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Brief article

ANCHORING is amodal: Evidence from a signed language

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ABSTRACT

Across languages, certain linguistic forms are systematically preferred to others (e.g. *bla* > *lba*). But whether these preferences concern abstract constraints on language structure, generally, or whether these restrictions only apply to speech is unknown. To address this question, here we ask whether linguistic constraints previously identified in spoken languages apply to signs. One such constraint, ANCHORING, restricts the structure of reduplicated forms (AB → ABB, not ABA). In two experiments, native ASL signers rated the acceptability of novel reduplicated forms that either violated ANCHORING (ABA) or obeyed it (ABB). In Experiment 1, signers made a forced choice between ABB and ABA forms; in Experiment 2, signers rated signs individually. Results showed that signers prefer signs that obey ANCHORING over ANCHORING violations (ABB > ABA). These findings show for the first time that ANCHORING is operative in ASL signers. These results suggest that some linguistic constraints are amodal, applying to both speech and signs.

1. Introduction

It is well known that across spoken languages, some linguistic structures are preferred to others; for example, syllables like *bla* are preferred to *lba* (e.g., Berent, Steriade, Lennertz, and Vaknin, 2007). But the nature of these constraints is controversial. One possibility is that these restrictions apply to speech, specifically (e.g., *lba* is harder to hear and to say than *bla*; Blevins, 2004; MacNeilage, 2008). On an alternative view, linguistic preferences stem from grammatical principles that are not specific to any particular linguistic modality (e.g., a formal constraint against syllables like *lba*; see Prince and Smolensky, 1993).[1]

To adjudicate between these possibilities, here, we turn to sign language phonology. Like spoken languages, all mature sign languages exhibit phonological patterning (Brentari, 1998; Liddell and Johnson, 1989; Sandler, 1989, 2012), but they are communicated in the manual modality. Our experiments ask whether some phonological constraints that have been previously identified in spoken language might apply across modalities—to both speech and signs.

Our case study concerns the phonological restrictions on *reduplication*. Reduplication copies all or part of a word (called a *base*), resulting in a new word whose meaning is linked to that of the base. For example, in Manam (an Austronesian language), the verb *pana* 'run' is the base of the reduplicated form *panana* 'chase' (Lichtenberk, 1983).

Reduplication is of interest because it is common across languages (Rubino, 2013), yet highly constrained (Lunden, 2004; Marantz, 1982; McCarthy and Prince, 1995). In particular, patterns like AB → ABB (where A and B are distinct phonological elements) and AB → AAB are well attested (e.g. *pana*, 'run' → *panana*, 'chase'; and in Ilocano, *púsa* 'cat' → *puspúsa*, 'cats'; Hayes and Abad, 1989). In contrast, patterns like AB → *ABA (e.g., *pana* → **panapa*) are scarce.[2]

Optimality Theory (Prince and Smolensky, 1993/2004) accounts for this regularity by appealing to abstract grammatical constraints on reduplication. One such constraint, ANCHORING (McCarthy and Prince, 1993), requires that a reduplicative copy be adjacent, or *anchored* to its

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[1] According to Optimality theory, all language users share a universal set of violable grammatical constraints. Particular grammars differ with respect to the relative ranking of these universal constraints, explaining why syllables such as *lba*, though cross-linguistically dispreferred, are nonetheless tolerated in some languages such as Russian. Here, we only ask whether grammatical constraints are amodal; their universality is not directly addressed by our inquiry.

[2] AB → ABA patterns are rare, but not entirely unattested; see Nelson (2005) for one example.

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base (see also McCarthy and Prince, 1995).[3] For example, *panana* (see (1)) obeys ANCHORING because the copy, or *reduplicant* (here, {$\mathbf{n}_{3c}\mathbf{a}_{4c}$}),[4] is adjacent to the portion of the base it is copied from (i.e., $\mathbf{n}_3\mathbf{a}_4$). The same holds for *papana* (2). In contrast, **panapa* (3) violates ANCHORING because the reduplicant is stranded from the portion of the base it copies by intervening material (i.e., $\mathbf{p}_1\mathbf{a}_2$ and{$\mathbf{p}_{1c}\mathbf{a}_{2c}$} are separated by n_3a_4). More generally, given a base AB, ABB and AAB are better formed than ABA.

