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Knowledge of Language Transfers From Speech to Sign: Evidence From Doubling

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Abstract

Does knowledge of language transfer across language modalities? For example, can speakers who have had no sign language experience spontaneously project grammatical principles of English to American Sign Language (ASL) *signs*? To address this question, here, we explore a grammatical illusion. Using spoken language, we first show that a single word with doubling (e.g., *trafraf*) can elicit conflicting linguistic responses, depending on the level of linguistic analysis (phonology vs. morphology). We next show that speakers with no command of a sign language extend these same principles to novel ASL signs. Remarkably, the morphological analysis of ASL *signs* depends on the morphology of participants' *spoken* language. Speakers of Malayalam (a language with rich reduplicative morphology) prefer XX signs when doubling signals morphological plurality, whereas no such preference is seen in speakers of Mandarin (a language with no productive plural morphology). Our conclusions open up the possibility that some linguistic principles are amodal and abstract.

Keywords: Language universals; Phonology; Morphology; Reduplication; Sign language

1. Introduction

Across languages, certain sound patterns are systematically preferred to others (e.g., *traf* > *rtaf*). The source of these preferences, however, is debated. One view asserts that phonological patterns are partly constrained by abstract linguistic principles (Chomsky & Halle, 1968; Prince & Smolensky, 1993/2004). An alternative account attributes phonological structure to embodied sensorimotor restrictions (Glenberg, Witt, & Metcalfe, 2013; Ohala, 1983; Pulvermüller & Fadiga, 2010) and familiarity (Bybee & McClelland,

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2005). While on the grammatical account, *rtaf* is structurally ill-formed, on the latter view, *rtaf* is disliked because it is unfamiliar and harder to hear and articulate.

We note that these possibilities are not necessarily mutually exclusive. It is trivial to show that knowledge of language is experience dependent, so grammatical and statistical knowledge can certainly both play a role (e.g., Pinker, 1999; Yang, 2004). By the same token, it is perfectly possible that some aspects of language are embodied (Fadiga, Craighero, Buccino, & Rizzolatti, 2002), whereas others are algebraic and abstract (Chomsky & Schützenberger, 1963). In any case, the role of familiarity, sensorimotor, and phonetic pressures in the phonological system is undeniable (e.g., Hayes, Kirchner, & Steriade, 2004; Ohala, 1975; Steriade, 1999). Our question here, however, is different. We do not question the role of experience and embodiment. Rather, we ask whether abstraction plays *some* role. Here, we explore this question from a novel perspective.

Our research asks whether speakers who have had no previous command of a sign language can spontaneously project grammatical principles from their *spoken* language to American Sign Language (ASL) *signs*. We reason that if knowledge of language is defined only by aural/oral restrictions, then it is unlikely that these principles will extend to a visual/manual modality. The phenomenon in question—a grammatical illusion, akin to ambiguous figures in vision—further challenges the attribution of these constraints to sensorimotor demands exacted by the stimulus itself. In contrast, if grammatical principles are algebraic and abstract, then cross-modal projections become a viable possibility. Our research gauges such projections.

The specific case study concerns the restrictions on doubling, as in *trafraf*. We represent doubling as XX—two (partially) identical prosodic constituents. Like ambiguous figures in vision, phonological doubling is structurally ambiguous. Doubling is amenable to two conflicting linguistic parses (at the levels of the phonology vs. morphology), and these parses elicit conflicting responses (aversion vs. preference). Since the input is unchanged, the shift in response must therefore reflect abstract linguistic constraints, rather than the familiarity with the stimulus and its sensorimotor demands. Whether those linguistic constraints are innate or acquired is not a question that we can answer here—the shift in response does not speak to the origin of the constraints. But it does suggest that these constraints are independent of idiosyncratic properties of the stimulus. As such, the structural ambiguity of doubling presents one logical argument in support of abstraction.

To further test the abstraction hypothesis, we next move to examine whether the grammatical restrictions on doubling can transfer across language modalities. Our evidence is presented in three steps that encompass language in two distinct modalities—spoken and signed.

Using novel English words, we first show that English speakers systematically shift their responses to doubling depending on the level of analysis—phonology or morphology. Thus, a single stimulus in a spoken language elicits *distinct* parses.

To test the complementary dissociation, we next examine whether stimuli in two distinct modalities—ASL signs and spoken English—would elicit the *same* structure parse even when the language modality is markedly different—signs in ASL. Our results show that speakers with no command of a sign language spontaneously project the restrictions on doubling to ASL signs.

To determine whether these projections are based on grammatical principles, we finally compare responses by speakers of two languages—Mandarin vs. Malayalam. The conflicting responses of these two groups to signs are inexplicable by the sensorimotor demands of the stimulus and its iconicity. Instead, these findings show that the structural analysis of ASL signs depends on the morphology of participants' spoken language. Together, these results suggest that some linguistic principles are not only abstract but also amodal.

1.1. The double identity of doubling: A brief formal analysis

Linguistic research suggests that doubling can be assigned two distinct parses (e.g., Inkelas, 2008; McCarthy, 1986; McCarthy & Prince, 1995; Urbanczyk, 2017). At the phonological level, doubling is encoded simply as two repeated elements (e.g., *nana* in *banana*); repetition bears no relation to meaning (e.g., to *bana*). At the morphological level, however, doubling can signal systematic links between form and meaning (e.g., in Manam, *pana* "run" → *panana* "chase"; Lichtenberk, 1983). We refer to phonological versus morphological doubling as *identity* versus *reduplication*, respectively.

Formally, identity is captured by two repeated elements (XX, where X refers to a phonological element, such as a syllable), whereas reduplication ($(\{X\}X_c)$) reflects a single element and its copy (indicated by the subscript c). One can liken this distinction to the contrast between two identical twins (two identical tokens of the same kind) and the reflection of a single individual in a mirror; the reflection is merely a copy—only one token exists. Fig. 1 illustrates this contrast.

Critically, these two parses elicit conflicting linguistic preferences, as they are each subject to distinct grammatical constraints. Phonological identity (XX) is systematically disliked, as it violates a phonological ban on adjacent identical elements (the Obligatory Contour Principle, OCP; Leben, 1973; McCarthy, 1986), so XX < XY.

In the case of morphological reduplication ($\{X\}X_c$), however, the base ($\{X\}$) is free of phonological identity (the second X_c element is merely a copy), so reduplication incurs no violation of the OCP. And since the base is shorter than an XY control (where Y is added phonological material, thus violating DEP—a ban on additional material; McCarthy & Prince, 1995), morphological reduplication is preferred (XX > XY).

