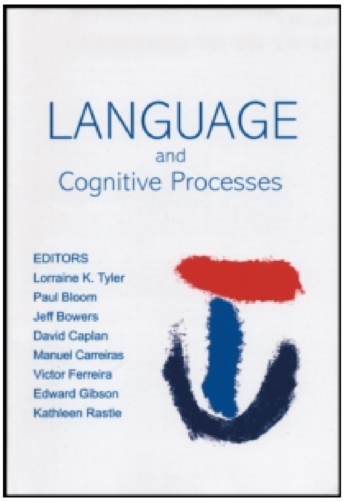

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Evidence for a domain-general mechanism underlying the suffixation preference in language

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Evidence for a domain-general mechanism underlying the suffixation preference in language

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The ability to distinguish between an inflectional derivation of a target word, which is a variant of the target, and a completely new word is an important task of language acquisition. In an attempt to explain the ability to solve this problem, it has been proposed that the beginning of the word is its most psychologically salient portion. However, it is not clear whether this phenomenon is specific to language. The three reported experiments address this issue. Experiments 1 and 2 established that suffixation-type preferences occur in language and in domains outside of language and that it is plausible that this same mechanism could account for alternative types of inflectional morphology. Experiment 3 indicated that the suffixation preference is both flexible and transferable across domains. In combination, these experiments

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suggest that the suffixation preference is driven by a cognitive mechanism that is both domain-general and flexible in nature.

Keywords: Attentional learning; Domain general; Inflectional morphology; Language; Suffixation preference.

One of the important tasks of language acquisition is the ability to distinguish between an inflection of a word, which is a variant of the original word (e.g., *can/cans*), and a completely new word (e.g., *can/scan*). Across languages, there are multiple types of inflection, including suffixation (e.g., adding a morpheme after the stem), prefixation (e.g., adding a morpheme before the stem), infixation (e.g., adding a morpheme inside the stem), and nonconcatenative devices (e.g., interleaving a string of vowels within a string of consonants). It has been suggested in the typological literature that there is a preference in natural language for suffixation (Bybee, Pagliuca, & Perkins, 1990; Cutler, Hawkins, & Gilligan, 1985; Cysouw, 2001; Dryer, 2005; Hall, 1988; Hawkins & Cutler, 1988; Hawkins & Gilligan, 1988). More specifically, Dryer (2005) reports that of 772 languages surveyed that use inflectional morphology, 64% have at least a moderate preference for suffixing, while only 19% had a similar preference for prefixing, and 17% had no preference for one over the other.

There is also evidence for the suffixation preference during language acquisition (Clark, 1998). One piece of supporting evidence presented by Clark is a slower rate of inflectional acquisition in prefixing languages (e.g., Mohawk) in comparison to suffixing languages in children. Furthermore, Clark found that English-speaking children imitate nonsense words with nonsense suffixes more easily than nonsense words with nonsense prefixes. In addition, Bruening and Brooks (2007) found that when referring to two identical objects, young children were more tolerant of word-form variations if the variation occurred at the end of the word rather than at the beginning. This research suggests that children interpret suffixed words to be more similar to the original word than are prefixed words.

While it is clear that consistency of an inflection type within a language (e.g., either suffixation or prefixation) assists the language learner in distinguishing inflected words from unrelated words, the reason for the cross-linguistic preference for suffixation compared to other forms of inflection is less clear.

One theoretical possibility is that the suffixation preference stems from factors that are specific to language or speech. In particular, it is possible that the suffixation preference stems from constraints built into the structure of language, which makes it easier to learn word variations when the modifications are at the end of the word. For example, languages could have differential stress patterns or differential co-articulation that could lead to a differential frequency of certain types of inflections over time. It is possible that this structure makes suffixes easier to acquire than prefixes. As a result, an added or changed suffix is perceived as a less drastic change of the original than an added or changed prefix, which results in suffixes being more easily understood as derivations of a word rather than an entirely new word. Another possibility is that the beginning portion of the word is its most salient part (e.g., Clark, 1991; Hawkins & Cutler, 1988) and that the early portion of a word is critical for word activation (e.g., Erdeljac & Mildner, 1999; Marslen-Wilson, 1987; Rodd, 2004; Tyler & Wessels, 1983; Wallace, Stewart, Sherman, & Mellor, 1995). In addition, it is possible that since affixes form a closed class, which is much smaller than the open class of roots (see Hawkins & Gilligan, 1988), the amount of communicated information is on average higher for roots than for affixes. Therefore, in a suffixing language, the listener can narrow down the lexical candidates faster than in a prefixing language.

Another theoretical possibility is that the suffixation preference stems from factors that are not specific to language or speech. For example, it could be argued that known attentional and memory factors predict that it is easier to detect variations in the beginning of a temporal structure than in the end (e.g., primacy effect). One such factor could be a greater distinctiveness of items in the beginning of a temporal sequence (e.g., Neath, 1993). For the domain of music, Repp (1992) reported that participants are less likely to detect a lengthened event in a musical performance when it occurs at the end of a musical phrase.

Once a language has an established pattern of inflectional morphology, this pattern can be propagated among language learners. One possibility is that the pattern propagates by means of associative learning (e.g., Greenberg, 1957). In particular, there are several theoretical proposals suggesting that in the course of learning, attention shifts towards consistently predictive stimulus dimensions and away from non-predictive dimensions (e.g., Jusczyk, 1993; Kersten, Goldstone, & Schaffert, 1998; Kruschke, 1992; Mackintosh, 1975; see also Hall, 1991). As a result, differences along a predictive dimension become more discriminable, whereas differences along a non-predictive dimension become less discriminable. Therefore, if differences at the beginnings of words are more likely to predict differences in lexical meaning, attention to the beginning would increase, whereas if differences at the endings are more likely to predict differences in lexical meaning, attention to the ending would increase.

More broadly, it is possible that language learning reflects the same constraints that are responsible for the differences in type of inflectional morphology across languages. For example, Gasser (1994) proposed a computational account of language acquisition, according to which words occur in time, and the information that appears first is the key to identification. This account predicts an advantage of processing information at the beginning of a sequence, and the advantage should hold for both linguistic and non-linguistic sequences. Under this account, words are a special case of sequentially presented information, and the suffixation preference would be a special case of preference for the beginning of a temporal sequence. It is possible that the domain-specific asymmetry is grounded in domain-general mechanisms. The idea here, which also is found in Hawkins' work (Hawkins, 1994, 2004), is that the domain-general preferences become grammaticalised over time (they get built into language or languages). Therefore, it is possible that languages display these preferences because of the computational demands of sequential processing in general. The preference may not be wired into the language faculty (the biological capacity for language), but may be wired into the mechanisms of sequential processing and reflected in the grammars of particular languages.

The primary goal of the present research is to examine factors that may potentially underlie the suffixation preference. First, the suffixation preference may stem from language-specific factors, in which case (a) this effect should be limited to language and (b) training to attend to the end of a temporal sequence in non-linguistic domains should not affect the suffixation preference in language. At the same time, finding analogues of the suffixation preference in other domains as well as cross-domain transfer of learning would suggest that the suffixation preference stems from factors that are not specific to language or speech. These predictions are consistent with the domain general account of the suffixation bias. Although it is a possibility that parallels across domains can exist without there being any connection, the data from Experiments 1–3 aim to argue against the likelihood of this claim. In Experiments 1–2, we examined variants of the suffixation preference in language as well as in non-linguistic domains by using a label extension task (Experiment 1) and a similarity judgement task (Experiment 2). In Experiment 3, we examined the flexibility of this preference and its transferability within and across domains.

EXPERIMENT 1: DEMONSTRATING THE SUFFIXATION PREFERENCE IN A LABEL EXTENSION TASK

Given that all of this presented research relies on the fact that adults have a suffixation preference in processing language, the first experiment sets out to demonstrate that participants actually are more likely to extend a suffixed object label (post-changed) to the same object than a prefixed object label (pre-changed).

