The Effect of Non-Linguistic Patterns on Linguistic Biases

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Abstract

The present study explores the effects of non-linguistic experiences on biases for linguistic judgments, specifically consonant deletion patterns. When two adjacent consonants come into contact as a result of morphological concatenation, many languages will delete the first consonant (e.g., /bepdok/ becomes /bedok/). Speakers of these languages (as well as English speakers) prefer deletion of the first consonant to the second consonant because the first consonant is perceptually weaker, making it more prone to misrepresentations and modifications. Following exposure to a non-linguistic analogue of consonant deletion in which the second consonant was deleted instead of the first, participants no longer preferred deletion of the first consonant in the metalinguistic judgment task. These results suggest that exposure to non-linguistic materials can interact with linguistic judgments.

Keywords: statistical learning, phonotactics, learning biases, analogy.

Introduction

One of the major questions in the cognitive science of language is how linguistic and non-linguistic experiences interact to build a productive system of language. For example, children learning language benefit from increased cognitive and social skills in their language capacities, but increased language capacities also help to scaffold cognitive and social growth (Dessalegen & Landau, 2008). Because language interacts with social, cultural and cognitive aspects of human functioning, it is important to understand how language influences non-linguistic cognition, in addition to how non-linguistic cognition influences language.

The discussions concerning linguistic and non-linguistic interaction have often turned to the question of linguistic relativity, the idea that the specific language one speaks has an effect on how the speaker perceives and interacts with the world (Whorf, 1956). In addition, there is a question of how linguistic knowledge can aid in higher level cognition (Gentner & Goldin-Meadow, 2003).

The question of how language and thought interact can be addressed not only as whether language affects thought, but also whether non-linguistic information can have an effect on language. While language is a direct way to express one's thoughts, there may be other, more subtle ways in which non-linguistic experience can affect language. These subtle effects could be used to understand the ways in which linguistic knowledge is specific to language (domain specific) and general to other cognitive processes (domain general). In domain specific views, language is believed to be a key component that to human cognition. The mechanisms that underlie language are separate from other species, and (in the most extreme theories) show no interaction with non-linguistic cognitive functions (Berent, 2012; Pinker & Jackendoff, 2009). In this view, non-linguistic cognition should have no influence on linguistic judgments. In a domain general view of language, foundations for the human language capacity arise through social and cultural transmission. The key to linguistic knowledge is an interaction between the need to communicate and the existence of high-level cognitive capacities such as abstract pattern learning and memory (Chater & Christiansen, 2010). Under this view, non-linguistic patterns should have a strong influence on linguistic constructs.

One of the strong pieces of evidence for a domain specific approach to language is the idea that there are biases for specific linguistic structures that have no non-linguistic analogues (Berent, Steriade, Lennertz, & Vaknin, 2007; Culbertson, Smolensky, & Legendre, 2012; Finley, 2012; Finley & Badecker, 2008). For example, Finley (2012) found that adult native English speaker show a bias for phonological patterns based on vowel height. Since vowel height is a linguistic construct, it is hard to imagine how such a bias could be influenced by non-linguistic factors.

Other evidence suggests that linguistic patterns may be stored as domain-general rules. Studies of statistical learning for speech segmentation showed similar results to linguistic and non-linguistic materials (Aslin, Saffran, & Newport, 1997; Saffran, Pollak, Seibel, & Shkolnik, 2007). In addition, Finley and Christiansen (2011) showed that adult learners can generalize a novel reduplication pattern to from non-linguistic materials to linguistic judgments.

In addition, robust use of analogy in both linguistic and non-linguistic learning tasks (Gentner, 2010) opens the possibility that learners will be able to form connections between non-linguistic patterns and linguistic patterns.

The evidence for both domain general and domain specific learning mechanisms suggests that grammatical principles have many influences. The goal of the present study is to provide experimental evidence that manipulation of nonlinguistic patterns can affect linguistic biases. Specifically, we focus on consonant deletion, a phonological pattern whereby a consonant will delete in the presence of two adjacent consonants.

Biases in Consonant Deletions

Consonant deletion is a phonological pattern in which one of two adjacent consonants delete (e.g., /depkot/ becomes

/dekot/). In these consonant deletion patterns, there appears to be a cross-linguistic preference to delete the first consonant (Steriade, 2001; Wilson, 2001). In Diola Fogny, when two consonants combine as a result of morphological concatenation, the first consonant deletes (e.g., /let+ku+jaw/ → [lekujaw] 'they won't go') (Sapir, 1975; Wilson, 2000, 2001). Wilson (2001) argues that the second consonant is in a perceptually stronger position (onset), while the first consonant is in a perceptually weaker position (coda). If a rule requires deletion of a consonant, speakers will choose to delete the weaker one. A perceptually weak consonant is more likely to be misheard or not heard at all, meaning that over time (diachronically), that consonant may be categorically deleted from the lexical item (Steriade, 2001, 2009).