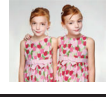
Condition	***Illustrations***	***Linguistic example***	***Formally***
Identity		*trafraf*	XX
Reduplication (Base and copy)	 	*{traf}$r_c a f_c$*	$\{x\}X_c$

Fig. 1. The two formal parses of doubling. Images licensed under Creative Commons.

The conflicting parses and their constraint violations are illustrated in (1). For each example, we provide the structure projected by the phonology and morphology, and note how it fairs against the two constraints in question—OCP and DEP. We indicate constraint violation with an asterisk; constraint satisfaction is indicated by a checkmark.

Note that, in our example (*trafraf*), which is modeled after a productive reduplicative pattern in Hebrew (e.g., *klavlav* "puppy"; from *kelev* "dog"), reduplication is partial—the initial consonant in the base, /k/, does not surface in the copied material. This omission is phonologically motivated, as full reduplication (*traf.traf*) would have yielded a complex onset word medially, which is ill-formed in monomorphemic words in Hebrew (Bat-El, 2006). Thus, although the copy is incomplete, the base is a syllable, and the morphological reduplicative parse is essentially $\{X\}X_c$.

(1) *Constraint violations by phonological doubling vs. morphological reduplication*

	Example	Structure	OCP	DEP
Phonology	*trafraf*	XX	*	
	trafmat	XY	✓	
Morphology	*trafraf*	$\{X\}X_c$		✓
	trafmat	$\{X\}Y$		*

Two consequences of this analysis should be highlighted. First, doubling is associated with different structural parses, hence, different responses. Second, each such parse is defined by an abstract algebraic relation; identity (XX), for instance, concerns any two X elements, and the same holds for "copy" ($\{X\}X_c$). As such, the restrictions on doubling could apply to any linguistic stimulus, irrespective of its phonetic form and its familiarity.

1.2. Experimental test: Spoken language

Our recent experimental findings show that people apply the restrictions on doubling across linguistic modalities—speech and sign (Berent, Bat-El, Brentari, Dupuis, & Vaknin-Nusbaum, 2016).

When presented with novel printed words (i.e., phonological forms in their spoken language), doubling was systematically avoided (e.g., *trafraf* < *trafmak*). But once doubling was presented as a morphological plural (e.g., *trafraf* is the plural of *traf*), the doubling dislike shifted into a reliable preference (e.g., *trafraf* > *trafmak*). The shifting responses are in line with the possibility that phonological and morphological doubling are subject to distinct linguistic constraints.

Remarkably, speakers spontaneously extended the same linguistic preferences to ASL signs. Thus, when English speakers with no command of a sign language were presented with signs with two identical syllables (XX), they showed a reliable doubling aversion (XX < XY). In contrast, once the same form indicated plurality (X is paired with a ball; XX is paired with a set of balls), doubling was actively preferred.

Could the shift reflect *iconicity*—a (metalinguistic) strategy that aligns form and meaning (e.g., aligns multiple objects with multiple X parts)? Additional aspects of the findings speak against this interpretation. In particular, doubling preferences to *signs* were modulated by the morphological structure of participants' *spoken* language—English vs. Hebrew. English speakers preferred XX signs only when reduplication signaled morphological plurality (e.g., one ball vs. multiple balls); Hebrew speakers did the same only when reduplication signaled morphological diminution (a large ball vs. a diminutive one). As explained below (in Section 3.1), these conflicting preferences for signs directly reflect the distinct morphological structure of these two spoken languages. For now, the critical point is that the association between form and meaning is not uniform (as would be expected by iconicity) but rather variable, and dependent on morphological experience.

Since a single linguistic form elicits conflicting preferences, participants must invoke abstract linguistic principles. And since these principles apply across modalities and depend on linguistic experience, they must be further amodal and linguistic in origin.

Our present research further tests this hypothesis. Experiments 1–4 first replicate the doubling preference using a new set of novel English words. Experiments 5–9 next demonstrate that speakers extend these preferences to signs. To examine whether the projections to signs depend on the morphological structure of spoken language, we contrast speakers of two additional morphologies—Malayalam vs. Mandarin Chinese.

2. Unimodal projection: Experiments 1–3 (Novel English words)

Experiments 1–3 examine doubling preferences in spoken language. In each trial, participants (native English speakers) made a forced choice between two novel English words that contrasted on the presence of doubling (e.g., *trafraf* vs. *trafmak*).

Experiment 1 examined isolated words, whereas Experiment 3b presented the same forms as morphological plurals. To this end, we followed a two-step procedure. First, people were presented with the base (e.g., *traf*), paired with a picture of a novel object (e.g., a ball-like object). They next saw a *homogeneous* set of objects of the same kind (e.g., several identical balls) and were asked to choose a name for these objects (e.g., *trafraf/traflam*).

To elucidate the basis of this shift, Experiments 2–3a introduced two critical controls. To ensure that the distinct outcomes of Experiments 1 vs. 3b are due to the encoding of morphological plurality (i.e., as form-meaning link), rather than the object set itself, Experiments 2a–2b also paired the same words with object sets (either homogeneous or heterogeneous), but the presentation of the base (in step 1) was eliminated. To demonstrate that the base-set pairing is not sufficient to elicit a doubling preference either, Experiment 3a repeated the same rating procedure, except that now, doubling was paired with a *heterogeneous* set of objects—a condition that is inconsistent with semantic plurality of the base (Fig. 2).[1]

We expect that, in the absence of explicit form-meaning links (in Experiment 1), English speakers will parse doubling as bare phonological forms, and consequently, they

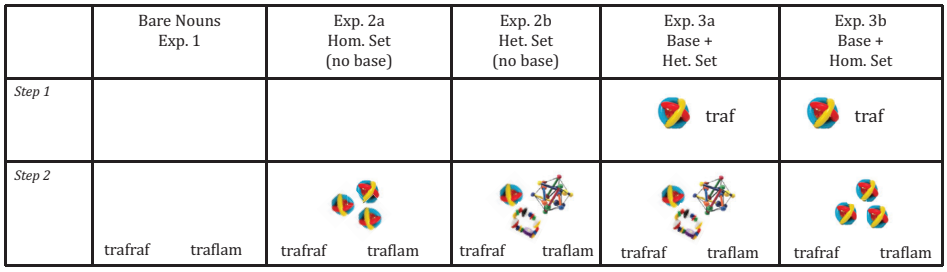


Fig. 2. An illustration of the procedure in Experiments 1–3 (Ball photo credit: FreeDigitalPhotos.net; image creators: Suat Eman; images of the other objects are licensed under Creative Commons [modified]).

should exhibit a doubling aversion. Critically, once the morphological link to the base is established (in Experiment 3b), the doubling dislike should shift to a preference. No doubling preference is expected in the control conditions (Experiments 2–3a).