Method

Participants

In this and all other experiments reported here, the participants were undergraduate students from The Ohio State University who participated to fulfil a psychology course requirement, and no participant took part in more than one experiment. In this experiment, there were 20 participants (17 men and 3 women). An additional two participants were excluded for failing to respond to at least 70% of the catch items.

Materials

The stimuli were 32 word pairs, each consisting of a target word and a test word. The target words were created using *Cool Edit* software (Syntrillium Software Corporation, 2000) by randomly connecting discrete syllables recorded by a female speaker (e.g., *Ta*-*Te*) with 0.06 s between syllables (see Johnson & Jusczyk, 2001; Saffran, Aslin, & Newport, 1996, for details of similar stimuli creation). All possible unique consonant-vowel syllables were created (e.g., Ba, Be, Bi, Bo, Bu) for a total of 90 syllables. Then, each syllable was assigned a number, and using a random number generator, they were combined to form words and add inflections. Therefore, each syllable could appear in any of the word positions at random. Test words were created by either adding a randomly selected syllable (inflection) to the beginning of the target word (pre-changed item: *BE*-*Ta*-*Te*), to the end of the target word (post-changed item: *Ta*-*Te*-*BE*), adding nothing to the target word (identical: *Ta*-*Te*), or changing the target word completely (different: *Pu*-*La*-*Fi*). Some syllable combinations were excluded if their meaning seemed inappropriate or humorous.

In addition, there were 32 triads of objects for each word pair. The triads consisted of an original target object (e.g., heart) centred on the top of the computer screen followed by two test objects on the bottom left and right of the screen. One of the test objects was identical to the target (e.g., heart), and the second object was new (e.g., star). The left-right positioning of the test objects was counterbalanced across trials, and the object sets were randomly assigned to be red, blue, green, or orange.

Design and procedure

In this and all other experiments reported, *Presentation* software (Neurobehavioral Systems, 2003) was used to deliver the instructions, present the stimuli, and record the responses. The participants were instructed that this task was measuring their ability to learn foreign words. Each participant received 32 randomly presented trials during which they heard a target object being labelled, and they were asked to extend the label to one of the test objects (e.g., 'This is a *Ta*-*Te*. Which one of these is a *BE*-*Ta*-*Te*?'). See Figure 1 for a sample post-changed trial. If they selected the object on the left, they were to press '1', and if they selected the object on the right, they were to press '0'. Of the 32 trials, 20 were the test trials of interest (10 post-changed test words, *Ta*-*Te*-*BE*; 10 pre-changed test words, *BE*-*Ta*-*Te*), and 12 of the trials were catch trials used to control for overall accuracy (six identical test words, *Ta*-*Te*; six different test words, *Pu*-*La*-*Fi*). Given the nature of the catch trials, there was an answer that would be considered correct (in contrast to the pre/post test trials). The goal of the task was to measure the likelihood of extending a suffixed object label (post-changed) to an identical object in comparison to the likelihood of extending a prefixed object label (pre-changed) to an identical object.

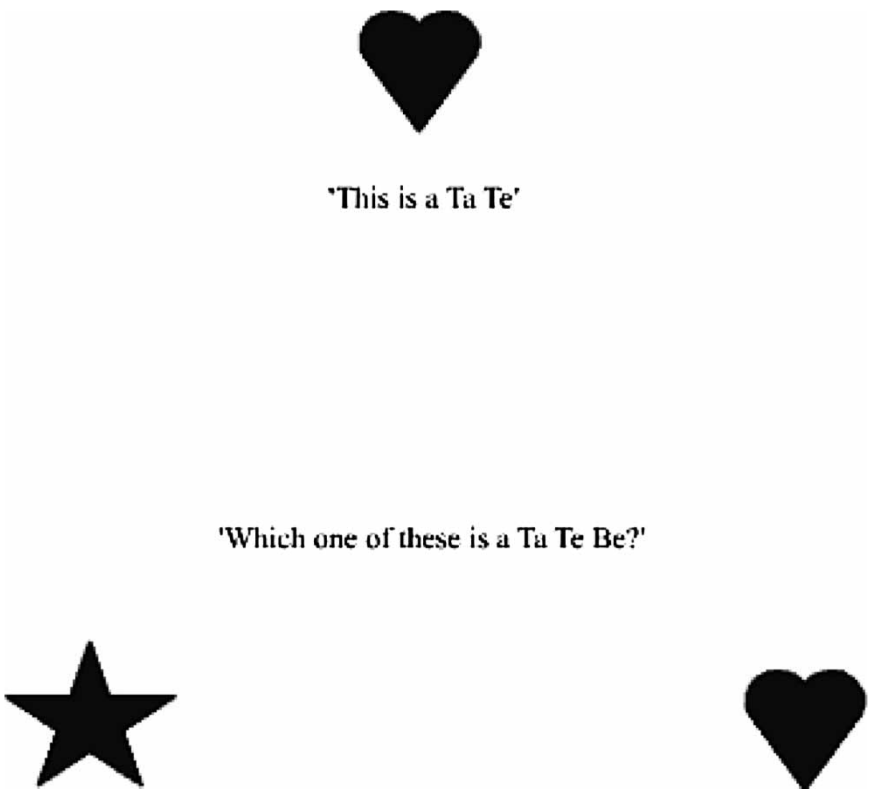


Figure 1. Sample post-changed trial for Experiment 1.

Results and discussion

Overall, participants were accurate on catch trials, exhibiting 94.58% accuracy, above chance, one-sample $t(19) = 24.21$, $p < .001$, $d = 11.11$. However, our primary interest was the analysis of participants' responses to the trials that included either pre-changed or post-changed words. More specifically, we wanted to investigate if participants were more likely to extend a post-changed label to an object than a pre-changed label. Participants frequently selected the novel object (e.g., not previously labelled) to be the likely referent when the object label was inflected (73.00% of the time), which is consistent with previous research with adults where participants nearly always selected a novel object to be the referent of a changed word (Jarvis, Merriman, Barnett, Hanba, & Van Haitsma, 2004). However, in this experiment, when participants did extend labels to the identical object, they were almost twice as likely to do so with a post-changed word ($M = 17.50\%$) than with a pre-changed word ($M = 9.50\%$), paired-sample $t(19) = 2.33$, $p < .05$, $d = 1.07$.

Experiment 1 determined that participants select an identical object to be the likely referent of an inflected label rather than a novel object more so when the object label was suffixed rather than prefixed. This is consistent with the suffixation preference. The goal of Experiment 2 was to investigate the suffixation preference not only within the domain of language, but also in other domains. Given that the label extension task of Experiment 1 makes an explicit reference to language, for Experiment 2, we substituted this task with a similarity judgement task, which can be used in a variety of domains (e.g., both linguistic and non-linguistic). The goal of Experiments 2A–2D is to demonstrate the suffixation preference in linguistic and non-linguistic domains by using a similarity judgement task.

Experiment 2 (A–D) consisted of a forced-choice similarity judgement task in which participants had to decide which of the two test items was more similar to the target item, with each item being a sequence of syllables, musical notes, or visual objects. For each triad (target sequence and two test sequences), the critical test sequences were created by adding information to the target sequence (stem), with one test sequence having information added to the beginning of the target sequence ('pre-changed item'), and another having information added to the end of the target sequence ('post-changed item'). The experiments included three domains: language (the target and test items were pseudo-words), music (the target and test items were sequences of musical notes), and visual (the target and test items were sequences of visual objects).

The suffixation preference predicts that adding information after a stem (post-changed item) should less drastically change an item than if the information were added before the stem (pre-changed item). Therefore, the post-changed item should be judged as more similar to the target than the pre-changed item in the language domain, which would correspond to the results of the label extension task of Experiment 1. Moreover, consistent with a general-cognitive account, these effects should be present across temporal domains, and effects of training may exhibit cross-domain transfer. The first issue is examined in Experiment 2, and the second issue is examined in Experiment 3.

