hochmann et al., 2010). Furthermore, recent work by Lany & Saffran (2011) demonstrated that 22-month-olds rely on both the phonological and distributional cues marking both grammatical and lexical word forms to facilitate early word learning. My findings compliment previous work by illustrating how infants can rely solely on phonological cues to identify content words and map them to objects. It is unclear however, whether infants’ ability to rely on phonological cues to guide word learning is universal in nature. That is, the auditory stimuli used in this study was based on characteristics specific the infants’ native language (e.g., “it” analogous to “is”). Thus, future research is indeed needed to clarify whether infants can rely on this cue when presented with novel words outside their native sound system.

Together, my results and previous findings demonstrate that infants can rely on a range of phonological, acoustic and distributional properties of speech to help identify grammatical versus lexical word forms in the speech stream which then contributes to infants’ developing expectations regarding what an appropriate word form is for an object label. Infants’ ability to rely on these properties of speech to guide their word learning may also provide insight into understanding how infants learn language with such effort and ease. That is, before infants’ productive vocabulary explosion at 18-months of age (Fenson, 1994), infants already can track and identify content-like words on the basis of their distributional and phonological properties and map these words to objects as labels.

Another important implication from the findings of this dissertation comes from Chapter 4, which sheds light on infants’ flexibility in overriding an established bias for well-formed phonotactically legal word forms. Results from Chapter 4 demonstrate how infants’ language system allows for a certain degree of flexibility in that they will use
information that clarifies the Switch task to guide their mapping of words containing phonotactically illegal sound patterns to objects. The phonological shape of these labels, however, constrains this flexibility. That is, if the forms do not structurally conform to what is considered to be a reasonable content-like word syllable pattern (CVC, CCVC), infants will not accept these labels. These findings highlight two important considerations. First, when infants are provided with information that indicates that the to-be learned linguistic form is intended to be a label, infants can weigh aspects of what an appropriate word form is differently and thus, will preferentially rely on the structural shape rather than the phonotactics of the word to guide their word-object mappings. The reliance on structural shape may stem from infants’ developing sensitivities to grammatical and lexical word forms over the first year of life (Shi & Werker, 2001; Shi, Werker & Morgan, 1999). That is, infants’ repeated exposure to the structural differences between these word classes, along with their developed preference for attending to content-like words, may lead infants to rely on this cue to guide their expectations as to what an appropriate label is for an object. Although these findings demonstrate a limited flexibility in infants’ willingness to accept poor forms as object labels, it remains to be seen whether additional contextual or referential cues may lead infants to accept even the poor forms as labels for objects.

Second, these findings offer insight into research investigating infants’ symbolic openness to different labels for objects. To date, research on early word learning has demonstrated that infants are flexible in the range of symbolic forms that they will accept as representing objects when rich social-referential cues are present in the word learning task (Campbell & Namy, 2003; Hollich, Hirsh-Pasek, & Golinkoff, 2000; Namy & Waxman, 1998; Woodward & Hoyne, 1999). That is, when presented with an interactive
word learning task, infants will demonstrate a general openness to the kinds of symbols that they are willing to adopt as object labels (e.g., Namy, 2001; Namy & Waxman, 1998; Namy, Campbell, & Tomasello, 2004). For example, Namy (2001) introduced 18-month-olds to range of different symbols (i.e., word, gesture, non-verbal sounds & pictograms) as labels for object categories. Results indicated that infants mapped each of these forms to the appropriate object categories; therefore treating all four symbols types as object names. These results along with previous work in the word learning literature demonstrate that the use of social-referential cues indicating the speakers’ intent in the word learning task facilitates young infants’ acceptance of a variety of symbols as object labels.

At the same time, one could make the argument that if the referential training phase clarifies to infants that they are engaged in a ‘naming’ task, their biases for well-formed phonotactically legal word forms as labels should be activated by this cue and thus, restrict the potential words infants are willing to map to objects. Although infants by 12-months have gathered knowledge about the structural, acoustic and phonological properties of content-like words (Morgan et al., 1996; Shi & Werker, 2001), their lexical representational space of word forms at this age is parse and in the stage of being further developed (Werker & Curtin, 2005). Thus, when infants’ are provided with a structurally well-formed word that contains an illegal sound combination as a potential label, they may be flexible in mapping this word form to an object given their limited phonological knowledge. Infants at this age are also very attuned to potential ‘naming’ tasks and thus, have a desire to learn a potential label for an object.