Finley (2011b) provided evidence that the preference for C1 deletion over C2 deletion is synchronic and present in speakers of English (a language that does not have regular consonant cluster deletion). In this experiment, monolingual English speaking participants were given a two-alternative forced choice test in which participants chose between two triads. In one triad, the first consonant was deleted (e.g., /bep, dok, bedok/). In another triad, the second consonant was deleted (e.g., /bep, dok, bepok/). Participants were more likely to choose the triads where the first consonant deleted (based on the criteria to choose which triad was more likely to belong to a 'real' language). This result suggests that participants prefer to delete the perceptually weak pattern, despite no exposure to this pattern in the native language.

Sources of Linguistic Biases

While it is agreed that linguistic biases are prevalent, the sources of such biases are not agreed upon. One possibility is that linguistic biases are derived from pre-existing linguistic knowledge or experience. This knowledge could be innate (Berent, et al., 2007), or inferred indirectly through the course of exposure to other patterns in the language. It is also possible that a bias for a particular linguistic pattern may have roots in domain general cognition (Chater & Christiansen, 2010). For example, cross-linguistic preferences to avoid changes to the first syllable of a word may result from domain general mechanisms (Beckman, 1998). The first and last items in a list are the most likely to be remembered (referred to as primacy and recency), suggesting that the first and last parts of a word will also be easiest to remember. If beginnings of the words are easier to remember, speakers may avoid altering that part of the word.

One issue with discerning whether non-linguistic cues can influence linguistic biases is that the linguistic and non-linguistic cues often interact, and the direction of interaction is often unclear. For example, initial syllables may be more likely to be remembered because they are less likely to be altered (and thus have fewer alternative forms to consider). In addition, other linguistic cues such as stress, prominence and volume may play also play in phonological processes, and these different factors may vary across different languages.

The goal of the present study is to determine whether a non-linguistic analogue of a linguistic pattern can alter a linguistic bias. If the non-linguistic cue can remove (or even reverse) the linguistic bias, it suggests that non-linguistic cues do affect how speakers perceive and interpret language. It is important to note that if a non-linguistic cue can affect a linguistic bias, it in no way implies that all linguistic biases have a non-linguistic basis. However, if a linguistic bias can be influenced by a non-linguistic cue, it opens the possibility that domain general influences affect at least some of the linguistic tendencies found cross-linguistically.

The present experiment makes use of the known linguistic bias in adult English speakers for deletion of C1 in a C1-C2 consonant cluster (Finley, 2011). The present experiment asks whether exposure to a non-linguistic analogue of C2 consonant deletion (as opposed to the preferred C1 deletion) can reduce or reverse the bias for C1 deletion in learners.

Methods

The present study used an artificial language that contained a non-linguistic analogue of a deletion pattern. In Finley (2011a, 2011b), consonant deletion was induced via triads in which two CVC (consonant-vowel-consonant) items were combined to form a CVCVC word (e.g., /bek dof bedof/). We created a non-linguistic analogue using sequences of shapes with various patterns. An analogue for perceptual dis-preference for two consonants in a row was created using visual aesthetics. In the present experiment we treated every consonant as a long rectangle with various patterns, and every vowel as a circle filled with various patterns. The fill patterns were used to create differences between the various circles and rectangles, while maintaining a strong sense of continuity between the shape and size of the circles.

Participants

All participants were adult native English speakers. Eighteen participants were recruited from Elmhurst College and the surrounding community. Each participant was given a $10 gift card for participating. Twelve participants were recruited from the University of Rochester community and paid $10 cash for their participation. Twelve control participants were recruited from the University of Rochester community were paid $5 cash for their participation. Some participants may have previously participated in an artificial grammar learning experiment, but no participant had been exposed to the stimuli or patterns used in the present experiment. The data for two additional participants could not be used due to malfunctions in the experimental program.

Design

The experiment was designed to test the ability of adult learners to extend a novel non-linguistic analogue of consonant deletion to a linguistic version of the same task. English speakers have been shown to prefer deletion of the

first consonant of a CC consonant cluster, complying with the general cross-linguistic tendencies (Finley, 2011b; Wilson, 2001). Importantly, the preference shown in English speakers appears without any prior exposure to the pattern. In these previous studies, participants were exposed to triads of shapes presented in the center of the screen for 1000ms. Participants were told that they would see one of two shapes followed by the combination of the first two shapes (participants were given a practice trial in which all squares and circles were identical, and given a chance to ask questions if necessary).