EXPERIMENT 2A: LANGUAGE'S SUFFIXATION PREFERENCE IN SIMILARITY JUDGEMENT TASK

Method

Participants

There were 17 participants (11 men and 6 women). Five additional participants failed to correctly respond to at least 70% of the catch items and were excluded from this experiment.

Materials

The stimuli were 42 triads, each consisting of a two-syllable artificial target word followed by two test words (see Table 1 for examples of stimuli). In the critical test trials, one of the test words was the target with a syllable added to the beginning (pre-changed item), and the other test word was the target with a syllable added to the end (post-changed item). These two types

TABLE 1
Example language stimuli from Experiments 2 and 3.

		Item type		
	Trial type	*Target item*	*Test item 1*	*Test item 2*
Test trials	Pre-Post	Ta-te	Be-ta-te	Ta-te-be
		Pe-ja	Pe-ja-ci	Ci-pe-ja
Catch trials	Pre-Identical	Ve-ga	Va-ve-ga	Ve-ga
		Da-zo	Da-zo	Fo-da-zo
	Post-Identical	Ma-ya	Ma-ya-yo	Ma-ya
		Go-zu	Go-zu	Go-zu-ne
	Pre-Different	Ho-mu	Ro-ho-mu	Pu-la-fa
		Me-he	Mi-lo-bi	To-me-he
	Post-Different	Za-vi	Za-vi-ze	Fu-no-bo
		Ra-co	Gu-na-ri	Ra-co-we
	Identical-Different	Zo-no	Zo-no	Ga-lu-me
		To-ri	Ti-le-hi	To-ri

of test items paired against one another made up 25 of the triads, which were considered the test trials of interest. In addition, there were 15 catch trials and 2 practice trials. The catch trials included one test item that was identical or almost identical to the target and another that was appreciably different from the target item, and (unlike test items), they had a correct answer. The goal of the catch trials was to control for overall accuracy.

Similar to Experiment 1, the test words were created by either adding a syllable to the beginning of the target word (pre-changed item: *BE-Ta-T*e), to the end of the target word (post-changed item: *Ta-Te-BE*), adding nothing to the target word (identical: *Ta-Te*), or changing the target word completely (different: *Pu-La-Fi*).

Design and procedure

Each participant received two randomly ordered practice trials followed by a short break, and then the remaining 40 trials were presented. During the break, participants could ask the experimenter any questions pertaining to the procedure. The 25 test trials and the 15 catch trials were presented in random order.

The participants were instructed that they would hear several sets of words. For each set, they would hear a two-syllable target word followed by two test words, and they were to decide which of the test words was more similar to the original target word. If the first test word was most similar, they were to press 'F' on the keyboard, and if the last test word was most similar, they were to press 'L'. To start each new trial, they were instructed to press the space-bar.

There was 1 s in between each word, and the order of the test words for all trial types was counterbalanced across sets. For example, in the Pre-Post test items, the pre-changed test item occurred first 50% of the time. The target word was presented from both of the computer speakers while the first test word was presented only from the left speaker, and the second test word was presented only from the right speaker.

Results and discussion

Overall, participants were accurate on catch trials, exhibiting 94.90% accuracy, above chance, one-sample $t(16) = 25.43$, $p < .001$, $d = 12.33$. However, the primary analysis focused on participants' responses to Pre-Post test items. For each trial, participants could either answer pre-changed or post-changed as the item that is more similar to the target, and therefore chance performance was 50%. As predicted, there was a clear tendency to choose the post-changed items as more similar to the original target word than the pre-changed items: in 88% of responses, participants considered the post-changed item to be more similar to the target than the pre-changed item, above chance, one-sample $t(16) = 9.64$, $p < .001$, $d = 4.68$.

This experiment presented evidence that the similarity judgement task did capture the suffixation preference exhibited in the label extension task. However, we deemed it necessary to further test the validity of the task by examining its ability to account for a broader range of phenomena found in the study of inflectional morphology. In particular, there are several accounts (Gasser, 1994; Hana & Culicover, 2008) which predict a hierarchy in different types of morphology. According to this account, it is computationally less demanding to establish the equivalence of two sequences when they differ in their endings than in their beginnings. Furthermore, it is easier to establish the equivalence of two sequences when they differ in their beginnings or endings than if they differ in their middle components (e.g., infixation). This hierarchy directly corresponds to the frequency of inflectional types (e.g., Dryer, 2005). Findings that a pre-changed or a post-changed item would be more similar to a target item than would be an infix item would further support the validity of the task used in Experiment 2A. These issues were addressed in Experiment 2B.

EXPERIMENT 2B: THE ABILITY OF THE SIMILARITY JUDGEMENT TASK TO ACCOUNT FOR INFIXATION

Method

Participants

There were 20 participants in this experiment (13 men and 7 women). Three additional participants were excluded from this experiment because they failed to correctly respond to at least 70% of the catch items.

Materials

The stimuli consisted of 74 sets, with each set consisting of a two-syllable artificial target word followed by two test words. Once again, in the critical trials, one of the test words was the target with a syllable added to the beginning (pre-changed item), and another test word was the target with a syllable added to the end (post-changed item). In addition, a third possible critical test word was the target with a syllable added to the middle of the sequence (infix item; e.g., *Ta-Te* was changed to *Ta-BE-Te*). These three types of test items paired against one another were considered the test trials of interest. There were 25 trials where Pre-Post were paired, 8 trials where Pre-Infix were paired and 8 trials where Post-Infix were paired as the test items to create the crucial test trials. In addition, there were 2 practice trials and 31 catch trials. Similar to Experiment 2A, catch trials included one test item that was identical or almost identical to the target and another that was appreciably different from the target (e.g., identical item *Ta-Te* was paired with different item *Pu-La-Fi*). The stimuli were created similarly to the previous experiments.

Design and procedure

The procedure was identical to Experiment 2A except this experiment used a larger number of trials to include trials containing an infix item. Each participant received 2 randomly presented practice trials followed by a short break, and then the remaining 72 trials were presented in random order. Once again, the participants were instructed that they would hear several sets of words. For each set, they would hear a two-syllable target word followed by two test words, and they were to decide which of the test words was more similar to the original target word.

Results and discussion

Overall, participants were accurate on catch trials, exhibiting 95.81% accuracy, above chance, one-sample $t(19) = 36.29$, $p < .001$, $d = 16.65$. Replicating Experiment 2A, participants were more likely to choose the post-changed items as more similar to the target than the pre-changed ($M = 80.00\%$), above chance, one-sample $t(19) = 6.86$, $p < .001$, $d = 3.15$. In addition, as predicted, in the critical test trials where a pre-changed item or a post-changed item was paired with an infix item, the pre-changed items and the post-changed items were both judged as more similar to the target than the infix items (Pre 69.38% and Post 89.38%), above chance, one sample $t\text{s} > 3.6$, $p\text{s} < .01$, $d\text{s} > 1.6$. These findings demonstrate that the similarity judgement task captures important phenomena pertaining to inflectional morphology.

Having established that this similarity judgement procedure captures typical inflectional patterns in the domain of language, the next step is to examine the suffixation preference in other domains that have temporal structure by using this same procedure. Experiment 2C examines this effect with sequences of musical notes, whereas Experiment 2D examines the effect with sequences of visual objects.

EXPERIMENT 2C: MUSIC DOMAIN'S SUFFIXATION PREFERENCE IN A SIMILARITY JUDGEMENT TASK

Method

Participants

There were 18 participants in this experiment (10 men and 8 women).

