Speakers aren't blank slates* (*with respect to sign-language phonology)!

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Abstract

A large literature has gauged the linguistic knowledge of signers by comparing sign-processing by signers and non-signers. Underlying this approach is the assumption that non-signers are devoid of any relevant linguistic knowledge, and as such, they present appropriate non-linguistic controls—a recent paper by Meade et al. (2022) articulates this view explicitly. Our commentary revisits this position. Informed by recent findings from adults and infants, we argue that the phonological system is partly amodal. We show that hearing infants use a shared brain network to extract phonological rules from speech and sign. Moreover, adult speakers who are sign-naïve demonstrably project knowledge of their spoken L1 to signs. So, when it comes to sign-language phonology, speakers are not linguistic blank slates. Disregarding this possibility could systematically underestimate the linguistic knowledge of signers and obscure the nature of the language faculty.

The last decades have seen a surge of interest in sign language research[1] (for reviews: Brentari & Coppola, 2013; Brentari & Goldin-Meadow, 2017; Galván-Ruiz et al., 2020; Goldin-Meadow, 2017; Goldin-Meadow & Brentari, 2017; Lillo-Martin & Henner, 2021; Lillo-Martin & Gajewski, 2014; Ortega, 2017; Paul et al., 2020; Petitto et al., 2016b). Indeed, sign language research illuminates the linguistic capacities of Deaf people, and sheds light on the human language faculty, generally.

Sign language research, however, also raises some challenges. To determine what linguistic principles guide signers' responses to signs, one must sift the contribution of linguistic principles from nonlinguistic constraints. A large literature has done so by contrasting native signers with non-signer control participants, speakers of some aural language (e.g., Cardin et al., 2016; Emmorey, Xu, & Braun, 2011; MacSweeney et al., 2004; Petitto et al., 2000). But whether sign-naïve speakers are, indeed, the proper controls and why are critical questions that are rarely addressed. While the immediate problem is methodological, its roots run deep. At stake are two basic theoretical issues: what is knowledge of language, and who has it.

A recent paper by Meade et al., articulates these considerations explicitly. Using a form-priming methodology, Meade and colleagues seek to evaluate how signers encode ASL features (e.g., handshape)—whether they rely only on the visual system, or on linguistic knowledge. Following common practice in the field, Meade et al. proceed to contrast signers with nonsigner controls. The authors explain their decision. They note that "non-signers can perceive form-based similarity in ASL, but do not have any associated linguistic representations" (p. 8). Accordingly, "Comparing these priming effects between signers and non-signers allowed us to differentiate between the perceptual and linguistic components of sign recognition, with the former being shared between groups and the latter being unique to the signers, who possess a phonological system in the visual-manual modality" (p. 1).

The logic is crystal clear. When it comes to sign language phonology, non-signers are devoid of any relevant knowledge of language—linguistic blank slates, so to speak. Indeed, phonological principles are intimately tied to language modality (e.g., Caselli, Occhino, Artacho, Savakis, & Dye, 2022; Hayes, Kirchner, & Steriade, 2004; Sandler, 2018), and in some accounts, knowledge of language is *embodied* (e.g., Glenberg, Witt, & Metcalfe, 2013; Sandler, 2018). Since the aural/oral and visual/manual channels (of spoken- and signed phonologies) are so different, it seems safe to assume that phonological principles of spoken language have little relevance to signs. Accordingly, non-signers present appropriate "controls" for the linguistic knowledge of signers.

Given that Meade et al.'s specific study concerned sensitivity to ASL features (e.g., handshape, location)—primitives that, by definition, *are* modality-specific, their

[1] We use the term "sign language" (generically) to refer to linguistic competence, expressed in the manual linguistic modality; when referring to a *specific* sign language (e.g., American Sign Language) we use a determiner (a sign language).

methodological assumption is arguably justified here. Still, the principled question remains: is phonological knowledge, in fact, fully modality-specific?

The question, to be clear, is *not* simply whether spoken and sign languages share formal structures, nor is it whether speakers and signers rely on common brain region in extracting phonological structure in their *respective* language modalities. Indeed, many previous studies have found that spoken and sign language share aspects of their design (e.g., Brentari, 1993; Corina, 1990; Klima & Bellugi, 1979; Padden & Perlmutter, 1987; Sandler, 1993; Stokoe, 1960; Supalla & Newport, 1978), and identified brain regions that subserve phonological computations across modalities (e.g., Emmorey, McCullough, Mehta, & Grabowski, 2014; MacSweeney, Waters, Brammer, Woll, & Goswami, 2008; Petitto et al., 2000). But the finding that a speaker and signer each extract similar phonological structures using similar brain structures *in their* ***respective*** *language modality* (e.g., speech, for English speakers) does not speak to the question of whether they can also spontaneously do so in an *unfamiliar* modality. For example, can an English speaker extract some of the phonological structure of ASL signs? And would they be doing so by engaging the same regions deployed by a signer?