The patterns of the circles and squares were made in exact analogy to a precious consonant deletion experiment in which two CVC words were combined to form a CVCV word (e.g., /bek/ + /dok/ → /bedok/) (Finley, 2011a, 2011b). The visual analogue treated every segment as a separate shape. For example, /a/ was a circle with black 'confetti' squares, and /k/ was a rectangle filled in with a diagonal brick pattern. Creating stimuli in this manner helped to keep the stimuli as analogous to an experiment that used linguistic materials. It also allowed non-linguistic materials to be balanced similarly to linguistic materials. Examples of the training stimuli can be found in Table 1.

Table 1: Examples of Training Stimuli.

Set 1	Set 2	Combined Form
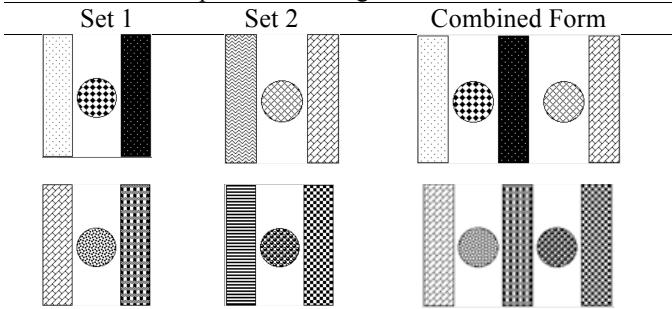
Training consisted of 24 triads repeated five times each in a random order. Immediately following exposure, participants were given a two-alternative forced choice test in two parts. The first part tested knowledge of the non-linguistic pattern, with examples found in Table 2. The second part tested biases towards C1 deletion in a linguistic consonant deletion pattern, with examples in Table 3.

Old Items The first type of test item specifically tested the learner's ability to recognize which of the rectangles was deleted in the exposure items. A participant could respond correctly to these items by remembering the specific items in the exposure set.

New Items The second type of test item used novel shape items. A participant could respond correctly to these items if they extend the pattern seen during exposure to novel items.

Sound Items The third type of test item was designed to assess whether participants who were exposed to the visual deletion pattern would show the same bias towards first-consonant deletion shown in previous studies. The stimuli were nearly identical to those used in previous studies of consonant deletion (Finley, 2011a, 2011b). Participants were told to select which of the following sets of three sounds was most likely to be from a real language. The sound items were presented in the same manner as the Old and New test items, choosing between deletion of the first consonant (C1) or the second consonant (C2) of a consonant cluster. Each item in the two-alternative forced-choice task was a tirad: CVC_1, C_2VC, CVCVC. Participants were told that they would be hearing two sets of three non-words where the third word was a combination of the first two (given /tooth+brush = toothbrush/ as an example), and their job was to select which set of three non-words they preferred.

Table 2: Example Old and New Test Items

	Set 1	Set 2	Combined Form
Old			
Second Deleted (Correct)			
First Deleted (Incorrect)			
New			
Second Deleted (Correct)			
First Deleted (Incorrect)			

All stimuli were designed so that the final consonant of the first CVC word was different from the first consonant of the second CVC word. For example, [pik ket] was not a possible pair of words in the experiment because it would be impossible to tell which consonant was deleted. Consonants were drawn from the set [p, t, k, b, d, g, s, f, z, v, m, n], and vowels were drawn from the set [a, i, e, o, u] Examples of Sound Items can be found in Table 3.

The Sound stimuli were recorded by an adult female native speaker of English in a sound attenuated booth at 12,000 Hz. Stress was placed on the first syllable using standard English pronunciation, with the exception that no vowels were reduced, meaning though all syllables contained partial stress (as English reduces unstressed syllables). All stimuli items were normalized for intensity (set at 70dB) using Praat (Boersma & Weenink, 2005).

There were 12 Old Items, 12 New Items and 30 Sound Items (however, a glitch in a group of participants caused

several participants to hear a random set of 20 of the 30 sound items). The Old and New test items were presented together in a random order, before the Sound Items. The items in each test condition were balanced such that half of the items showed deletion of the first consonant/rectangle first, while the other half of the items showed deletion of the second consonant/rectangle first.

Table 3: Sound Item Examples.

	CVC 1	CVC 2	Combined Form
Second Deleted (Non-Linguistic Bias)	div	nup	divup
First Deleted (Linguistic Bias)	div	nup	dinup
Second Deleted (Non-Linguistic Bias)	kaf	gez	kafez
First Deleted (Linguistic Bias)	kaf	gez	kagez

All phases of the experiment were run in Psyscope X (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants were given both written and verbal instructions. The entire experiment took approximately 20 minutes.