2.1. Methods

2.1.1. Participants

Experiments 1–3 included three groups of participants; Experiments 1–2 were assigned 24 participants each; Experiment 3 (divided into two blocks) included 24 participants per block. Participants were native English speakers, recruited through Amazon Mechanical Turk. Attention to the task was gauged through attention checks (e.g., "press on the right key"), and participants were excluded if their error rate exceeded 20%.

2.1.2. Materials

The materials consisted of 30 pairs of novel English nouns—either with doubling or no doubling controls (e.g., *trafraf* vs. *traflam*, see Appendix A). Pair members shared the same CCVC base, and they each exhibited a phonotactically legal CCVC.CVC structure. Each trial presented the two pair members (with order counterbalanced) for a forced choice.

In Experiment 1, these words were presented with no further context (i.e., bare nouns); Experiment 2–3 paired the same words with a set of objects. In Experiment 2a, these objects were of a single kind (e.g., multiple balls, i.e., a *homogeneous set*); in Experiments 2b–3a, the objects were of different kinds (e.g., a ball, a pacifier, and a rattle, i.e., a *heterogeneous set*). Participants were asked to determine which form (e.g., *trafraf* or *trafmat*) forms a better name for the set.

Experiment 3a–3b elicited the same choice, except that prior to choosing the name for the object set, people were presented with the base. Thus, participants were first presented the base (e.g., *traf*) paired with a single object. They next saw a set of objects (either homogeneous, or heterogeneous, in Experiments 3a–3b, respectively), followed by a word pair, and were asked to choose which word presents a better name for the object. The

homogeneous and heterogeneous conditions in Experiments 2a–2b and 3a–3b were presented together, in a mixed order. To combat fatigue, Experiments 3a-b was divided into counterbalanced blocks of trials, assigned to two distinct groups of participants. Trial order in all experiments was randomized.

2.2. Results and discussion

In this and all subsequent experiments, we inspected the data for outliers (participants whose mean fell over 2.5 *SD* from the group mean). Two participants were eliminated from Experiments 3.

Fig. 3 presents the proportion of doubling responses. In this and all subsequent experiments, scatter plots present the doubling responses of individual participants, columns indicate the means, and chance level (0.5) is marked by the dashed line. Statistical analyses tested the proportion of doubling responses against chance (0.5) by means of mixed-effects logistic regression models. These models compare the intercept against 0 (chance, in log odds) using participants and item-pairs as random effects.

To determine whether responses to plural sets (in Experiments 3a–3b) were further modulated by the semantic properties of the set, a second model contrasted responses to homogeneous and heterogenous sets (with random intercepts by subject and items, and random slopes for trait type by subjects and items). Statistical results are provided in Table 1.

Results showed that doubling was systematically avoided in bare phonological forms (in Experiment 1). A similar doubling aversion obtained when the words were paired with object sets (with no base, in Experiments 2a–2b). The introduction of the base (in Experiment 3a) likewise elicited no reliable doubling preference when the object set was heterogeneous. But once a licit form-pairing link was established, and reduplication was paired with a homogeneous set (in Experiment 3b), the doubling aversion shifted into a systematic preference. The contrast between responses to licit and illicit plurals (in Experiments

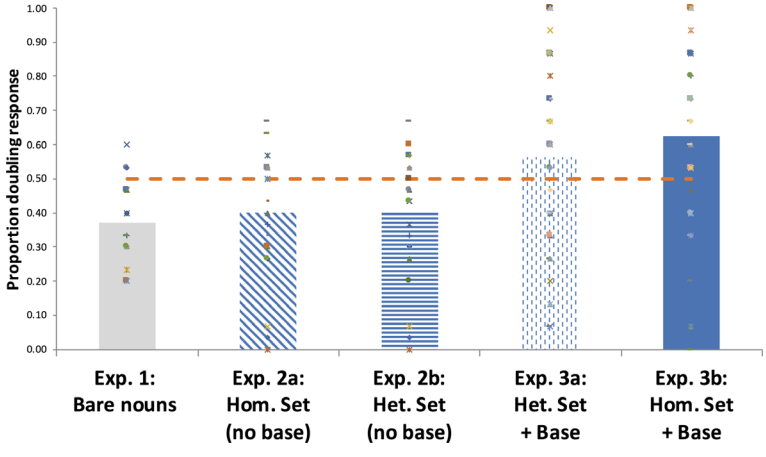


Fig. 3. Doubling preference for novel words.

Table 1
Doubling preferences for novel words

Exp.	Condition	Description	Mean	Intercept	*SE*	*Z*	*p*
1	Bare nouns	Words only (print)	0.37	−0.60	0.16	3.7	.0002
2a	Illicit plurals	Hom. Set (no base)	0.40	−0.56	0.26	2.2	.03
2b		Het. Set (no base)	0.40	−0.53	0.23	2.3	.02
3a		Base + Het. Set	0.56	0.38	0.23	1.6	.11
3b	Licit plurals	Base + Hom. Set	0.62	0.78	0.27	2.9	.004
3a–b	Licit vs. illicit plurals			0.89	0.47	1.89	.06

3a and 3b) was marginally significant. Together, these results suggest that doubling can be assigned two different parses, depending on the level of analysis—phonology vs. morphology.[2]

3. Cross-modal projections

The results of Experiments 1–3 demonstrate that doubling preferences dissociate from idiosyncratic properties of the stimulus (its frequency and its sensorimotor demands), as a single stimulus (whose statistical and sensorimotor demands are invariant) can elicit *conflicting* responses—aversion vs. preference.

Experiments 4–9 investigate the complementary dissociation, namely, whether doubling preferences can remain *invariant* despite radical changes to the stimulus modality—from speech to sign. At stake, then, is whether speakers can spontaneously project grammatical principles from their spoken language to ASL signs.

The possibility that knowledge of language transfers across modalities is in line with several studies. The pioneering research of Rachel Mayberry and her colleagues has shown that language experience with a sign language facilitates the acquisition of spoken language (Hall, Ferreira, & Mayberry, 2012; Mayberry, Lock, & Kazmi, 2002). Another study has shown that speakers spontaneously constrain the semantic interpretation of signs (specifically, their telicity, Strickland et al., 2015). These results, however, do not directly establish whether cross-modal transfer is due to the projection of grammatical principles, specifically. Indeed, early exposure to a sign language (in Hall et al., 2012; Mayberry et al., 2002) can offer social and cognitive benefits, and the constraints on the interpretation of signs (Strickland et al., 2015) could be explained not by grammatical principles but by iconicity. The case of doubling allows us to address the role of grammatical transfer specifically.

