The Importance of Temporal Information for Inflection-type Effects in Linguistic and Non-linguistic Domains

Julie M. Hupp (hupp.34@osu.edu)
Center for Cognitive Science
1961 Tuttle Park Place
The Ohio State University
Columbus, OH 43210, USA

Vladimir Sloutsky (sloutsky.1@osu.edu)
Center for Cognitive Science
1961 Tuttle Park Place
The Ohio State University
Columbus, OH 43210, USA

Peter Culicover (culicover.1@osu.edu)
Department of Linguistics and Center for Cognitive Science
1712 Neil Avenue
The Ohio State University
Columbus, OH 43210, USA

Abstract

One of the important tasks of language acquisition is the ability to distinguish between an inflectional derivation from a target word, which is a variant of this word (e.g., *tool* → *tools*), and a completely new word (e.g., *tool* → *stool*). 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 or whether it stems from a more general cognitive mechanism, with beginnings of sequences being more salient than endings. The three reported experiments were designed to answer this question. In these experiments, participants judged the similarity of test sequences to target sequences across three domains: linguistic, musical and visual. The test items were judged as more similar to an original target item if information was added to the end of that item rather than to the beginning of the item across all three domains. This suggests that there may be a more general cognitive mechanism underlying the well-documented suffixation preference, according to which changes in the end of the word are more readily interpreted as inflectional derivations from the target word.

Introduction

One of the important tasks of language acquisition is the ability to distinguish between an inflectional derivation from a target word, which is a variant of this word (e.g., *tool* → *tools*), and a completely new word (e.g., *tool* → *stool*).

There are multiple types of inflections that exist across languages, including prefixation (e.g., adding a morpheme before the stem), suffixation (e.g., adding a morpheme after the stem), infixation (e.g., adding a morpheme inside the stem), and nonconcatenative devices (e.g., interleaving a string of vowels with a string of consonants).

Two types of inflections are frequently present in many European languages, prefixes and suffixes, and it has been established that suffixes are easier to acquire (e.g., interpret suffixation as an inflectional derivation) than prefixes. This finding is not specific to the English language. Cross-linguistically, the suffixing preference results in stems generally being ordered before the added morpheme because language users prefer to process stems before the added morpheme (Hawkins & Cutler, 1988). Overall, suffixing is more frequent than prefixing (Hawkins & Gilligan, 1988). A number of explanations have been proposed, although any single explanation alone may not fully account for this phenomenon.

First of all, there are positional differences with the addition of a morpheme at the beginning and the end of the word, which is important because words take place in time (Gasser, 1994). For example, words are often recognized before they are completed (Tyler, Marslen-Wilson, Rentoul, & Hanney, 1992). The information that reaches the ear first may be the key to the identification of that piece of information. If this is the case, then the temporal aspect of language may be the underlying reason for suffixation preferences in language.

Similarly, the psychologically most salient part of any word is its beginning portion (Clark 1991; Hawkins & Cutler, 1988). This is to say that the effect of distorting a word is more severe if the distortion is at the beginning of the word (e.g., prefix) rather than the end (e.g., suffix). This is true in both comprehension and production. In comprehension, adding a morpheme to the end of a word does not affect the recognition of the word, and in production, it is easier to produce a familiar sequence

followed by a modification in the form of a suffix than the reverse, a modification first and then the familiar word (Clark, 1991).

These contentions seem to be supported by the literature on language acquisition. In particular, Slobin (1985) claimed that children use procedures or strategies called Operating Principles (OP) in their linguistic development. He proposed many different principles that children use, but the one of importance for this area is OP (ATTENTION): BEGINNING OF UNIT. This principle states that children pay attention to the first syllable of an extracted speech unit. They store it separately and in relation to the unit with which it occurs. If a child were specifically attending to the beginning of a word, then adding a morpheme to the end of the word would be less detrimental to the recognition of that word than adding the morpheme to the beginning of the word.

Clark has done much research on the area of children and inflections that add support to suffixation preference from a developmental perspective. She has found that children acquire inflections from their earliest word use and continue to comprehend and produce them throughout their linguistic development (1995). In general, children begin to add noun and verb inflections between 18 and 24 months; however, they consistently learn suffixes before prefixes, even when these inflectional forms express equivalent information (1995; 1998). In addition, children aged 5 to 7 find nonsense suffixes are easier to imitate than nonsense prefixes (1998).