Results

Proportion of Set2/C2 deletion responses for all three different test items are given in Figure 1, with numerical values for means and standard deviations in Table 4.

Table 4: Means (and Standard Deviations).

Condition	Old	New	Sounds
Control	0.53 (0.10)	0.47 (0.11)	0.37 (0.11)
Experimental (Old Items Above Chance)	0.78 (0.11)	0.78 (0.18)	0.63 (0.26)
Experimental (Old Items Below Chance)	0.46 (0.059)	0.47 (0.14)	0.44 (0.21)

We compared the results for the experimental condition to the Control condition by a 2x3 mixed design ANOVA. We found a significant effect of Training ($F(1, 37) = 10.89$, $p = 0.002$), a significant effect of Test ($F(2, 74) = 7.13$, $p = 0.001$), and no interaction, $F<1$.

In order to test whether the bias existed in the Controls, and whether the bias was reversed in the Experimental condition, we compared the responses to 50% chance via one-sample t-tests. The results were significant for the Control condition $t(11)=4.33$, $p=0.0012$ (in that the Control condition was significantly below chance), but the results were not significant for the Experimental Condition,

$t(26)=1.15$, $p=0.26$. Because the experiment was concerned with whether exposure to the non-linguistic deletion pattern would change the bias towards C1 deletion in the consonant test, we compared the responses to the Sound Test Items between the Control and the Experimental Condition. There was a significant difference, $t(37) = 2.45$, $p = 0.019$.

Figure 1: Overall Results: Means and Standard Errors.
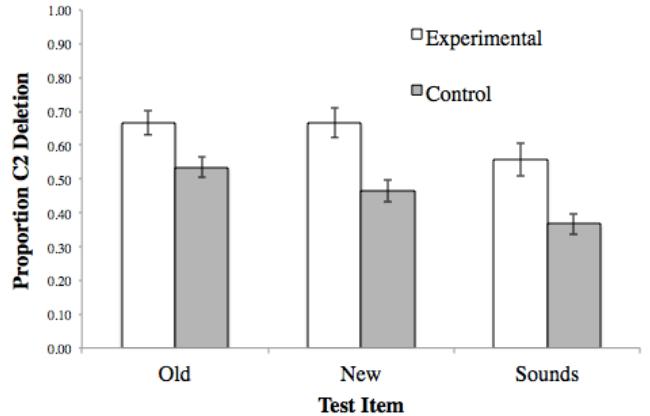
One possibility for the failure to find a significant difference between the Sound test items and chance (in the one-sample t-test) was that some participants failed to learn the non-linguistic pattern or remember the items heard in training. One cannot expect the non-linguistic pattern to have any effect on the linguistic pattern without learning the pattern (or at least recognizing the items heard in training). For this reason, we divided participants in the Experimental Condition into two groups: those that scored above 50% in the Old Items, and those that scored 50% (chance) or below in the Old Items. Of the 27 participants in the Control Condition, 17 scored above chance in the Old Items, and 10 scored at or below chance. These are presented in Figure 2.

Figure 2: Results with Participants in Experimental Condition: Separated by Response Rate: Means and Standard Errors
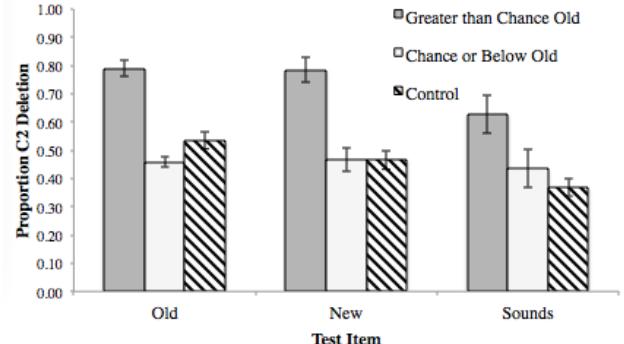
The participants who scored at or below chance for Old Items showed results very similar the Control Condition. When compared to the Control Condition via ANOVA, we found no effect of Training ($F<1$), a marginal effect of Test ($F(1, 40) = 3.00$, $p = 0.061$) and no interaction ($F(1, 40) = 1.64$, $p = 0.21$). When the Sounds Test items were

compared to 50% chance via one-sample t-tests, there was a marginally significant effect, $t(16)=2.04$, $p=0.0585$. Of the 17 participants who scored above chance for Old Items, three participants scored below 40% C2 deletion in the Sound Items. For this minority of participants, exposure to the non-linguistic pattern did not affect the bias. However, the majority of the 17 participants showed C2 deletion at a rate greater than that of the mean of the Control condition.