Like spoken languages, reduplication is frequent in ASL (Wilbur, 2009), and signers freely generalize it to novel forms (Andan, Bat-El, Brentari, & Berent, 2018; Berent, Dupuis, & Brentari, 2014). In past research, we have demonstrated that speakers with no command of a sign language systematically constrain the reduplicative structure of signs (Berent et al., 2016). We thus begin by reviewing our previous evidence for cross modal projection. Next, we present a formal analysis that proposes principled constraints on

such projection. Finally, we test our formal proposal by contrasting cross-modal projections by speakers of two additional morphologically distinct languages: Malayalam and Mandarin.

3.1. Cross modal projection: English versus Hebrew speakers

Our past research has asked whether speakers spontaneously project the grammatical restrictions on doubling to an unfamiliar language modality. In the experiments, participants were presented with a pair of novel disyllabic ASL signs—either ones with two identical syllables (XX) or with non-identical syllables (XY). Their task was to indicate which form (XX and XY) is more likely to present a better sign in ASL. One condition presented the signs as bare phonological forms. Another condition made it clear that doubling signals a morphological operation—either plurality or diminution. In both cases, people first saw the base sign (X) paired with a single object and asked to choose among the matched XX and XY signs. The plurality condition paired these options with a group of identical objects; in the diminutive condition, the options were paired with a diminutive version of the base (see Fig. 4).

Results showed that the phonological condition yielded a doubling aversion (XX < XY), in line with responses to spoken words. But once doubling signaled morphological reduplication, a reliable doubling preference emerged. Moreover, the doubling preferences for signs were modulated by the morphological structure of participants' spoken language—English vs. Hebrew (see Fig. 4c). English speakers extended the doubling preference to plurals, but not to diminutives; Hebrew speakers showed the opposite—a doubling preference for diminutives, but not for plurals.

We attribute the contrasting preferences to signs to the different morphologies of participants' spoken language. In particular, the English morphology expresses plurals productively (using suffixation), and it also has a semi-productive diminutive suffix (e.g., *doggy*, *booklet*). English, however, clearly does not express semantic diminution by reduplication. While English morphology shows some limited use of reduplication to expresses dismissal (e.g., *reduplication shmeduplicaon*, Nevins & Vaux, 2003) intensification (bye-bye) and echo formation (*ding-dong*), reduplication never indicates semantic diminution or attenuation.

Hebrew, on the other hand, does have productive reduplicative nominal morphology (e.g., *klavlav* "puppy" from *kelev* "dog"; *gvarvar* "a teenager, a man-wannabe" from *gever* "man"), and reduplication invariably expresses diminution. As we show below, the different responses to signs can be explained by the distinct morphological structures of these two spoken languages.

3.2. The formal conditions on cross-modal projection

We propose that speakers can project at least some of the grammatical constraints from their spoken language to signs. When signs are presented as bare phonological forms in a new language modality, doubling will be interpreted as phonological identity (which violates the OCP), so XX signs will be dispreferred; if the same form acquires a morphological parse, then

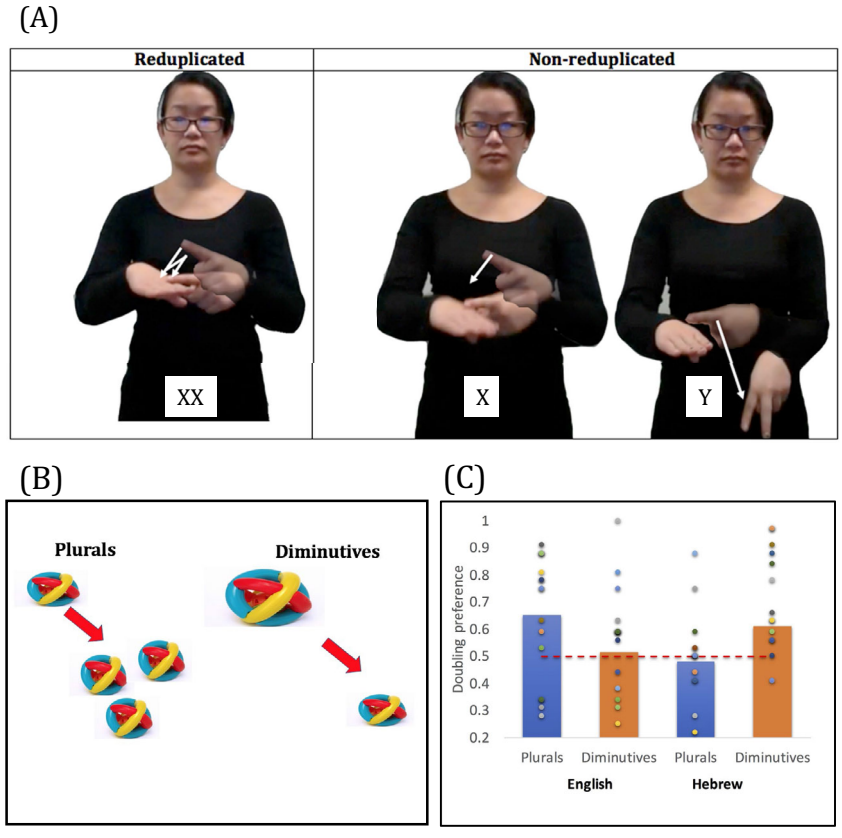


Fig. 4. Doubling projections to signs. (A) presents an example of novel XX and XY signs. (B) illustrates the plural and diminutive conditions (Ball photo credit: FreeDigitalPhotos.net; image creators: Suat Eman). (C) presents the doubling preference of English and Hebrew speakers for Plurals and Diminutives (data from Berent et al., 2016; Images licensed under Creative Commons Attribution License.)

doubling will be preferred (XX > XY). Our main goal here is to outline the formal conditions promoting the projection of a reduplicative parse in the morphological condition.

We suggest that the assignment of a reduplicative parse will depend on two factors. One is the semantics of reduplication (plurality vs. diminution); another is the morphological system of participants' spoken language.

We assume that augmentation (e.g., semantic plurality) is the unmarked semantic interpretation of reduplication (Kajitani, 2005; Urbanczyk, 2017; Uspensky, 1972), so the conditions on the projection of a reduplicative parse to plurals are relatively lax—all that speakers need is *some* evidence that plurality can be expressed morphologically on the relevant lexical category (here, nouns; the preferred lexical category associated with objects). English presents the relevant evidence, as it has a productive nominal inflection (by a suffix), so English speakers freely project the reduplicative parse to nominal plurals.

Diminution, by contrast, is the marked semantic value for reduplication. So when people come to consider the projection of a reduplicative parse to diminutives, the conditions

are far more stringent. Merely having evidence that their native morphology marks diminution will not suffice. Instead, the morphology must express diminution on the relevant lexical category, and it must do so by reduplication, specifically.