Materials

Each stimulus set was made up of a two-note target melody and two test melodies. The melodies were arpeggiated, and all keys (major and minor) were represented. The test items were created in *Cool Edit* software (Syntrillium Software Corporation, 2000) by adding notes to either the beginning (pre-changed item) or the end (post-changed item) of the target melodies using a similar randomisation process to form 42 sets as in Experiment 2A. Included in these sets were once again test items that were identical to the target and test items that were appreciably different from the target to create catch trials. There were 2 practice trials, 25 test trials, and 15 catch trials.

Design and procedure

The overall design and procedure was identical to the original similarity judgement language task (Experiment 2A). The main difference was that instead of hearing pseudo-words, the participants were instructed that they would hear a small target musical melody followed by two test melodies. From this, they were to decide which test melody was the most similar to the original target melody.

Results and discussion

Overall, participants were accurate on catch trials for this experiment as well, exhibiting 91.85% accuracy, above chance, one-sample $t(17) = 20.35$, $p < .001$, $d = 9.59$. Similar to the language conditions and consistent with the suffixation preference, participants were more likely to choose the post-changed items as more similar to the target than the pre-changed items ($M = 71.56\%$), above chance, one-sample $t(17) = 4.03$, $p = .001$, $d = 1.90$. These findings extend the suffixation-like preference to another aspect of the auditory domain (music), and finding similar effects in the visual domain would provide even stronger support for the general cognitive account of temporal sequence processing.

EXPERIMENT 2D: VISUAL DOMAIN'S SUFFIXATION PREFERENCE IN A SIMILARITY JUDGEMENT TASK

Method

Participants

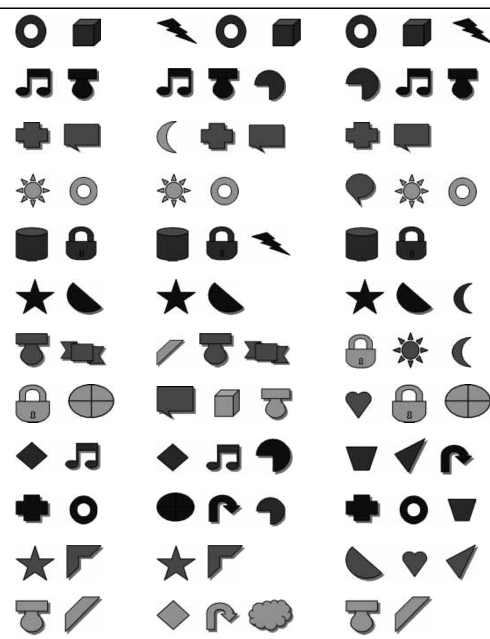
There were 17 participants in this experiment (11 men and 6 women). Two additional participants were excluded from this condition because they failed to correctly respond to at least 70% of the catch items.

Materials

The stimuli consisted of object sequence videos created using *Macromedia Flash* software (Macromedia Studio MX, 2002). There were a total of 25 objects that were randomly combined to create the target sequences using a similar randomisation process as in previous experiments to form 42 triads as before (see Table 2 for example stimuli). Therefore, each object could appear in any of the positions at random. The target sequences were composed of either all red, blue, green, or orange shapes. Approximately equal numbers of each colour were represented across sequences. Each set consisted of a target sequence made of two simple objects that flashed sequentially (from the exact same location) for 1 s each while centred at the top of the computer screen (e.g., cross, heart). Then, 1 s later, the first of two test sequences appeared at the bottom of the screen. There was 1 s in between each test sequence, and the order of the test sequences was counterbalanced across sets. The first test sequence appeared on the bottom left of the

TABLE 2
Example visual stimuli from Experiments 2 and 3.

		Item type		
	Trial type	*Target item*	*Test item 1*	*Test item 2*
Test trials	Pre-Post			
Catch trials	Pre-Identical			
	Post-Identical			
	Pre-Different			
	Post-Different			
	Identical-Different			



computer screen, and the second test sequence appeared on the bottom right of the screen. Within a sequence, all objects flashed from the same location, and all sequences presented one object at a time.

There were once again four possible test item types. The test items were created by adding an object (e.g., diamond) for 1 s either at the beginning of the target sequence (pre-changed item: diamond, cross, heart), at the end of the target sequence (post-changed item: cross, heart, diamond), no change at all to the target sequence (identical: cross, heart) or change the sequence completely (different: star, light bulb, lock). The object that was added was of a different colour than the target sequence: a red target sequence would have a blue object added as the pre- or post- object (and vice-versa), and green and orange were similarly paired. For example, the target sequence was a red cross followed by a red heart, and the post-changed item was a red cross, a red heart, and then a blue diamond. Once again, there were 2 practice trials, 25 test trials, and 15 catch trials. The 40 test and catch trials were randomly presented.

Design and procedure

The overall design and procedure were similar to the previous experiments using the similarity judgement task. The main difference was that participants were instructed that they would see a target sequence of objects on the top of the screen followed by two test sequences on the bottom of the screen. They were to decide which test sequence was more similar to the initial target sequence.

Results and discussion

Participants were accurate on catch trials with an accuracy of 98.04%, above chance, one-sample $t(16) = 63.23$, $p < .001$, $d = 30.67$. Similar to the language and music auditory conditions, participants were more likely to choose the post-changed items as more similar to the target than the pre-changed items ($M = 91.53\%$) in the visual condition as well, above chance, one-sample $t(16) = 13.72$, $p < .001$, $d = 6.66$.

Overall, the effect was found across all three domains, suggesting that the suffixation preference is not simply specific to language (or even to the auditory domain). The results of Experiment 2 clearly indicate that across different domains, the addition of a single element to the beginning of the sequence was perceived as a greater change than the addition of a single element to the end of the sequence. Therefore, the suffixation preference, which is often considered a useful linguistic bias for solving the inflectional problem, does not appear to be specific to language, but it may rather stem from the processing of temporally organised information more generally.

In addition, Experiment 2 established the baseline preferences across all three domains (language, visual, and music), which was an important first step in determining whether the preference could be changed in the course of training. Flexibility is an important aspect of the mechanism underlying inflectional morphology given the existence of various inflectional systems cross linguistically. The diversity of inflectional patterns indicates a flexible system. Experiment 3 examined whether this baseline preference can be changed, and if so, whether this change will transfer to other domains. Both flexibility and transfer would support a general cognitive account with associative learning being a candidate mechanism. The goal of Experiments 3A–3D is to examine the effects of training and subsequent transfer on the suffixation preference within and across linguistic and non-linguistic domains.

Recall that cross-linguistic studies demonstrate that people readily learn inflectional patterns other than suffixation. Therefore, the suffixation *preference* in the domain of language is just that, a preference, and not a rigid constraint. Given the flexibility within the language domain, finding comparable flexibility in non-linguistic domains would further support the general cognitive account of the suffixation preference in language. Furthermore, if learning of inflectional morphology is sub-served by language-specific mechanisms, there should be little or no transfer of a learned preference between language and other domains. At the same time, finding transfer to and from language would generate even stronger support for a general cognitive mechanism responsible for temporal sequence processing that includes language.

Experiments 3A–3B address these issues by first training participants to attend to the end of a sequence and to consider the pre-changed item to be more similar to the target. The training in Experiment 3A was in the language or visual domain (which was tied to language), while the training in Experiment 3B was in a non-linguistic visual domain. Then, the transfer of this newly learned preference was measured within and across domains, using a similarity judgement task similar to that in Experiment 2. To determine the change in preference, each participant's test score in a given domain was compared with a no-training baseline in the similarity judgement task established in Experiment 2. Experiments 3C–3D involved a similar goal of training, this time based in a non-linguistic causal framework in the visual domain where the goal was to attend to the final object in a sequence, and then the subsequent transfer to a labelling task was examined. To determine the effect of transfer, each participant's score was compared to the no-training baseline established in the labelling task of Experiment 1. Experiment 3C utilised training objects that were verbalisable while Experiment 3D visual training was removed from the linguistic domain by using nonverbalisable training objects.