(1) *pa**na**__**na**__*: [$p_1a_2\mathbf{n}_3\mathbf{a}_4$]{$\mathbf{n}_{3c}\mathbf{a}_{4c}$}
(2) ***__pa__**pa*: {$\mathbf{p}_{1c}\mathbf{a}_{2c}$}[$\mathbf{p}_1\mathbf{a}_2n_3a_4$]
(3) *****pa**na**__pa__***: [$\mathbf{p}_1\mathbf{a}_2n_3\ a_4$]{$\mathbf{p}_{1c}\mathbf{a}_{2c}$}

Previous experimental work has shown that similar constraints on reduplication are operative in English and Hebrew. Specifically, reduplicative forms like *slaflaf* (where the copy, *laf*, is a contiguous substring of the base, *slaf*) are preferred to noncontiguous forms (e.g., *slafsaf*) by speakers of both Hebrew and English—a language that does not have such forms of reduplication (Berent, Bat-El, and Vaknin-Nusbaum, 2017). These findings suggest that some constraints on reduplication are active in the minds of speakers. Here, we ask whether similar restrictions on reduplication are active in the minds of signers.

Like in spoken languages, reduplication is frequent in sign languages (Sandler and Lillo-Martin, 2006), including ASL (e.g., Wilbur, 2009). For example, reduplication is used to form nouns from verbs (X → XX, e.g. SIT 'sit' → SIT-SIT 'chair'; Klima and Bellugi, 1988). Experimental evidence has shown that ASL signers extend reduplication to novel signs by relying on an abstract rule (Berent, Dupuis, and Brentari, 2014). But whether ASL reduplication conforms to ANCHORING is unclear.

If ANCHORING constrains speech, then *a priori,* there is no reason to expect similar preferences for signs. In contrast, if ANCHORING exists, and is amodal, then it is conceivable that similar preferences (e.g., {ABB, AAB} > ABA) should apply to signs. Furthermore, if ANCHORING is productive, then signers should be able to extend this preference to novel forms. Accordingly, signers should favor novel ABB and AAB signs (that obey anchoring) over ABA forms (which violate it). The following two experiments examine these predictions.

2. Experiment 1

To test whether signers are sensitive to ANCHORING, in Experiment 1 we presented native ASL signers with a matched pair of novel signs: one sign obeyed ANCHORING whereas the other violated it (i.e., ABB and ABA, respectively). Signers were asked to make a forced choice as to which form would make a better ASL sign. If signers are sensitive to ANCHORING, then they should prefer ANCHORING-consistent forms over ANCHORING-inconsistent forms (i.e. ABB > ABA).

2.1. Methods

2.1.1. Participants

12 Deaf native ASL signers took part in this experiment. All signers were from the greater Boston area, and all had been exposed to ASL between the ages of 0 and 8 years, with a majority (8/12) exposed before age 5. All participants were paid $30 for their participation. Each participant was debriefed and provided their informed signed consent according to the local IRB guidelines.

2.1.2. Stimuli

The experimental stimuli consisted of 22 pairs of novel, tri-syllabic signs: ABB and ABA (where "A" and "B" are distinct syllables). Within each pair, signs shared the same "A" and "B" syllables and differed only in their syllable orders. Syllables were chosen for each pair such that "A" always differed from "B" in both handshape and place of articulation. All signs were phonotactically legal in ASL, akin to the structure of ASL compounds (Brentari, 1998; Sandler, 1989, 1999).

2.1.3. Video recording

Three types of signs were recorded during the session: ABB signs (which conform with ANCHORING); ABA signs (which violate ANCHORING); and a third type, AAB, which was used only in Experiment 2. Signs were recorded in matched triplets, with each triplet containing one sign of each of the three types (e.g., ABB, ABA, AAB) and all signs within a triplet containing the same "A" and "B" syllables. Triplet members thus differed from each other only in terms of their syllable order.

Signs were articulated by a hearing, native bilingual/bimodal ASL signer whose mother is Deaf. All signs were recorded in a single session in Photobooth on a Macintosh using a built-in camera. During recording, the signer sat directly across from the camera such that her entire torso, lap, and head were visible. The signer was then familiarized with the complete set of syllables and syllable-combinations used in the experiment, and given ample opportunity to practice.

To ensure uniformity of sign production, the signer articulated all signs along to the rhythm of a metronome, at a rate of one beat per syllable (88 bpm). All sound was removed from videos prior to their inclusion in the experiment. Throughout the session, the signer was monitored by two fluent signers and corrected as needed to ensure consistency in facial expressions and emphasis (e.g. to ensure consistent stress). All signs were further inspected by one of the authors (DB), a sign language phonologist to ensure that they were clear, fluent, and faithful to the intended number of syllables (in line with Brentari & Poizner, 1994; Jantunen, 2013).