English morphology clearly has no reduplicative diminution, so English speakers are unable to project reduplication to diminutives. Hebrew, on the other hand, does express nominal diminution productively, by reduplication (e.g., *kelev* "dog" → *klavlav* "puppy"), so Hebrew speakers can freely project diminution to signs. Our analysis thus explains why English and Hebrew speakers project reduplication to plurals and nominal diminutives, respectively.

One question, however, is left unanswered: why do Hebrew speakers avoid the projection of reduplication to plurals? Like English, Hebrew has productive nominal inflection (by affixation), so one would expect Hebrew speakers to freely project reduplication to plurals, which they clearly do not. Our analysis attributes this finding to the fact that reduplication in Hebrew marks diminutives. Specifically, we propose that if a language has a reduplicative morphology denoting a particular semantic value, the speakers of this language will block the projection of a reduplicative parse for the opposite semantic value. Since Hebrew has reduplicative diminution, and since diminution is semantically opposite to plurality, Hebrew speakers do not project reduplication to plurals (even though Hebrew has a productive plural suffix).

This analysis correctly predicts that Hebrew speakers assign a morphological parse for nominal diminutives, but not plurals, whereas English speakers project reduplication to the unmarked plurals, but not diminutives. The formal conditions are on cross-modal projections are summarized in below (2).

(2) *Constraints on the cross-modal projection of a reduplicative parse*

A speaker of language L is presented with a surface form XX associated with a lexical category LCi (e.g., noun) and a semantic property S. When presented with XX in a new language modality, the speaker will assign XX a morphological parse (i.e., reduplication) if one of the following conditions applies:

A. *L uses reduplication to mark LCi for S, but not for ~S; otherwise*
B. *S is the unmarked value of XX and L marks LCi for S by the morphology (e.g. by reduplication, affixation)*

4. Cross modal projections by Malyalam and Mandarin speakers: Experiments 4–9 (Novel signs)

The discussion so far opens up the possibility that speakers can extend at least some grammatical principles from their spoken language to linguistic signs, and this proposal is supported by the results from English and Hebrew. To further investigate this hypothesis, here we extend our investigation to another pair of contrasting morphological systems—

those of Malayalam vs. Mandarin Chinese. These two morphologies are of interest because they contrast from each other in systematic ways, and they also differ from the English and Hebrew morphologies in our previous studies.

4.1. Malayalam and Mandarin morphology

Malayalam marks nouns for plurality (Asher & Kumari, 1997; Jiang, 2010), either via suffixation (e.g. *aaLu-kaL* "persons") or reduplication (e.g. *urang-ura-ppe* "continuous sleep"), where reduplication is used for augmentation across lexical categories (e.g., *vee-gam-veegam* "faster and faster"). Diminution, by contrast, is typically marked by compounding (e.g., paSu "cow" + *kuTTi* "child" → paSu-kkuTTi "calf"; peNNu "woman" + *kuTTi* "child" → peN-kuTTi "adolescent woman").

Malayalam thus presents its speakers with positive evidence that nouns can be morphological marked for plurality (per condition 2A). When it comes to diminution, however, this language provides no evidence for the projection reduplication to diminutives (per Condition 2B); while Malayalam can mark diminution (via compounding, Asher & Kumari, 1997), it does not do so by reduplication. Our analysis thus predicts that Malayalam speakers should project reduplication to plurals, but not to diminutives.

Mandarin Chinese, by contrast, lacks productive plural morphology (i.e., in violation of Condition 2A; Li & Thompson, 1981); while some nouns can be reduplicated (e.g. [ren2-ren2] "person-person (every person)," [tian1-tian1] "day-day (every day)"), this process is not fully productive. Mandarin speakers, then, are devoid of the evidence necessary to project reduplication to either nominal plurals or diminutives.

As such, Mandarin and Malayalam complement our previous comparison of English and Hebrew (see Table 2). English has productive plural inflectional morphology, whereas Mandarin does not; Hebrew has reduplicative diminution, whereas Malayalam has reduplicative augmentation. Our experiments examine whether the contrastive morphological structure of Malayalam and Chinese constrains the interpretation of XX signs. Experiments 4–6 were administered to Malayalam speakers; Experiments 7–9 administered the same manipulations to speakers of Mandarin.

Table 2
Productive inflectional morphology of spoken language (plural vs. diminutive) and the projected parse to signs

	L1 Morphology (spoken)		
Language	Plural	Diminutive	Semantic Conditions for the Projection of a Reduplicative Parse for Signs
English	+	−	$\text{Plural}_{(B)}$
Hebrew	+	R+	$\text{Diminutive}_{(A)}$
Malayalam	R+	−	$\text{Plural}_{(A\&B)}$
Mandarin	−	−	None_{B}

Note: +/− indicates the presence/absence of the morphological operation in the language; R indicates its expression by reduplication, specifically. A and B refer to the constraints on reduplication (per (2)).

4.2. Malayalam versus Mandarin

The primary goal of Experiments 4–9 is to gauge the effect of participants' spoken morphology on the projection of morphological reduplication to signs. But before turning to morphological reduplication, we first sought to re-establish that, in the absence of morphological context, phonological doubling in signs is disliked, akin to the aversion of phonological doubling in spoken language. To this end, Experiment 4 first asked Malayalam speakers to make a forced choice between XX/XY signs presented in isolation; Experiment 7 administered the same manipulation to Mandarin participants.

Experiments 5–6 next presented Malayalam speakers with the same signs in a morphological context, suggestive of either plurality or diminution. Experiments 5a–6a presented doubling in a *licit* semantic context (i.e., one that paired the base X and XX signs with a homogeneous set of objects of the same kind)—either as plurals or as diminutives (in Experiments 5a vs. 6a, respectively). As a further check that the choice is guided by the morphological analysis of the base, Experiments 5b–6b paired the same XX signs and their base (X) with objects of different kinds, such that a morphological analysis was now *illicit*. Experiments 8–9 administered the same morphological manipulations to speakers of Mandarin Chinese.

If speakers transfer grammatical knowledge cross-modally, then Malayalam and Mandarin speakers should exhibit different preferences for ASL signs. Malayalam speakers should only project the reduplicative parse to plurals, and consequently, they should prefer XX signs presented as plurals, but not as diminutives. In contrast, Mandarin speakers should show no doubling preference for either plurals or diminutives. Finally, both groups should exhibit doubling aversion when doubling indicates phonological identity (for bare signs).

4.3. Methods

4.3.1. Participants

Participants in Experiments 4–9 comprised of six groups ($N = 24$ participants per group), either native speakers of Malayalam (in Experiments 4–6) or Mandarin (in Experiments 7–9). Mandarin speakers were tested at Northeastern University. Malayalam speakers were recruited through Amazon Mechanical Turk. Participants were queried about their linguistic experience; no participants reported a command of a sign language.