EXPERIMENT 3A: LANGUAGE AND VISUAL TRAINING FOLLOWED BY A SIMILARITY JUDGEMENT TASK

For Experiment 3A, participants were either trained in the language condition or the visual condition for a pre-changed item preference (opposite the post-changed item preference observed in Experiment 2). The language and visual domains were selected to represent training in both the auditory and visual domains. Then, they were randomly tested using the similarity judgement task in one of three domains: language, music, or visual. The goal of this experiment was to examine the flexibility and transferability of the suffixation preference within and across domains.

Method

Participants

There were 53 participants in the language training condition (32 men and 21 women). Of these participants, 16 were subsequently tested in the language condition, 17 in the music condition, and 20 in the visual condition. There were an additional 50 participants in the visual training condition (33 men and 17 women). Of these participants, 18 were subsequently tested in the visual condition, 16 in the language condition, and 16 in the music condition. Three additional participants in the language training condition were excluded for failing to correctly answer at least 70% of the catch trials during the testing phase.

Materials, design, and procedure

The participants were instructed that in different languages, different aspects of the word contain the meaning, and they would be tested on their ability to learn such rules. They were told that in some languages, if two words had the same ending, then the words had similar meanings. They were instructed to select the word that had the same meaning as the target word. The goal of training was to change the post-changed item preference found in the similarity judgement tasks in Experiment 2 to a pre-changed item preference.

Language training condition. The training stimuli consisted of 11 test trials from the language condition of Experiment 2A, chosen at random with a few trivial qualifications (e.g., approximately equal numbers of each test item occurring first). Each set consisted of a two-syllable artificial target word followed by two test words (pre-changed item and post-changed item). A pre-changed item preference would be demonstrated if words that have a syllable added to the beginning were judged to be more similar to the original target word than if a syllable was added to the end of the original target word.

Visual training condition. The training stimuli consisted of 11 test trials from the visual condition of Experiment 2D, with each set consisting of a two-part visual sequence followed by two test sequences (pre-changed item and post-changed item). This subset was chosen at random with some minor qualifications (e.g., approximately equal number of each set colour). In addition to the basic instructions given in the language training condition, the participants in the visual training condition were instructed that in some cultures, sequences of objects are used for words. They were told that in some languages, if two words had the same ending, then the words had similar meanings (e.g., if two sequences end in the same object, then they share meanings). In this case, a pre-changed item preference would be demonstrated if sequences that have an object added to the beginning were judged to be more similar to the original target sequence than if an object was added to the end of the original target sequence.

In both training conditions, participants were presented with a two-part target item followed by two test items, and they were to decide which of the test items was more similar in meaning to the initial target item. They were not explicitly instructed to pay attention to any particular element of the sequence. In this case, feedback on the correct answer was provided following each of the first three trials (e.g., 'The correct answer was *Bee-Ta-Tee*') to assure that the participants understood what was being expected of them (e.g., to select the pre-changed item as most similar to the target). Then, the participants were presented with eight no-feedback trials. The final eight trials were used as a manipulation check to assure that the participants were correctly performing the task.

After training for a pre-changed item preference in the language or visual domain, the participants took part in a seemingly unrelated testing phase (shortened version of Experiment 2A, 2C, or 2D in a similarity judgement task with 14 test trials and 15 catch trials) in which their preferences were assessed in one of the three domains (language, music, visual).

Results and discussion

Language training condition. Participants were accurate on catch trials across all three test domains with 94.17% accuracy when they were tested in language, 94.00% accuracy when they were tested in visual, and 93.33% accuracy when they were subsequently tested in music (above chance, one-sample $ts > 22.00$, $ps < .001$, $ds > 11.00$). The percentage of post-changed item responses for the testing phase of Experiment 3A (i.e., after training) was compared with its respective no-train baseline from Experiment 2 (i.e., the language condition of Experiment 2A). From this comparison, a difference score between post-changed item preference in the trained condition and the baseline was calculated for every participant. Mean raw scores, from which difference scores were derived, are presented in Table 3. Note that a difference score of zero would reflect no change in preference after training, and therefore no successful transfer of such a preference, whereas a positive score indicates successful training and/or transfer resulting in a lower post-changed item preference.

As expected, given the similar nature of the tasks and stimuli, once the participants were successfully trained for a pre-changed item preference in the language domain, testing in the language domain revealed lower post-changed item response scores ($M = 39.29\%$) than without training ($M = 88.66\%$), with the difference score being reliably above 0, one-sample $t(15) = 4.17$, $p = .001$, $d = 2.15$.

More importantly, after participants were trained for a pre-changed item preference in the language domain, this preference transferred to both the music and visual domains. After training in language, participants exhibited evidence of a significant decrease in post-changed item responses in the music domain (mean difference score = 29.39%) and in the visual domain (mean difference score = 29.46%), with all difference scores being reliably above 0, one-sample $t\text{s} > 3.4$, $p\text{s} < .01$, $d\text{s} > 1.6$. This was a marked change compared with Experiment 2. In short, when participants were trained to attend to the end of a word in the language domain and then were tested either in the language, music, or visual domain, this change in preference transferred to non-trained domains.

Visual training condition. In this condition, participants were accurate on catch trials across all three test domains with 97.92% accuracy when they were tested in language, 94.44% accuracy when they were tested in visual,

TABLE 3
Calculation of difference scores for Experiments 3A and 3B.

Training condition	*Testing condition*	*Baseline Post score from Experiment 2*	*Experiment 3 Post score*	*Difference score*
Language (3A)	Language	88.66	39.29	49.37
	Music	71.83	42.44	29.39
	Visual	91.60	62.14	29.46
Visual (3A)	Visual	91.60	29.37	62.23
	Music	71.83	51.79	20.04
	Language	88.66	34.38	54.28
Non-linguistic Visual (3B)	Visual	91.60	62.77	28.83
	Language	88.66	73.57	15.09

and 93.78% accuracy when they were tested in music (above chance, one-sample ts > 24.50, ps < .001, ds > 11.50). Once again, a difference score between the percentage of post-changed item responses for the testing phase of Experiment 3A and the average post-changed preference observed in Experiment 2 was calculated for every participant in each test condition. Mean raw scores after visual training are presented in Table 3.

As expected, given the task and stimuli similarity, once the participants were successfully trained for a pre-changed item preference in the visual domain, testing in the visual domain revealed lower post-changed item scores ($M = 29.37\%$) than without training ($M = 91.60\%$), with the difference score being reliably above 0, one-sample $t(17) = 6.45$, $p < .001$, $d = 3.13$.

Similar to the language training condition, after participants were trained in the visual domain, this training transferred to the other two domains, with participants exhibiting a significant decrease in post-changed item responses in both the music domain (mean difference score = 20.04%) and in the language domain (mean difference score = 54.28%), with all difference scores being reliably above 0, one-sample ts > 2.9, ps ≤ .01, ds > 1.5. This was again a marked change compared with Experiment 2.

Overall, when participants were trained to attend to the end of a sequence in the language or visual domain, they (a) exhibited a shift towards a pre-changed item preference within the trained domain and (b) transferred this learned preference to other domains. Both findings are important: the learning flexibility and transfer of preference across domains supports the idea that the suffixation preference is not specific to language, but is rather a product of a domain-general mechanism for processing temporal information.

However, it could be argued that since training in the visual domain was based in a linguistic framework (e.g., participants were told to treat the objects as words), the transfer from the visual domain to the language domain was driven by this framework. Although this possibility does not explain the transfer from the visual domain to the music domain, it is crucial to examine the transfer from the visual domain to the language domain when visual training is not based in a linguistic context. This issue was addressed in Experiment 3B.