The resulting video recordings were clipped in iMovie so that each sign began at the beat immediately before the signer raised her hands, and ended once the signer's hands had returned to rest, after the fifth metronome beat. Final sign durations were 3 s. Fig. 1 illustrates one triplet; for additional phonetic detail, see Fig. S3.

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.cognition.2018.07.016.

2.1.4. Procedure

Instructions to participants were pre-videotaped in ASL (modeled by the same signer who signed the experimental stimuli). Each trial consisted of two matched signs presented side by side (ABB vs. ABA), counterbalanced for order. Signers were instructed to watch each pair of videos and indicate which form made a better sign in ASL using the keypad. The experiment began with three practice trials (using stimuli distinct from experimental signs). No feedback was given during practice or experimental sessions. Signs were presented in a random order using E-Prime 2.0.

2.2. Results

Fig. 2 presents the proportion of ANCHORING-consistent choices made by participants (for the raw data from Experiments 1–2, see SI). An inspection of the means suggests that signers favored ABB over ABA forms. A binomial exact *t*-test demonstrated that this preference was significantly higher than chance ($Z = +4.62$, $p < .001$).[5]

[3] Formally (McCarthy and Prince, 1993:67): "In R + B, the initial element in R is identical to the initial element in B. In B + R, the final element in R is identical to the final element in B." In R + B the reduplicant (R) precedes the base (B), and in B + R it follows it.

[4] In these examples, a 'c' subscript indicates an element that has been copied from the base.

[5] A logistic regression on the data produced similar results ($\beta = 0.7998$, $SE = 0.4005$, $z = 1.997$, $p = .0458$). Only the results of the binomial *t* test are listed here.

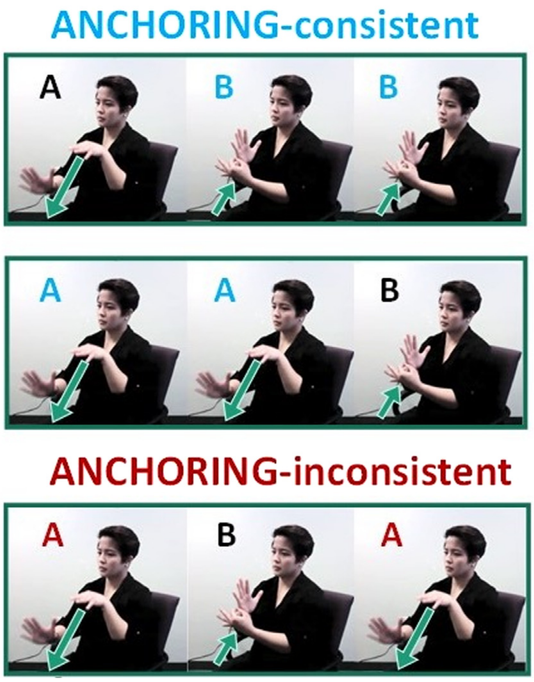

Fig. 1. An illustration of a matched triplet of ABB, AAB, and ABA signs.

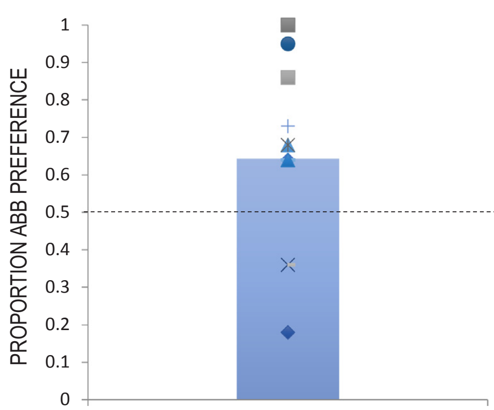

Fig. 2. Proportion of participants choosing ANCHORING-consistent forms (ABB); symbols show individual participant means. The line indicates chance.

2.3. Discussion

The results of Experiment 1 show that signers prefer ANCHORING-consistent over ANCHORING-inconsistent forms. This finding is in line with the possibility that signers are sensitive to ANCHORING. But since this task required participants to compare signs that contrasted only on this dimension, it is unclear whether signers attend to anchoring spontaneously, even when well-formedness can be informed by any other property of the stimulus (e.g., movement, handshape). Experiment 2 addresses this question.