4.3.2. Materials

The materials were the 32 pairs of novel disyllabic XX/XY ASL signs from Berent et al. (2016). XX signs featured two identical syllables; the matched XY signs paired the same X syllable with another syllable Y, which contrasted with the X syllable on its movement and handshape. All signs were phonotactically legal, and they were recorded by a native ASL signer. The list of all items is provided in Supplementary Materials.

Each experiment elicited a forced choice between the pair member (XX/XY), counterbalanced for order (left vs. right). Experiments 4 and 7 featured isolated signs; participants were instructed to choose which sign would be a better sign in ASL. Experiments 5–6 and 8–9 paired the signs with objects, such that doubling signaled either a plural or a diminutive, respectively. Participants indicated which sign makes a better name for the object in ASL. In the licit condition, the base X and disyllable XX/XY were paired with the object of the same kind; in the illicit condition, the objects were of different kinds. The licit or illicit conditions were presented in a mixed randomized list.

The instructions for each group were presented in its native language. In the "no object condition," people were told that "In this experiment, you will see novel signs in ASL. These signs are not currently used in that language, but we believe they are possible ASL signs. In each trial, you will be presented with two such novel signs. Your task is to determine which sign would be a better sign in ASL. Please indicate your response by clicking on the bubble below that sign." People were further told, "we realize that you are not familiar with ASL, but please just go with your gut feeling."

Instructions to the plural/diminutive conditions were similar. Here, however, people were told that they would first see a novel object along with its name in ASL, followed by another object/group of objects, related to the initial object you observed, along with two names for this object/group of objects in ASL.

To situate the research at a broader context, people were further told that "Human beings form language in different ways. Most people use speech, whereas Deaf people often use sign languages. Research shows that sign languages are very different from pantomimes, so if you do not know a sign language, you probably will not be able to comprehend the signer (just as speakers of Malayalam/Mandarin cannot comprehend French). This research examines whether Malayalam/Mandarin speakers can nonetheless discern some of the meaning of a sign language."

4.4. Results and discussion

As in previous experiments, we removed outliers (participants whose mean response fell over 2.5 *SD* beyond the group mean) from the analysis. This resulted in the elimination of one speaker of Malayalam (in Experiment 5) and two speakers of Mandarin (one in Experiments 7–8, each). Fig. 5 presents the doubling preferences of Malayalam and Mandarin speakers to signs; the results of statistical tests are presented in Table 3.

4.4.1. Malayalam speakers

When presented with signs alone (i.e., bare phonological forms, in Experiment 4, see Fig. 5), Malayalam speakers exhibited a reliable doubling aversion, akin to the responses of English speakers to bare words (Experiment 1) and to signs (Berent et al., 2016). These results suggest that Malayalam speakers spontaneously project phonological identity to signs; signs with identical syllables are systematically dispreferred.

Remarkably, once doubling was presented as a licit morphological operation of plurality (in Experiment 5a)—the doubling dislike shifted into a reliable preference. As expected, no such preference emerged for licit diminutives (in Experiment 6a). Similarly,

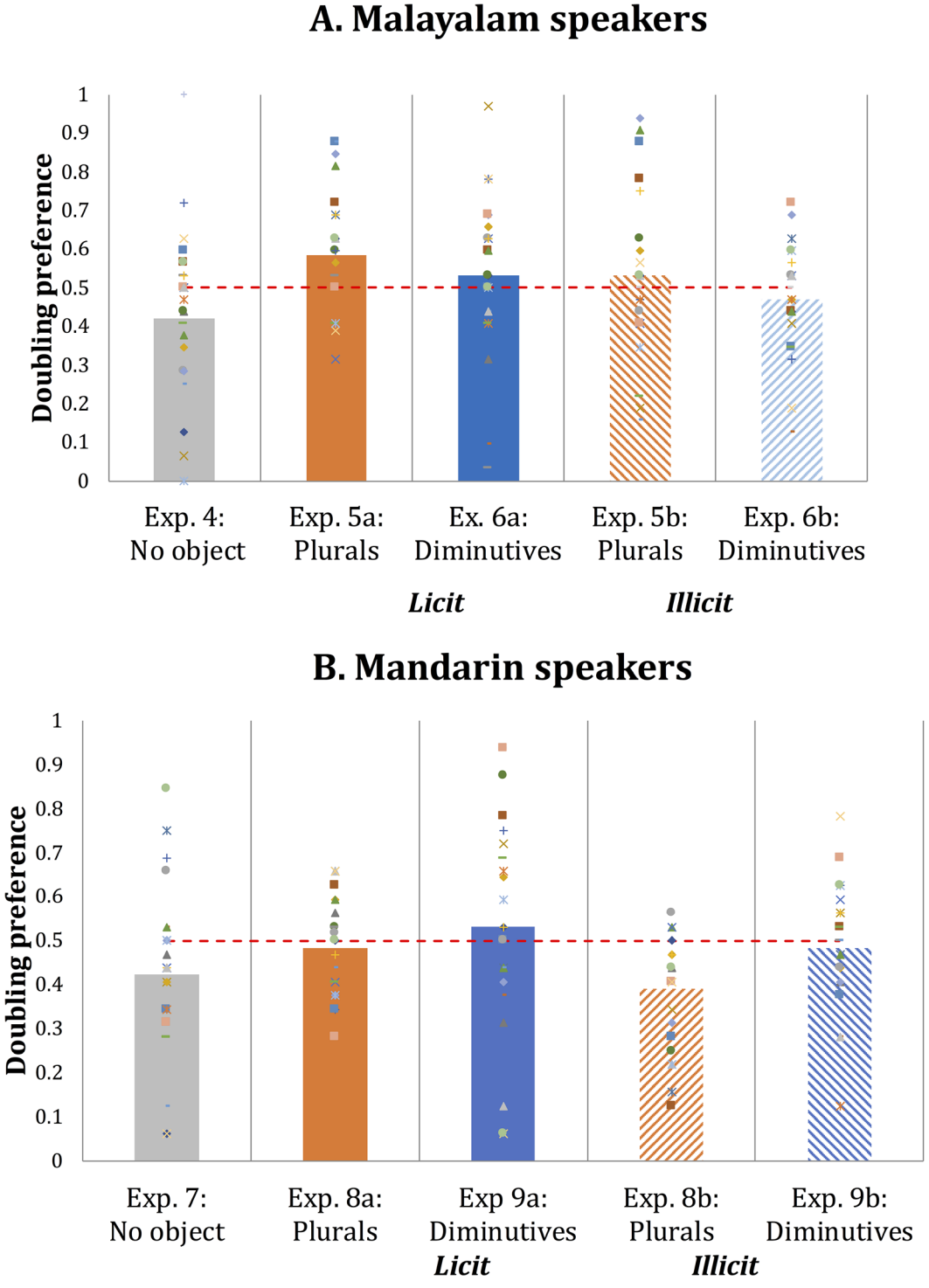


Fig. 5. Doubling preferences to signs by Malayalam and Mandarin speakers.