EXPERIMENT 3B: VISUAL TRAINING IN A NON-LINGUISTIC FRAMEWORK FOLLOWED BY A SIMILARITY JUDGEMENT TASK

The experiment used a variant of associative learning by making only the last element in a sequence predictive. Participants were shown a target sequence that was followed by a video of a dog. They were given a cover story explaining that the sequence made the dog appear. They were then shown two test sequences and asked which one will also make the dog appear. Both test sequences were identical except for the last element, with one sequence sharing the last element with the target while the other sequence did not. Consistent with theories of attentional learning (see Hall, 1991), it was expected that participants would shift attention to the predictive element (which was the last element in the sequence).

Method

Participants

There were 40 participants in this experiment (22 men and 18 women). Of these participants, 20 were subsequently tested in the visual condition, and 20 in the language condition. Three additional participants were excluded for failing to answer at least 70% of the final eight items in the training phase (manipulation check trials), and three additional participants were excluded for failing to correctly answer at least 70% of the catch trials during the testing phase.

Materials

The training stimuli consisted of 24 sets similar to the visual condition of Experiment 3A, with each set consisting of a two-part visual sequence followed by two test sequences; however, the corresponding test sequences for this training session were modified. In these test sequences, the first and second objects were identical in both test sequences, so that the participants could only use information from the end of the sequence (e.g., the final object) to make their selection, whereas the final object either matched the final object from the target or it was a novel object (see Table 4 for example stimuli). All objects within a set were the same colour (red, blue, green, or orange), and colour was evenly distributed across sets. There were also two videos used for feedback: one of a small dog appearing from behind a box accompanied by the sounding of a horn (this was shown to indicate that the answer was correct), and one of the box without any dog appearing and no

TABLE 4
Example training stimuli for Experiment 3B.

Item type		
Target item	*Correct test item*	*Incorrect test item*
		
		

sounding horn (this was shown to indicate that the answer was incorrect). The visual and language similarity judgement test stimuli for the critical testing phase were identical to those used in Experiment 3A (14 test trials and 15 catch trials).

Design and procedure

The 24 sets of training stimuli each appeared twice in a randomised block design. The participants were instructed that they would see a sequence of objects that caused a dog to appear, and they were shown the corresponding video. Then, they were instructed that they would see two additional sequences, and they were to select which of the new sequences also caused the dog to appear. If the answer was correct, they were shown the video of the dog appearing from behind a box accompanied by the sounding of a horn. If the participant was incorrect, they were shown the video of the box without any dog appearing or horn sounding. The sequence that ended with the same object as the target sequence was the correct answer and caused the dog to appear and a horn to sound in 80% of the trials. To better approximate a realistic language system (e.g., word beginnings do not predict lexical meaning 100% of the time), in 20% of the trials, the correct answer was reversed (incorrect trials). The 20% of incorrect trials were randomly assigned with a few restrictions: no particular set would be wrong more than once, and no incorrect trial would appear in the final eight trials. The final eight trials were used as a manipulation check to assure that the participants were correctly performing the task.

Similar to Experiment 3A, the goal of training was to change the post-changed item preference found in the similarity judgement tasks of Experiment 2 to a pre-changed item preference. In this case, a pre-changed item preference would be demonstrated if sequences that have the same final object were selected as more similar to the target. After training for a pre-changed item preference in the visual domain, once again, the participants took part in a similarity judgement testing phase in which their preferences were assessed in either the visual or language domains. During visual and language testing, participants were presented with the same similarity judgement task that was used in previous experiments.

Results and discussion

In this experiment, participants were accurate on catch trials across both test domains with 92.67% accuracy when they were tested in language and 90.29% accuracy when they were tested in visual (above chance, one-sample $t\text{s} > 18.00$, $p\text{s} < .001$, $d\text{s} > 8.20$). Once again, a difference score between the percent of post-changed item responses for the testing phase and the average baseline post-changed item preference observed in Experiment 2 was calculated for every participant in each test condition (see Table 3 for raw scores).

As expected, once the participants were successfully trained for a pre-changed item preference in the visual domain, testing in the visual domain revealed lower post-changed preferences ($M = 62.77\%$) than without training ($M = 91.60\%$), with the difference score being reliably above 0, one-sample $t(19) = 3.63$, $p < .01$, $d = 1.66$. More importantly, after participants were trained for a pre-changed item preference in the visual domain without a linguistic context, this preference once again transferred to the language domain (average difference score = 15.09%), with the difference score being reliably above 0, one-sample $t(19) = 2.14$, $p < .05$, $d = 0.98$. These findings replicated and further extended results of Experiment 3A.

Overall, when participants were trained to attend to the end of a sequence in the visual domain that was not based in a linguistic framework, they (a) exhibited a modification of the post-changed item preference and (b) transferred this learned preference to the language domain. Once again, both findings are important: the learning flexibility and transfer of preference across domains supports the idea that a domain-general mechanism can account for language's suffixation preference.

However, unanswered questions still remain. First, it is possible that the similarity judgement task does not accurately represent what is happening in language. The reported transfer experiments examined similarity of form, but what about form-meaning correspondence? This has yet to be determined. Second, the argument can be made that this transfer phenomenon can be occurring due to participants responding strategically (e.g., they have figured out the goal of the study), which would imply that these results are the product of an artificial task. By training the participants in the non-linguistic visual domain and then testing them in a label extension task (e.g., Experiment 1), both of these concerns are addressed. In addition to addressing the form-meaning correspondence concern by having participants actually extend labels, one could argue that the possibility of strategic performance is greatly reduced given the dissimilar nature of these tasks. However, questioning the participants about their experiences still seemed necessary. Therefore, these concerns led to Experiment 3C which investigates the training and transfer of preference to a label extension task after which participants were questioned about the goal of study.

EXPERIMENT 3C: TRANSFERRING VISUAL TRAINING TO LABEL EXTENSION TASK

Participants in this experiment were trained to attend to the end of sequence in one of two conditions (language training of Experiment 3A or non-linguistic visual training of Experiment 3B). Then, all participants were tested in the labelling task of Experiment 1. This was designed to determine if training participants to attend to one particular aspect of a sequence (the end) has an effect on the form-meaning correspondence. In addition, participants were given an exit questionnaire to determine if they correctly identified the goal of the study.

Method

Participants

There were 40 participants (18 men and 22 women) who were tested in the labelling task of Experiment 1. Of these participants, 20 were initially trained in the language training of Experiment 3A, and 20 were initially trained in the non-linguistic visual framework of Experiment 3B. Five additional participants were excluded for failing to answer at least 70% of the manipulation check trials of the training phase, and seven additional participants were excluded for failing to correctly answer at least 70% of the catch trials during the testing phase.

Materials

Language training condition. The linguistic training stimuli were identical to those in Experiment 3A, which consisted of 11 Pre-Post trials. Each set consisted of a two-syllable artificial target word followed by two test words (pre-changed item and post-changed item). A pre-changed item preference would be demonstrated if words that have a syllable added to the beginning were judged to be more similar to the original target word than if a syllable was added to the end of the original target word.

Non-linguistic visual training condition. The non-linguistic visual stimuli used for training were identical to those in Experiment 3B, which consisted of 24 sets of object sequences (target and two test sequences). Each set consisted of a two-part visual sequence followed by two test sequences. In each test sequence, the first and second objects were identical, so the participants could only use the final object of each sequence to make their selection. The final object either matched the final object in the target sequence or it did not. There were once again two videos for participant feedback (one of a dog appearing to indicate a correct response and one without a dog appearing to indicate an incorrect response).

Test stimuli. The test stimuli for all participants were identical to those used in the labelling task of Experiment 1, which consisted of 32 word pairs (target word with pre-changed, post-changed, identical or different test word). These word pairs were connected to a triad of objects (target object and either identical or novel test object).

Exit questionnaire. To determine the likelihood of the participants performing strategically from training to test, each participant received a paper and pencil exit questionnaire after completion of the computer portion of the study. The questionnaire contained five questions including filler questions such as 'Was the task challenging? If so, why?' and 'What were the words like?'. The question of interest was 'What was the goal of the study?'.