Overall, children seem to find it easier to process information added to the ends of words than to the beginnings, and it has been argued that the beginning of the word is its most psychologically salient portion. This would explain why children are better at learning suffixes rather than prefixes. These findings map quite well onto the adult research on inflectional morphology.

However, it is not clear whether this phenomenon is specific to language or whether it stems from a more general cognitive mechanism.

We suggest that this ability may reflect a more general property of processing of temporally organized information: changes in the beginning of a sequence are easier to detect than at the end of the sequence. If this is the case, then non-linguistic information that has temporal structure may also give rise to inflection-type effects, such that changes at the end of the sequence would more likely be considered variants of the original string than changes at the beginning of the sequence.

To test this hypothesis, we conducted three experiments, using language (Experiment 1), music (Experiment 2), and visual sequences (Experiment 3).

Experiment 1: Inflections in the Linguistic Domain

Method

Participants There were 17 participants in this experiment. The participants were undergraduate students from The Ohio State University who participated to fulfill a psychology course requirement. Five participants failed to correctly respond to at least 70 % of the catch items and were excluded from this experiment.

Design and Materials The stimuli consisted of 42 sets, with each set consisting of a 2-syllable artificial Target word followed by two Test words. One of the Test words was the Target with a morpheme added to the beginning (Test-Pre). The other Test word was the Target with a morpheme added to the end (Test-Post).

The Target words were constructed by randomly connecting discrete syllables (e.g., *Ta-Te*) with .06 sec between syllables (see Johnson & Jusczyk, 2001; Saffran, Aslin, & Newport, 1996, for details of stimuli creation). The Test words were created by either adding a syllable to the beginning of the Target word (Test-Pre: *BE-Ta-Te*), to the end of the Target word (Test-Post; *Ta-Te-BE*), adding nothing to the Target word (Test-Identical: *Ta-Te*), or changing the Target word completely (Test-Different: *Pu-La-Fi*).

On each trial, participants received a Target word, followed by two Test words (the order of each of the Test words was counterbalanced), and their task was to determine which of the Test words was more similar to the Target.

There were six types of sets determined by pairing of the types of Test words: Pre-Post, Pre-Identical, Post-Identical, Pre-Different, Post-Different, and Identical-Different. The first type was the focal interest (e.g., 25 Pre-Post sets), whereas the remaining 5 conditions were catch trials (3 sets for each condition, and 2 additional Identical-Different sets for the practice trials). The set types varied within participants.

Procedure Each participant received 2 randomly presented practice trials with a break to ask the experimenter any questions, and then the remaining 40 trials were presented randomly. *Presentation* software was used to deliver the instructions, present the stimuli and record the responses.

The participants were instructed that they would hear a 2-syllable Target word followed by two Test words, and they were to decide which of the Test words was more similar to the initial 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 sec in between each word, and the order of the Test words was counterbalanced across sets. The Target word was heard from both of the computer speakers

while the first Test word was heard only from the left speaker and the second Test word was heard only from the right speaker.

Results and Discussion

Overall, participants were accurate on catch trials, exhibiting over 90% accuracy ($M = 94.90\%$), above chance, one-sample $t (16) = 25.43$, $p < .001$.

However, the analysis of participants' responses to Pre-Post items was of considerable interest. Data analyses focused on the percent of participants' responses in which the Test-Post item was considered more similar to the Target than the Test-Pre item. Overall, in more than 85% of responses ($M = 88.00\%$) participants deemed the Test-Post item to be more similar to the Target than the Test-Pre item, above chance, one-sample $t (16) = 9.64$, $p < .001$. Thus, as expected there was a clear tendency to choose the Test-Post items as more similar to the original Target word than the Test-Pre words.

Having established that the procedure captures the effect in the domain of language, we conducted Experiments 2 and 3, using the same procedure with music tones and visual patterns.

Experiment 2: Inflection-type Effects in the Domain of Music

Method

Participants There were 18 participants in this experiment. The participants were undergraduate students from The Ohio State University who participated to fulfill a psychology course requirement.

Design and Materials The design was the same as in Experiment 1, except the sets were made up of a 2-note Target melody and two Test melodies. The Test items were created by adding notes to either the beginning (Pre) or the end (Post) of the Target melodies.