Table 3
Doubling projections of Malayalam and Mandarin speakers to signs

Exp.	Condition	Description	Mean	Intercept	*SE*	*Z*	*p*
Malayalam							
4	No Object	Signs only	0.42	−0.39	0.19	−2.11	.03
5a	Pluras Licit	Base + Homogeneous. set	0.58	0.41	0.19	2.12	.03
5b	Plurals Illicit	Base + Heterogenous. set	0.53	0.17	0.24	0.69	.49
5a vs. 5b	Plurals: licit vs. illicit			0.27	0.11	2.33	0.02
6a	Diminutives Licit	Base + dimn. Object (same kind)	0.53	0.13	0.23	0.55	.58
6b	Diminutives Illicit	Base + dimn (different kinds)	0.47	−0.13	0.13	−0.99	.32
6a vs. 6b	Diminutives: Licit vs. illicit			0.26	0.15	1.71	0.09
Mandarin							
7	No Object	Signs only	0.42	−0.38	0.21	1.81	.07
8a	Pluras Licit	Base + Homogeneous. set	0.48	0.07	0.11	−0.66	.51
8b	Plurals Illicit	Base + Heterogenous. set	0.39	−0.48	0.14	−3.39	.0007
8a vs. 8b	Plurals: licit vs. illicit			0.39	0.12	3.29	0.001
9a	Diminutives Licit	Base + dimn. Object (same kind)	0.53	0.16	0.30	0.54	.59
9b	Diminutives Illicit	Base + dimn (different kinds)	0.48	−0.08	0.15	−0.52	0.60
9a vs. 9b	Diminutives: Licit vs. illicit			0.22	0.14	1.58	0.11

illicit morphological operations (in Experiments 5b & 6b) elicited no doubling preference. Responses to the licit and illicit morphological conditions further differed significantly for plurals (in Experiments 5a vs. 5b), but not for diminutives (in Experiments 6a vs. 6b).

We suggest that the projection of a reduplicative parse to signs is informed by knowledge of participants' spoken language. The projection of plurality (the unmarked reduplicative semantics) merely requires that the language exhibits some form of morphological plurality, whereas diminution (the marked reduplicative semantics) further requires that evidence from diminutive reduplicants, specifically (see (2)). Since, in Malayalam, morphological reduplication only expresses augmentation (not diminution), Malayalam speakers only projected the reduplicative parse to licit plurals, but failed to do so for diminutives. As for Mandarin speakers, they do not assign any morphological parse to XX, due to the absence of plural or diminutive morphology in their spoken language (per condition B).

It is possible, however, that the doubling preference for plurals is based not on morphological knowledge but on metalinguistic strategy; perhaps people simply prefer to link signs with multiple identical parts to plural sets, a constraint that could be due to iconicity. This interpretation, however, is countered by the failure of Hebrew speakers to project reduplication to plurals. Mandarin presents another opportunity to dissociate the grammatical and metalinguistic strategy. If the doubling preference for plurals is based

on a nonlinguistic strategy, then like English and Malayalam speakers, Mandarin participants should exhibit robust doubling preferences for semantic plurals. The grammatical account in, by contrast, predicts no doubling preferences for speakers of Mandarin Chinese—a language in which nouns take neither plurals nor diminutive reduplication.

4.4.2. Mandarin speakers

Results (see Fig. 5; Table 3) are in line with this grammatical prediction. Mandarin speakers exhibited no doubling preferences for licit reduplicative forms—either plurals or diminutives (in Experiments 8a–9a, respectively). Likewise, illicit diminutives (i.e., small objects of a different kind, in Experiment 9b) elicited no reliable preference, and responses to illicit and licit diminutives (in Experiments 9a vs. 9b) did not differ significantly. In fact, illicit plurals (in Experiment 8b) elicited a reliable doubling aversion, results that differed significantly from responses to licit plurals (in Experiments 5a vs. 5b). And in line with all other speakers (of English, Hebrew, and Malayalam), when presented with bare signs, Mandarin speakers showed a marginally significant doubling aversion (in Experiment 7).

The aversion of bare signs and illicit doubling confirms that Chinese speakers were tuned to the structure of signs. Nonetheless, unlike speakers of English and Malayalam (and similar to Hebrew speakers), Chinese speakers showed no preference for licit plurals. These results counter the metalinguistic/iconic account for the interpretation of XX signs. Instead, these results suggest that the parsing of XX signs is governed by linguistic principles, informed by spoken language morphology.

5. General discussion

This research asked whether linguistic preferences reflect solely idiosyncratic properties of the stimulus (its sensorimotor demands, familiarity, and iconicity) or whether some linguistic principles are abstract.

To address this question, we examined whether grammatical principles transfer across language modalities. In particular, we examined whether speakers spontaneously project grammatical principles from their spoken language to ASL signs.

Our case study exploits the structural ambiguity of doubling. Linguistic theory suggests that doubling (e.g., *trafraf*, generally, XX) can be associated with two conflicting parses, akin to ambiguous visual figures. At the phonological level, doubling is represented as phonological identity (XX), a parse that violates a ban on identical phonological elements. At the morphological level, however, doubling is parsed as reduplication ($\{X\}X_c$, with a single element at the base), a parse that is better-formed than non-reduplication, either the morphologically complex {X}Y or simple XY, where in both there is additional phonological material (Y).

Our results with novel English words are consistent with this analysis. Experiment 1 found that when people are presented with bare phonological forms, doubling (i.e., phonological identity) is systematically disliked (e.g., *trafraf* < *trafmat)*. But once

doubling is presented as morphological plurality (i.e., as reduplication, in Experiment 3b), the doubling aversion shifts into a reliable preference (e.g., *trafraf* > *trafmat*). No doubling preference was found for illicit or ambiguous plurals (i.e., heterogeneous sets, or sets that were not paired with a base, in Experiments 2–3a). The finding that a single form elicits such conflicting responses demonstrates that linguistic preferences dissociate from the sensorimotor and statistical properties of the stimulus.

Experiments 4–9 next demonstrate the opposite dissociation. Here, we show that speakers with no command of a sign language extend the same principles to speech and to *signs*. Thus, speech and signs elicit the same responses despite marked differences in familiarity and sensorimotor characteristics.