Design and procedure

Language training condition. The design and procedure in the language training condition was identical to that of Experiment 3A. The participants were instructed that if two words had the same ending, then the words had similar meanings. They were instructed to select the test word that had the same meaning as the target word. Once again, feedback was given for the first three trials followed by eight no-feedback trials that were used as a manipulation check to assure that the participants were correctly performing the task. The goal of training was to increase participants' attention to the final portion of the word.

Non-linguistic visual training condition. The design and procedure in the non-linguistic visual training condition was identical to that of Experiment 3B. The participants were to select the test sequence that would cause the dog to appear in the video. The test sequence that ended with the same object as the target sequence was the correct answer and caused the dog to appear in 80% of the trials. Once again, the final eight trials were used as a manipulation check to assure that the participants were correctly performing the task. The goal of training was to increase participants' attention to the final portion of the visual sequence.

Testing phase. After training to attend to the end of the sequence in either the linguistic domain or the non-linguistic visual domain, the participants took part in a seemingly unrelated testing phase. The testing phase was identical to the procedure of Experiment 1 where the participants heard a target object being labelled, and they were asked to extend the inflected label (pre-changed or post-changed) to one of the test objects (identical or new).

Results and discussion

Participants were accurate on catch trials with 95.63% accuracy, above chance, once sample $t(39) = 18.15$, $p < .001$, $d = 5.81$. For this experiment, a difference score was calculated for each participant between their percentage of pre-changed item extensions to the identical object in the baseline labelling task of Experiment 1 in comparison to the percentage of pre-changed item extensions to the identical object in the labelling task after training in either the language domain or the non-linguistic visual domain. See Table 5 for the calculations of the difference scores. Note that a difference score of zero would reflect no change in preference, whereas a positive difference score indicates successful training and/or transfer resulting in a higher percentage of label extensions of pre-changed items.

As expected, once participants were trained for a pre-changed item preference in the language domain (similarity judgement task), this lead to increased pre-changed item extensions in comparison to the baseline of Experiment 1 (labelling task), with the difference score ($M = 28.50\%$) being reliably above 0, one-sample $t(19) = 7.02$, $p < .001$, $d = 3.22$. This was a significant increase from Experiment 1.

Most notably, once participants were trained for a pre-changed item preference in the non-linguistic visual framework, they increased their pre-changed item extensions in comparison to the baseline of Experiment 1, with the difference score ($M = 9.25\%$) being reliably above 0, one-sample $t(19) = 2.16$, $p < .05$, $d = 0.99$. This was once again a significant increase after training.

For the exit questionnaire, the open-ended question 'What was the goal of this study?' was coded by a hypothesis blind coder to produce three categories of responses. Of the 40 participants, 36 indicated that the goal of the study was to examine general cognitive or perceptual processes (e.g., 'To estimate my cognitive ability or ability to memorise what I see') or with something about learning foreign languages as the experimental directions indicated (e.g., 'Learning a foreign language'). These were combined into one category because many participant responses overlapped both categories. Two participants did not know the goal (e.g., 'I have no idea'). However, two participants in the language training condition did answer as if they understood the goal of the training/transfer design of the study (e.g., 'To

TABLE 5
Calculation of difference scores for Experiment 3C and 3D.

Training condition	*Testing condition*	*Baseline Pre score from Experiment 1*	*Experiment 3 Pre score*	*Difference score*
Language (3C)	Labelling task	9.50	38.00	28.50
Non-linguistic Visual (3C)	Labelling task	9.50	18.75	9.25
Nonverbalizable Visual (3D)	Labelling task	9.50	22.50	13.00

see if people apply a rule learned earlier to a later test'). Given that these two participants may have been performing strategically in this experiment, the analysis was conducted again excluding these participants. Once again, after participants were trained for a pre-changed item preference in the language domain, they increased their pre-changed item extensions in comparison to the baseline of Experiment 1, with the difference score ($M = 5.21\%$) being reliably above 0, one-sample $t(17) = 6.17$, $p < .001$, $d = 2.99$. Even excluding the participants who may have been performing strategically, this was a significant increase from Experiment 1.

After training to attend to the end of a sequence in either the linguistic domain or non-linguistic visual domain, participants successfully extended this training to a dissimilar label extension task. This adds support to the claim that the mechanism that underlies sequence processing in general can account for linguistic phenomena such as the suffixation preference. In addition, according to participant responses on the exit questionnaire, the successful transfer across these tasks does not appear to be a result of participants' strategic performance.

However, it is still not clear whether or not participants were relying on language even in the visual training of this experiment because the visual stimuli may have been easily verbalisable. For example, the participants may have been labelling the objects to themselves (e.g., diamond, heart, cross), which calls into question if this is truly a visual task and not an auditory or even linguistic one. The final experiment will investigate if this training and transfer are possible even when participants are not likely to verbalise the objects during training.

EXPERIMENT 3D: TRANSFERRING NON-VERBALISABLE VISUAL TRAINING TO LABEL EXTENSION TASK

Participants in this experiment were trained to attend to the end of sequence in a task similar to that of the non-linguistic visual training of Experiment 3B and 3C; however, non-verbalisable objects were used in the training procedure. Then, as in Experiment 3C, participants were tested in the label extension task of Experiment 1. This was designed to determine if training participants to attend to one particular aspect of a sequence (the end) has an effect on the form-meaning correspondence.

Method

Participants

There were 20 participants (16 men and 4 women) who were tested in the label extension task of Experiment 1 after initial training in the non-linguistic visual framework of Experiment 3B using non-verbalisable stimuli. Five additional participants were excluded for failing to answer at least 70% of the manipulation check trials of the training phase, and three additional participants were excluded for failing to correctly answer at least 70% of the catch trials during the testing phase.

Materials

The non-verbalisable visual stimuli used for training consisted of 24 sets of object sequences (target and two test sequences) that were created from 72 objects. The sets were created using a similar randomisation process as in earlier experiments. Each object was an object that was not easily verbalisable. The low degree of verbalisability was demonstrated in a calibration study where a separate group of participants ($n = 15$) were presented with 96 objects twice in two randomly ordered blocks (24 objects from Experiment 3C and 72 objects from this experiment). The object was deemed verbalisable if participants used a unique identifying label each time the object was presented (e.g., labelled as ‘heart’ each time it was presented). Only 30% of these new objects were consistently labelled from one trial to the next whereas 90.83% of the objects in 3C were consistently labelled in this calibration study.

Each set consisted of a two-part visual sequence followed by two test sequences. In each set, the first and second objects were identical in both test sequences, so the participants could only use the final object to make their selection. The final object either matched the final object of the target sequence or it did not. Each sequence of objects was red, blue, green, or orange. See Table 6 for example stimuli. There were once again two videos for participant feedback (one of a dog appearing to indicate a correct response and one without the dog appearing to indicate an incorrect response).

TABLE 6
Example training stimuli for Experiment 3D.

	Item type	
Target item	*Correct test item*	*Incorrect test item*

The test stimuli for all participants were identical to those used in the labelling task of Experiment 1, which consisted of 32 word pairs (target word with pre-changed, post-changed, identical, or different test word). These word pairs were connected to a triad of objects (target object and either identical or novel test object).

Design and procedure

The design and procedure were similar to that of the visual training conditions of Experiment 3B and 3C. The participants were to select the test sequence that would cause the dog to appear in the video. The test sequence that ended with the same object as the target sequence was the correct answer and caused the dog to appear in all of the trials. Once again, the final eight trials were used as a manipulation check to assure that the participants were correctly performing the task. The goal of training was to increase participants' attention to the final portion of the visual sequence.

After training to attend to the end of the non-verbalisable visual sequence, the participants took part in a seemingly unrelated testing phase. The testing phase was identical to the procedure of the label extension task of Experiment 1 where the participants heard a target object being labelled, and they were asked to extend the inflected label (pre-changed or post-changed) to one of the test objects (identical or novel).