When comparing infants’ symbolic openness in interactive tasks as compared to previous work using the Switch task (e.g., Fennell & Waxman, 2010; MacKenzie, Graham
& Curtin, 2011), it highlights the powerful influence that social-referential cues have in the word learning process and the important role intentionality of language plays in the word learning process. That is, when word learning tasks include information clarifying the intention of the speaker through the use of referential cues such as pointing and eye gaze direction, infants demonstrate a symbolic openness to the types of labels they will accept for objects (e.g., Woodward & Hoyne, 1999; Hollich et al., 2000; Campbell & Namy, 2003). When these cues are not present in the Switch task, infants then constrain the types of linguistic forms they will map to objects (e.g., MacKenzie, et al., 2011; MacKenzie, et al., 2012a; MacKenzie, et al., 2012b; MacKenzie, Graham, Curtin & Archer, under review). Thus, it is possible that these additional cues lead the infant to override a default bias to privilege specific word forms over other types of linguistic forms when making word-object mappings. This argument aligns with findings from Chapter 4, which illustrates a shift in infants’ flexibility to map word forms that violate the phonotactics of their native language when provided with a minimal cue that clarifies the purpose of the task.

Indeed, it could be argued that infants’ differential performance across these two tasks reflects different word learning processes, rather than activating or overriding a bias for specific labels for objects. True word learning can be understood as an infant understanding the full referential nature of language, in that, infants are able to not only map a word to an object, but also extend that label to other members of the same category (Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Mervis & Bertrand, 1992). Therefore, the Switch task could be understood as a more stimulus-response learning process, rather than engaging in true word learning that requires a more symbolic and referential mapping process. If this were the case however, one would expect that infants would make an
association between any auditory sound and the presence of some object. The findings from my dissertation studies, along with previous work (MacKenzie et al., 2011) suggest that infants are engaging in more than just a simple associative process in the Switch task. That is, when presented with a novel object and novel linguistic sound, infants constrain the types of linguistic forms they will map to objects. Overall, these findings demonstrate that when infants are engaged in the Switch task, their default bias for well-formed phonotactically legal word forms are activated and constrains the types of linguistic forms they will map to objects. It is yet to be determined whether infants are viewing these newly learnt word-object mappings as labels that extend to other members of the same category. Future research would need to be conducted to clarify the degree to which infants’ are viewing these newly learnt labels as symbolic referents.

An important question that stems from results of this dissertation is where does infants’ bias for well-formed phonotactically legal word forms as object labels originate? My proposal is that infants, over the course of their development, use their accumulated knowledge about the sound system of their native language to facilitate the development of their lexicon. That is, over the first year of life, infants are not only attending to and tracking the statistical regularities of speech in general but also the unique properties of their native language. This accumulated knowledge of their native language in turn, contributes to infants’ ability to learn language more efficiently by using these cues to guide their expectations as to what an appropriate label is for an object. In support of this notion, research has demonstrated that right from birth, infants have a perceptual bias toward listening to speech over non-speech stimuli (Voulomanos & Werker, 2004; Vouloumanos & Werker, 2007). Neonates also demonstrate early preferences for hearing
their mother’s voice, stories and songs heard prenatally, and their native language (Moon, Cooper & Fifer, 1993; Fifer & Moon, 2003). Further support for early perceptual sensitivities to language comes from studies demonstrating that newborns are sensitive to word boundaries (Christophe, Dupoux, Bertoncini & Mehler, 1994), can distinguish dissimilar languages on the basis of rhythmic patterns (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, Amiel-Tison; 1988; Nazzi, Bertoncini & Mehler, 1998), can categorically discriminate lexical versus grammatical words (Shi, Werker & Morgan, 1999), can distinguish between stress patterns of multisyllabic words (Sansavini, Bertoncini & Giovanelli, 1997), and can differentiate between good and poor syllable forms (Bertoncini & Mehler, 1981). Overall, it can be suggested that newborns’ bias and sensitivity for speech, irrespective of its origins, may act as an adaptive advantage by directing infants to attend to speech over types of auditory stimuli. This attunement to speech may then in turn, facilitate more in depth processing and acquisition of the specific properties of their native language (Vouloumanos & Werker, 2007; Werker & Yeung, 2005).

In summary, the findings of this dissertation expand our understanding of how infants’ growing knowledge of their native sound system shapes and constrains their developing expectations of what an appropriate label is for an object. Indeed, by 12-months of age, infants are able to recruit and use their knowledge about native phonotactics, as well as the phonological and structural shape of grammatical word classes and to guide their word-object mappings. These results speak to the sophistication of infants’ early word learning ability. That is, without any social-contextual support in the word learning task, infants rely on the sound properties of the to-be-learned label to determine whether it is an appropriate label for an object, namely, a phonotactically legal content-like word.
Furthermore, when provided with an additional cue that clarifies the purpose of the Switch task, infants can weigh this information along with the linguistic properties of the label to help guide their word-object mappings.
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CHILD DEVELOPMENT

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