3. Experiment 2

In Experiment 2, signers were presented with a single novel sign per trial. Signs were one of three matched types, including both types used in Experiment 1 (e.g. ABB and ABA) as well as a third type, AAB, used only in Experiment 2. ABA forms, as before, violated ANCHORING, while both AAB forms and ABB forms obeyed it. The inclusion of AAB forms in the experiment allowed us to determine whether participants' anchoring preferences depend on the location of the copy with respect to the base. Signers were asked to rate each sign on a 1–5 scale (1 = worst, 5 = best), but were given no further guidance for the basis of their ratings.

If signers spontaneously constrain ANCHORING, then they should prefer ANCHORING-consistent forms (i.e. [AAB and ABB] > ABA) even when the task does not elicit attention to this aspect of a sign's structure.

3.1. Methods

3.1.1. Participants and materials

Thirteen participants took part in Experiment 2. Data from two participants were excluded from analysis (one misinterpreted the task instructions, and data for the second was discarded due to experimenter error). The final analysis includes data from the 11 remaining participants, all of whom had participated in Experiment 1 in the same session. Stimuli consisted of 25 matched triplets of novel signs.

3.1.2. Procedure

Instructions were pre-videotaped in ASL and presented to participants prior to the experiment. The experiment did not include a separate practice session, but participants could ask questions concerning the instructions during the first three trials. No feedback was provided.

In each trial, participants saw a novel sign and were asked to rate it on a 1–5 scale, where 1 was the worst score a sign could receive and 5 the best. Participants were told that a highly dispreferable sign should receive a score of 1, an excellent sign a score of 5, and a sign that fell somewhere in the middle a score of 2–4. Participants were given no further guidance for what should serve as the basis of their ratings, and were told to "follow their gut" for each video. Participants indicated their rating for each sign using the keypad. Signs were presented in a randomized order using E-Prime 2.0.

3.2. Results and discussion

An inspection of the means (see Fig. 3) shows that AAB and ABB signs both received higher ratings than ABA signs. A one-way repeated measures ANOVA found a significant effect of sign type ($F1(2, 20) = 5.33$, $MSE = 0.34$, $p < .02$; $F2(2, 48) = 37.00$, $MSE = 0.11$, $p < .001$).

Planned comparisons showed that ANCHORING-consistent forms were significantly preferred over ANCHORING-inconsistent ABA forms. This was true for both ABB ($F1(2, 20) = 8.66$, $p = .008$; $F2(2, 48) = 60.29$, $p < .001$) and AAB signs ($F1(2, 20) = 7.08$, $p = .02$; $F2(2, 48) = 49.29$, $p < .001$). Responses to the two ANCHORING-consistent sign types (AAB and ABB) did not significantly differ (both $Fs < 1$).

These results show that signers spontaneously prefer ANCHORING-consistent forms (both AAB and ABB) over

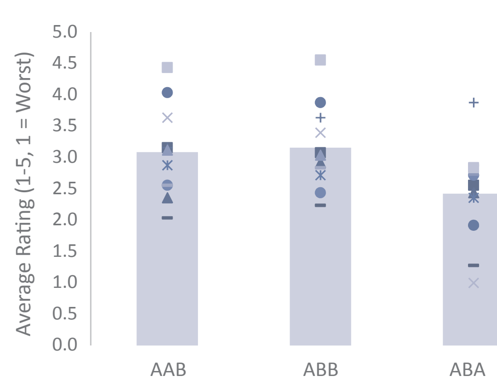

Fig. 3. Participants' preference for ANCHORING-consistent signs (ABB and AAB) and ANCHORING-inconsistent signs (ABA). Symbols are individual participant means.

ANCHORING-inconsistent forms (ABA), even in the absence of task demands that draw attention to reduplication. In contrast, signers do not show any preference between the two ANCHORING-consistent forms (i.e., AAB = ABB), suggesting that so long as a reduplicated sign satisfies ANCHORING, the location of the reduplicant with respect to the base does not affect its relative well-formedness. Together, the results from Experiment 2 demonstrate that signers apply their anchoring preference spontaneously to signs.