Discussion

The results of the present study demonstrate that linguistic biases can be reduced or altered due to exposure to non-linguistic material. These results have important implications for cognitive science. First, it suggests that biases found for linguistic patterns are malleable. Different experiences can prime the listener to expect different types of linguistic stimuli, and therefore diminish a pre-existing bias. This means that an innate bias for a particular linguistic structure could be overridden if provided with exposure to the right kinds of data. This may help to create a theory of linguistic biases that can account for the fact that there are exceptions to almost every posited linguistic universal (Evans & Levinson, 2009).

Second, the results support a theory in which linguistic and non-linguistic data interact. In understanding the domain specificity of language, one must understand what aspects of language interact with non-linguistic cognition, as well as the mechanisms that control this interaction. The results of the present study provide an insight into this question. In the present study, the non-linguistic deletion pattern had a direct analogue to the consonant deletion pattern. This direct analogy allowed participants in the Experimental Condition to interpret the linguistic material differently than participants in the Control condition.

A proposed analysis of the influence of linguistic experiences, non-linguistic experience, and linguistic biases on linguistic biases is presented in Figure 3.

Figure 3: The interactive of linguistic experiences, non-linguistic experiences and linguistic biases on linguistic judgments.
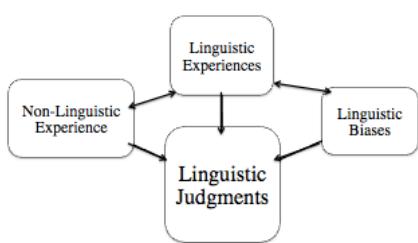
Linguistic judgments are affected by our linguistic experiences; native English speakers are able to make judgments about English due to their exposure to English. Linguistic judgments are also affected by biases that are independent of language exposure, such as the bias for C1 deletion over C2 deletion found in the control condition.

The Experimental condition demonstrated that non-linguistic experiences can affect linguistic judgments. The non-linguistic experience pushed the participants away from a bias towards C1 deletion. The mechanism proposed in Figure 3 also allows for interaction between linguistic and non-linguistic experiences, as well as an integration between linguistic biases and linguistic experiences. Non-linguistic experiences affect the type of language you are exposed to, and linguistic biases affect the likelihood that you will learn and be exposed to certain types of linguistic materials (Finley, 2012).

The diagram in Figure 3 also allows for individual differences in when non-linguistic experiences will affect linguistic judgments. When non-linguistic experiences and linguistic biases are in conflict (as in the present experiment), biases may trump non-linguistic experiences for some individuals. A small majority of participants in the Experimental condition showed a bias for C1 deletion, despite learning the non-linguistic pattern. This suggests that analogy from non-linguistic to linguistic patterns do not occur for everyone.

Third, the present experiment demonstrates that language and thought interact, and that the direction of interaction can go from non-linguistic patterns to linguistic patterns. The question of language and thought need not extend only to whether language affects thought, but whether non-linguistic patterns can affect how language is perceived language. The present experiment demonstrates that our non-linguistic experiences can affect how we perceive language.

One question that remains for future research is to understand when non-linguistic patterns may affect linguistic judgments in real-world situations. The present experiment made an arbitrary analogy between consonant deletion and shape deletion. Such direct analogies are rarely found in the real world. Given that patterns in language tend to be abstract and arbitrary, it is difficult to find a non-linguistic pattern that can be directly linked to language. One possibility may lie within the cognitive and linguistic development of infants and young children. As children learn patterns in their behavior and the behavior of others, they may use those patterns to help learn linguistic patterns. Conversely, children may use their ability to learn patterns to help learn both non-linguistic cognitive skills, as well as linguistic skills. For example, Dessalegen and Landau (2008) demonstrated that children can use labels to solve otherwise difficult non-linguistic tasks. In addition, the robust use of analogy in learning (Gentner, 2010), suggests that learners are capable of analogy from linguistic to non-linguistic material and vice versa. Future research will work to formalize when and how this analogy occurs.

The results of the present experiment provide further evidence for interaction between linguistic and non-linguistic patterns. Human learners have a remarkable ability to use analogy to extend a pattern from a non-linguistic domain to a linguistic domain. Despite the fact that English speakers (as well as speakers of several other

languages) show a bias towards C1 deletion, this bias was reduced after exposure to a pattern in which the non-linguistic analogue of C2 was deleted (as opposed to an analogue of C1).

Acknowledgments

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