Procedure The overall procedure was identical to Experiment 1. The main exception was that instead of hearing 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 over 90% accuracy ($M = 91.85\%$), above chance, one-sample $t (17) = 20.35$, $p < .001$.

Similar to Experiment 1, data analyses of central interest focused on the percent of participants' responses in which the Test-Post item was considered more similar to the Target than the Test-Pre item. Once again, the participants were more likely to choose the Test-Post items as more similar to the Target than the Test-Pre items ($M = 71.56\%$), above chance, one-sample $t (17) = 4.03$, $p = .001$.

Experiment 3a: Inflection-type Effects in the Visual Domain

Method

Participants There were 17 participants in the visual domain. The participants were undergraduate students from The Ohio State University who participated to fulfill a psychology course requirement. Using the same exclusion criterion as in Experiment 1, 2 participants were eliminated from this experiment.

Design and Materials The design was the same as in Experiments 1 and 2. The stimuli in this experiment consisted of object sequences. There were a total of 25 objects that were randomly connected to form the Target sequences. The Target sequences were composed of either all red, blue, green or orange shapes. Each set consisted of a Target sequence made of two simple objects that flashed for 1 sec each while centered at the top of the computer screen (e.g., Cross, Heart).

Then, 1 sec later, the first of two Test sequences appeared at the bottom of the screen. There was 1 sec 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 computer screen, and the second Test sequence appeared on the bottom right of the screen. The Test items were created by adding an object (e.g., Diamond) for 1 sec either at the beginning of the Target sequence (Test-Pre; Diamond, Cross, Heart), at the end of the Target sequence (Test-Post: Cross, Heart, Diamond), no change at all to the Target sequence (Identical: Cross, Heart) or changed the sequence completely (Different: Star, Light Bulb, Lock). The object that was added was of a different color than the Target sequence: a red Target sequence would have a blue object added (and vice-versa), and green and orange were similarly paired.

Procedure The overall set up of the experiment was similar to Experiments 1 and 2. In this experiment, the 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 overall accuracy over 95% ($M = 98.04\%$), above chance, one-sample $t (16) = 63.23$, $p < .001$.

Similar to Experiments 1 and 2, participants were more likely to choose the Test-Post items as more similar to the Target than the Test-Pre items ($M = 91.53\%$), above chance, one-sample $t (16) = 13.72$, $p < .001$.

Having established that this effect is present in the visual domain, it was important to investigate the effect of temporal information in this domain. Therefore,

Experiment 3b was conducted as a control experiment for the visual domain without the addition of temporal information.

Experiment 3b: The Visual Domain without Temporal Information

Method

Participants There were 18 participants in the visual control condition. The participants were undergraduate students from The Ohio State University who participated to fulfill a psychology course requirement.

Design and Materials The design was the same as in the previous experiments. The stimuli in this experiment consisted of the same object sequences that were used in Experiment 2 without the addition of temporal information. That is to say that the participants viewed a row of stationary shapes instead of a dynamic sequence of shapes.

The Target appeared at the top of the screen while the Test items simultaneously appeared at the bottom of the screen. Once again, the positioning of the Test sequences was counterbalanced across sets. One Test sequence appeared on the bottom left of the computer screen, and one Test sequence appeared on the bottom right of the screen. Similar to Experiment 3a, the Test items were created by adding an object (e.g., Diamond) either to the left of the Target sequence (Test-Pre; Diamond, Cross, Heart,), to the right of the Target sequence (Test-Post: Cross, Heart, Diamond), no change at all to the Target sequence Identical: Cross, Heart) or changed the sequence completely (Different: Star, Light Bulb, Lock).

Procedure The overall set up of the experiment was similar to the previous experiments. In this experiment, the participants were instructed that they would see a Target sequence of objects on the top of the screen and 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 overall accuracy over 95% ($M = 95.55\%$), above chance, one-sample t (17) = 42.26, $p < .001$.

Similar to Experiments 1, 2 and 3a, participants were more likely to choose the Test-Post items as more similar to the Target than the Test-Pre items ($M = 80.89\%$), above chance, one-sample t (17) = 7.52, $p < .001$.

However, when this control condition is compared to the original visual domain experiment, it appears that the absence of temporal information attenuates this effect. There is a higher propensity to choose the Test-Post items as more similar to the Target than the Test-Pre items when there is the addition of temporal information, independent-samples t (33) = 2.07, $p < .05$.