Consider, for example, the results from speakers of Malayalam. When presented with isolated XX signs, Malayalam speakers exhibited a reliable doubling aversion (XX < XY)—a result that mirrors the doubling aversion of spoken phonological forms (in Experiment 1). But once the doubling was interpretable as a licit morphological operation (i.e., when the base X and the form XX were associated with objects of the same kind), the doubling dislike shifted into a reliable preference (XX > XY); no shift occurred when this morphological parse was semantically illicit (i.e., when the base X and the plural XX were associated with objects of different kinds).

Remarkably, the doubling preferences for signs were systematically constrained by the morphological structure of participants' *spoken* language. This conclusion was supported by the conflicting responses to signs, observed among speakers of Malayalam and Mandarin Chinese. Unlike Malayalam speakers, Mandarin participants did not extend a doubling preference to licit plurals (in Experiment 8a). This is not because the Mandarin participants were invariably insensitive to the structure of signs. Indeed, when the signs suggested phonological identity (in the absence of context, or because plurality was illicit, in Experiment 7 & 8b), Mandarin speakers showed a reliable doubling aversion. It is also unlikely that the response of Mandarin speakers to licit plurals simply reflects a type II error: a replication of Experiment 8 with another sample ($N = 23$) yielded the same results; the mean doubling preference for licit plurals ($M = 0.51$) did not reliably differ from chance ($Z < 1$).

The contrast between the responses of Chinese speakers to signs and those of English and Malayalam speakers suggests that doubling preferences for plurals cannot be due to iconicity. Similarly, this divergence speaks against the possibility that the responses of Mandarin speakers are due to their familiarity with English as a second language; had this been the case, one would have expected Mandarin and English speakers to converge on the same preferences, contrary to our findings.

We suggest that these conflicting responses to signs are due to the morphology of participants' spoken language. While the Malayalam morphology uses reduplication to mark nouns for plurality, Mandarin has no productive plural morphology. Accordingly, Malayalam (but not Mandarin) presents its speakers with the evidence necessary to extend a reduplicative parse to plurals. The conflicting projections of Malayalam and Mandarin speakers to signs complement our previous findings from English (which supports only the plural, but not diminutive analysis) and Hebrew (with the complementary pattern). The preferences of these speakers matched their respective morphologies and, as

expected, differed from those in our present studies. Together, then, these results demonstrate that the representation of signs was spontaneously constrained by grammatical knowledge of spoken language.

How can speakers extend grammatical principles from their spoken language to signs? We suggest that such cross-modal projections are possible because at least some grammatical principles are encoded algebraically. For example, if the ban on identical phonological elements (the Obligatory Contour Principle) is represented as *XX (where X is any prosodic constituent), then this ban will apply whenever identical prosodic constituents are presented irrespective of stimulus modality. By the same token, if morphological reduplication is encoded formally, as a correspondence between two constituents (the base and the copy), then this formal relation can be also be projected to prosodic constituents in signs.

Our past research has indeed shown that English speakers can spontaneously identify at least one such constituent—the syllable—from signs (Berent, Dupuis, & Brentari, 2013). Like spoken syllables, signed syllables are marked by peaks of phonetic energy (specifically, by movement). Accordingly, speakers are presented with salient phonetic cues that allow them to parse signs into identical syllabic constituents, and once those constituents are extracted, speakers can potentially determine the identity of these constituents and their correspondence. Whether these linguistic phonetic cues are further *necessary* for the projection of a grammatical parse, or whether speakers would project grammatical principles even to stimuli that are clearly nonlinguistic is unknown. Future research is necessary to address this question.

At yet a broader level, our results demonstrate that the representations that are projected to linguistic stimuli doubly dissociate from their sensorimotor demands, their iconicity and familiarity. A single form in a spoken language can elicit conflicting responses, whereas isomorphic phonological forms in two distinct modalities (speech and sign) can be treated alike. This double dissociation suggests that some linguistic constraints concern neither speech nor sign. Rather, these are abstract algebraic principles that operate across the board, irrespective of stimulus modality.

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Notes

1. One could, of course, label a heterogeneous set by referring to a *superordinate* conceptual level (e.g., *ball* + *rattle* → *toys*), but these plurals use a different base (e.g., *toys* isn't the plural of *ball*). Thus, if X stands for a member of a heterogeneous set, then this set cannot be referenced by a morphological form that takes X as its base (e.g., XX, or X + suffix).

2. An inspection of the items suggests that four of our bases resembled existing English words (*smol*, *tram*, *gran* and *blat*). To ensure that our conclusions are not skewed by this handful of items, we repeated the analyses after removing those four pairs. The results remained unchanged. Specifically, bare nouns elicited a reliable doubling aversion ($M = 0.38$, $\beta_0 = -0.57$, $Z = -3.43$, $SE = 0.16$, $p = .0007$), whereas the licit plural condition elicited a reliable doubling preference ($M = 0.62$, $\beta_0 = 0.71$, $Z = 2.67$, $SE = 0.26$, $p = .007$). As expected, no doubling preference obtained in the illicit plural conditions. In fact, the heterogeneous (no base) ($M = 0.41$, $\beta_0 = -0.52$, $Z = -2.08$, $SE = 0.25$, $p = .04$) and homogeneous (no base) conditions ($M = 0.39$, $\beta_0 = -0.58$, $Z = -2.25$, $SE = 0.26$, $p = 0.03$) each elicited a reliable doubling aversion; the same trend was marginally significant for the heterogeneous plural condition as well ($M = 0.57$, $\beta_0 = 0.40$, $Z = 1.73$, $SE = 0.24$, $p = .08$).

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Appendix S1: The novel signs used in Experiments 4–9.

Appendix A:

Pair	Base	Word 1 (doubling)	Word 2 (no doubling)
1	traf	trafraf	traflam
2	snog	snognog	snogmot
3	tros	trosros	trosnot
4	gref	grefref	greflek
5	smol	smolmol	smolrog
6	slan	slanlan	slanmot
7	plon	plonlon	plonmuk
8	drak	drakrak	draknad
9	klop	kloplop	klopnosh
10	tram	tramram	tramlut
11	stim	stimtim	stimkam
12	flon	flonlon	flonmog
13	drof	drofrof	drofmok
14	slod	slodlod	slodmog
15	klen	klenlen	klenmof
16	blas	blaslas	blasnol
17	smat	smatmat	smatnod
18	trel	trelrel	trelnat
19	krav	kravrav	kravmal
20	praf	prafraf	praflak
21	grof	grofrof	grofnom
22	snad	snadnad	snadmak
23	plaf	plaflaf	plafnut
24	flak	flaklak	flakmal
25	blaf	blaflaf	blafron
26	fros	frosros	froslak
27	gran	granran	granlat
28	dran	dranran	dranlat
29	krag	kragrag	kragnel
30	blat	blatlat	blatnog