Results and discussion

Participants were accurate on catch trials with 97.92% accuracy, above chance, one-sample $t(19) = 57.91$, $p < .001$, $d = 26.57$. Once again, for this experiment, a difference score was calculated for each participant between their percent of pre-changed item extensions to the identical object in the baseline labelling task of Experiment 1 in comparison to the percent of pre-changed item extensions in the labelling task after training in the non-verbalisable visual domain. See Table 5 for the calculations of the difference scores. Note that a difference score of zero would reflect no change in preference, whereas a positive difference score indicates successful training and/or transfer resulting in a higher percentage of label extensions to pre-changed items.

Once participants were trained for a pre-changed item preference in the non-verbalisable visual framework, they increased their pre-changed item extensions in comparison to the baseline of Experiment 1, with the difference score ($M = 13.00\%$) being reliably above 0, one-sample $t(19) = 3.07$, $p < .01$, $d = 1.41$. This was once again a significant increase after training.

After training to attend to the end of a sequence in the visual domain with arguably no use of language, participants successfully extended this training to a dissimilar label extension task. Results of Experiment 3D clearly indicate that the verbalisability of stimuli does not affect training or transfer. This finding adds support to the claim that the mechanism that underlies temporal sequence processing in general can account for linguistic phenomena such as the suffixation preference.

GENERAL DISCUSSION

After Experiment 1 demonstrated the suffixation preference in language, by using a similarity judgement task, Experiment 2 established that the suffixation preference is not limited to language. These results indicated that the suffixation-like preference is also present in the musical and visual domains, thus suggesting that this preference could be a general property of processing temporal sequences. In addition, Experiment 2B added further support to this general-cognitive account in that it was able to successfully explain not only the differences between prefixes and suffixes, but also the differences between these two types of inflections and infixes.

Note that there were differences in the suffixation preference in the baseline tasks across the three domains. The visual domain exhibited the strongest post-preference followed by the language domain and then the music domain. These differences may have had to do with differences in cognitive demands and/or levels of familiarity across domains. For example, it may have been more cognitively taxing to remember musical melodies than pseudo-words, and participants were more likely to be familiar with memorising words but not with memorising musical melodies. Conway and Christiansen (2005) and Marcus, Fernandes, and Johnson (2007) also demonstrate that there are differences in statistical learning across domains in adults and children, and that some domains afford better learning for various parts of a sequence. These differences warrant further investigation to better understand the cognitive mechanism underlying this processing.

Experiment 3 further examined the possibility of a general cognitive mechanism underlying the suffixation preference by investigating the flexibility and transferability of this preference within and across domains. A flexible mechanism is necessary to account for the existence of different inflectional patterns in various language systems. Both training and transfer were successful in all conditions as indicated by positive difference scores. It was found that this preference was flexible, with training resulting in participants' modification of their post-changed item preference or label extensions. More importantly, this trained preference was found to be transferable to other domains, even when training and testing tasks were seemingly unrelated. This preference flexibility and successful transfer across domains provides support for the domain-general mechanism underlying language's suffixation preference. Experiments 3B–3D further suggest that attentional learning (i.e., learning to shift attention from beginnings to ends of sequences) can account for the observed across-domain transfer. Experiments 3C–3D also demonstrates that this is more than just similarity in form, but also has connection to semantics by using the label extension task.

These findings support the general-cognitive account of the suffixation preference, with the suffixation preference not being limited to the domain of language. Participants were found to focus on the beginnings of temporal sequences, which is consistent with the account of greater distinctiveness of items in the beginning of a temporal sequence. The flexibility of the preferences and the cross-domain transfer of learning, especially under the associative learning regime of Experiments 3B–3D and the form-meaning correspondence of Experiments 3C–3D, further support the general-cognitive account of the suffixation preference.

The introduction presented several theoretical alternatives to account for the suffixation preference. One class of alternatives focused on factors that are specific to language, most notably constraints that are built into language and the saliency/importance of the initial portion of a word. These language-specific factors are unable to account for the suffixation preference that was found across domains or the fact that there was cross-domain transfer of learning. The other class of alternatives was based on factors that are not specific to language or speech, such as memory factors, attentional learning, and the computational demands of sequence processing. The current data are in support of this class of alternatives, although it does not yet distinguish between them. Memory factors, such as the primacy effect would suggest that we have better memory for the initial portion of a sequence, which would be in line with the presented findings. The attentional learning account suggests that we shift our attention towards informative portions of a sequence, which would also agree with the current findings. In addition, participants were trained in an attentional learning paradigm to modify their suffixation preference, which suggests that this is a plausible alternative as to how we attend to and process sequential information. Finally, computational demands of sequential processing predict not only that there is an advantage of processing the beginnings of words but also the beginnings of any temporal sequence. In addition, computational accounts also predict that processing the beginning/end of a sequence is more privileged than processing the middle of a sequence. Both the data from the suffixation preference being present across domains and the differential processing of pre/post changed items in comparison to infix-items further supports this account. This preference may be wired into the mechanism that processes temporal information, and it is reflected in language's use of inflectional morphology.

Overall, the reported findings also have broader implications for the understanding of language acquisition and language processing. For example, language acquisition and language processing are thought to be sub-served by mechanisms that are specific to the domain of language. However, there is a growing body of evidence that some aspects of language acquisition and language processing may stem from general mechanisms (e.g., Christiansen & Chater, 2001; Dienes, Altmann, & Gao, 1999; Gomez & Gerken, 2001; Hay & Diehl, 2007; Lewis, Vasishth, & Van Dyke, 2006; Newport & Aslin, 2004; Saffran, 2003; Saygin, Dick, Wilson, Dronkers, & Bates, 2003; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002; St. Clair, Monaghan, & Ramscar, 2008). Although inflectional morphology is only one aspect of language, the fact that it appears to be sensitive to cognitive factors that are not specific to language brings new evidence to the debate.

There are some limitations to these experiments that restrict our conclusions. First, the reported experiments only examined inflectional perception, and these findings may or may not generalise to inflectional production. For example, in language comprehension, where identifying the stem of a word might take priority, attention to the beginning of that word may be crucial; however, in production, where getting the right inflection in place is crucial, it might require more attention to the end of the word. Therefore, general cognitive factors may be able to account for perception of temporal sequences, but production of temporal sequences may or may not require different mechanisms. Second, it should be noted that the affixes in our current design are members of an open class as opposed to a realistic inflectional system of closed class affixes. The fact that we were able to replicate linguistic patterns in the research (Experiment 1) implies that this is not a problem; however, the two systems may utilise different strategies. To better understand this phenomenon, it is also necessary to study this process in a cross-linguistic sample which includes monolingual speakers of languages that show differential inflectional patterns. For example, speakers of languages that rely more heavily on infixation or prefixation may show differential patterns of processing the sequential information in these studies. Establishing this will inform our current theory.

In sum, this research demonstrated that for sequential processing, (a) the suffixation-like preference is present in other domains that have temporal structure, (b) this preference may account for the varying prevalence of different types of inflections, (c) this preference is flexible, and (d) a modified preference is transferable across domains. The cognitive mechanism that would account for the cross-domain performance could explain the suffixation preference in language, and the flexibility/transferability of this preference would account for the variety of inflectional systems cross-linguistically. It should be noted that finding the suffixation preference across domains (Experiment 2) as well as the cross-domain transfer that was exhibited in Experiment 3 is necessary but not sufficient to demonstrate that the underlying mechanism is domain-general. For example, the asymmetric learning and transfer as well as the fact that all participants were speakers of English would suggest that the mechanism needs further evaluation before irrefutable claims of generality can be made. However, this is a solid first step in this research endeavour. Overall, these results suggest that language's suffixation preference may stem in part from mechanisms of sequential processing that are not specific for language.

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