General Discussion

The results of the three reported experiments clearly indicate that across the three domains, the beginning of the sequence was more salient than the end of the sequence, and as a result, 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. Presence of this tendency across the three domains indicates that this tendency is not limited to language. More specifically, the "suffixation preference" found in the linguistic domain appears to be analogues for sequences of musical tones and visual patterns, all having a temporal component.

Results of Experiment 3b indicate that the temporal component is fundamental: once the temporal component is removed and stimuli are presented simultaneously, the effect is diminished.

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 rather it stems from processing of temporally organized information.

To better understand this phenomenon, it is important to investigate this bias in native speakers of languages that do not have the same dominant suffixing preference (e.g., Thai). This may further reveal the direction and strength of this tendency.

In addition, there are several important questions that are to be answered in future research. First, it is unclear whether this tendency to consider the beginning of a sequence as more salient than the end of a sequence appears as a domain-general attentional bias or whether it first manifests itself in the domain of language, and then gets extended to other temporally organized domains. Although the former possibility seems more likely, a developmental study using the same set of stimuli is necessary to answer this question.

Given the fact that the effect exists in the visual domain even without temporal information, it is important to investigate possible explanations. Since the visual images without temporal information were presented in a manner that resembles the structure of written material, it is possible that this structure brought about the positional biases similar to those in the linguistic domain. For example, while reading English, one visually scans from left to right; therefore, this same mechanism could account for the effect in Experiment 3b even without temporal information. To better understand the phenomenon, it is necessary to structure the visual information so that a left to right scanning pattern does not temporally constrain the information (e.g., vertical presentation of the stimuli). In addition, this explanation may be further expanded if the effects would vary not only according to the presentation of the stimuli, but also developmentally. This explanation could be ruled out if children who do not yet read readily show this effect in the visual domain without temporal information.

Another important question is how flexible is this tendency in non-linguistic domains. The suffixation preference is very flexible in the domain of language

(otherwise people would not be able to acquire various kinds of inflectional morphology), and if it stems from a general mechanism, this tendency has to exhibit flexibility in other domains as well. These issues are currently under investigation.

In sum, the results suggest that when information is added to the end of a Target sequence, it is perceived as more similar to the original Target than if the same information was added to the beginning of this Target. This was true across all three domains investigated, suggesting that there might be a general cognitive mechanism of processing of temporal information that may underlie the suffixation preference, which is prominently present in the linguistic domain.

References

Clark, E. V. (1991). Acquisitional principles in lexical development. In S. A. Gelman & J. P. Byrnes (Eds.), *Perspectives on language and thought: Interrelations in development*. Cambridge, MA: Cambridge University Press.

Clark, E. V. (1995). Language acquisition: The lexicon and syntax. In J. L. Miller & P. D. Eimas (Eds.), *Handbook of perception and cognition, 2nd ed.: Speech, language, and communication*. New York, NY: Academic Press.

Clark, E. V. (1998). Morphology in language acquisition. In A. Spencer & A. M. Zwicky (Eds.), *The handbook of morphology*. Malden, MA: Blackwell.

Gasser, M. (1994). Acquiring receptive morphology: A connectionist model. *Annual Meeting of the Association for Computational Linguistics*, 32, 279-286.

Hawkins, J. A., & Cutler, A. (1988). Psycholinguistic factors in morphologicalasymmetry. In J. A. Hawkins (Ed.), *Explaining language universals*. New York, NY: Basil Blackwell.

Hawkins, J. A., & Gilligan, G. (1988). Prefixing and suffixing universals in relation to basic word order. *Lingua*, 74, 219-259.

Johnson, E. K., & Jusczyk, P. W. (2001). Word segmentation by 8-month-olds: When speech cues count more than statistics. *Journal of Memory & Language*, *44*, 548-567.

Slobin, D. I. (1985). Crosslinguistic evidence for the language-making capacity. In D. I. Slobin (Ed.), *The Crosslinguistic study of language acquisition, Vol. 1: The data; Vol. 2: Theoretical issues*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science*, *274*, 1926-1928.

Tyler, L. K., Marslen-Wilson, W. D., Rentoul, J., & Hanney, P. (1992). Continuous access processes in spoken word recognition. *Journal of Memory and Language*, *27*, 368-381.