4. General discussion

Are linguistic phonological restrictions specific to speech, or are some linguistic constraints shared across language modalities? To address this question, here we examined whether signed and spoken language share common linguistic constraints. Our case study concerned the constraint ANCHORING (McCarthy and Prince, 1993). We reasoned that if ANCHORING strictly constrains speech, then *a priori*, there is no reason to expect signers to dislike ABA signs. In contrast, if ANCHORING is an amodal linguistic principle, then this constraint could conceivably extend to the manual modality.

Our present results show for the first time that, like speakers, signers favor ANCHORING-obeying (ABB and AAB) forms to ANCHORING-violating (ABA) signs. It is unlikely that this preference is solely due to experience with ASL. As noted, tri-syllabic forms composed of non-identical syllables are generally rare in ASL (Wilbur, 2009). And while ABB forms have been documented, particularly in compounds, no sign has been reported to follow an AAB form (Sandler, 1989). So while the ABB preference could potentially be based on experience with ASL, this explanation fails to account for the (equally strong) preference for the unattested AAB forms. The most likely explanation for these results, then, is that the ANCHORING constraint, identified previously in spoken languages, extends to ASL signs.

These findings are in line with previous research showing that some linguistic preferences are amodal (Berent, Bat-El, Brentari, Dupuis, and Vaknin-Nusbaum, 2016; Berent, Dupuis and Brentari, 2013; Stone, Petitto and Bosworth, 2017; Strickland et al., 2015). For example, previous experiments have demonstrated that English speakers with no command of a sign language nonetheless spontaneously project their phonological knowledge of syllable structure to signs (Berent et al., 2013). Similarly, English speakers apply restrictions on phonological identity (*XX) across modalities. In particular, English speakers dislike phonological forms with identical strings in both speech (e.g., *slaflaf*) and sign (e.g., XX), but they show a reliable doubling preference when doubling has a morphological function (Berent et al., 2016). These results show that speakers of spoken languages spontaneously generalize their knowledge to signs. Our present findings extend these conclusions by showing that a constraint previously documented in spoken languages is also spontaneously enforced by ASL signers on signs.

What is the nature of such amodal constraints? One possibility is that the parallel outcomes in speech and signs reflect distinct sets of sensorimotor pressures that operate separately in each modality to disfavor ABA forms. The similarity in their outcome is essentially a coincidence; it reflects the accidental convergence between two sets of sensorimotor pressures that happen to converge cross the two modalities. While this possibility cannot be ruled out, the existence of such constraints remains to be shown. Much of the existing evidence for shared constraints on speech and gestures concerns the integration between speech and co-speech gestures (e.g. Goldin-Meadow, 2010; McNeill, 1992; Roustan & Dohen, 2010; for a review, Goldin-Meadow and Alibali, 2013), so it is unclear whether the cross-modal link concerns shared motor constraints or whether it is mediated by semantics. The possibility that such constraints exist and could account for reduplication is far from evident.

Another challenge to the sensorimotor account is presented by parallel experiments with non-signers (Berent, Bat-El, Andan, Brentari, and Vaknin-Nusbaum, submitted for publication). The sensorimotor account would predict that the constraints on speech and signs would extend, irrespective of linguistic experience, to both signers and non-signers. But our results show that, when non-signers are presented with the same stimuli, they show a reliable *dispreference* for doubling (i.e., ABB < ABA).

An alternative explanation for the results asserts that linguistic constraints are amodal and abstract. Processes such as reduplication, or ANCHORING apply not to specific speech acts (e.g., the syllable *ba* or *ga*) but to abstract constituents such as "syllable" (Berent, 2013). These constituents define abstract equivalence classes, akin to algebraic variables (Marcus, 1998). Because ANCHORING constrains only the form of mental representations (i.e., the location of the copy) and not their substance, they can apply to any syllable alike, irrespective of whether it is spoken or signed. The hypothesis that phonology is algebraic (Berent, 2013) offers the representational mechanism that allows linguistic constraints to apply across language modalities, to both speech and signs.

Another open question raised by our findings concerns the origins of such principles—whether they form part of Universal Grammar (McCarthy and Prince, 1993) or whether signers have induced them from their linguistic experience. It is important to keep in mind that the origins question is orthogonal to the nature of the constraint. In particular, the possibility that ANCHORING is abstract does not necessarily mean that this constraint is innate. And indeed, Sandler (1989) has shown that ABB signs can occasionally arise by means of compounding (e.g., 'home' A + 'work' BB → ABB 'homework'). So while the universality of ANCHORING must remain an open empirical question, our results suggest that this constraint is amodal.

5. Declarations of interest

None.

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