The logic carefully outlined by Meade and colleagues suggests that they wouldn't. We, however, believe that this logic ought to be reconsidered. Informed by recent empirical findings from adults (Berent, Bat-El, Andan, Brentari, & Vaknin-Nusbaum, 2021a; Berent, Bat-El, Brentari, Dupuis, & Vaknin-Nusbaum, 2016; Berent, Bat-El, Brentari, & Platt, 2020; Berent, Bat-El, & Vaknin-Nusbaum, 2017; Berent, Dupuis, & Brentari, 2014) and infants (Berent, de la Cruz-Pavía, Brentari, & Gervain, 2021b), we argue that the linguistic phonological knowledge of non-signers *is* relevant to the processing of signs. This relevance does not simply arise because sign language lacks phonological structure (as some might naïvely assume). On the contrary—it is precisely because signs are abstract, and phonologically structured, that some of speakers' knowledge of their *spoken* language can help them process signs. Phonology, then, is partly *amodal.*

This commentary briefly outlines the logic of *amodal phonology*, and, as a proof-of-principle, we also summarize some key findings in its support. In so doing, we do not wish to suggest that the question of amodal phonology is settled; our goal, instead, is to call attention to this possibility. We believe this view carries broad implications for what phonology is, and how it ought to be studied across multiple disciplines.

1. *Infants spontaneously extract rules from sign language*

It is commonplace to equate phonology with a specific linguistic channel—English phonology seems to be strictly "about" speech; ASL phonology concerns manual patterns. A large literature has indeed shown that phonology and its channel are intimately linked, as phonological processes often "conspire" to improve language perception and production; this is true for the phonologies of both speech (e.g., Hayes et al., 2004) and signs (Caselli et al., 2022; Sandler, 2018).

But there is also evidence that some (other) aspects of phonology are abstract, and shared across languages. Indeed, when people hear phonological patterns such as *bogugu* and *milolo*, they automatically extract abstract algebraic rules (here ABB) which they readily generalize to new forms (e.g., *wofefe*)—adults do so for their native language (e.g., in Semitic languages, where this rule applies Berent, Everett, & Shimron, 2001; Berent & Shimron, 1997; Frisch, Pierrehumbert, & Broe, 2004), and so do infants (Marcus, Vijayan, Bandi Rao, & Vishton, 1999), even newborns (Gervain, Berent, & Werker, 2012).

Repetition rules, such as ABB or AA, however, specify an abstract *relation*, namely identity, i.e., a relation that holds between any two syllables X and Y), and because this relation is algebraic (Berent, 2013; Marcus, 2001), it potentially holds regardless of whether the elements in question are spoken (e.g., *didi*, *momo*) or signed (e.g., , ). So, it stands to reason that, if the language system can extract these phonological rules in one linguistic modality (speech), then it can also do so in another (signs).

Recent research from our labs supports this conclusion (Berent et al., 2021b). In a brain imaging study using near-infrared spectroscopy (NIRS), we presented six-month-old infants who were sign-naïve with either two identical signed syllables (AA) or controls (AB, with two distinct syllables, Figure 1A), and observed their brain response. Not only did these infants readily extract this phonological rule from *signs*, but they did so by recruiting the linguistic network of their *spoken* language.

Three pieces of evidence support this conclusion. First, infants' brain responses to reduplicative signs (AA) differed reliably from their responses to controls (AB), suggesting that infants extracted the AA *rule* (Figure 1C). Second, the extraction of the reduplication rule recruited *linguistic*, rather than visual processing. To control for visual processing, we superimposed the spatiotemporal properties of the signs on nonlinguistic cartoons of a leaf, such that the leaf's shape and motion strictly matched the signer's hand (Figure 1B). Results showed that infants did extract the reduplication rule from both linguistic signs and visual controls, but the effect of the rule on the brain differed markedly in the two cases. In linguistic signs, reduplication triggered *stronger* activation (AA>AB), whereas in nonlinguistic cartoon stimuli, reduplication elicited *weaker* activation (AA<AB) relative to control sequences (Figure 1C). Third, infants' responses to the AA rule in signs were indistinguishable from newborns' response to a similar repetition rule in speech (Figure 1C, based on a reanalysis of Gervain, Berent, Dupoux, & Werker, 2012), and they activated a left-lateralized brain network that is known to underlie language processing in adults (e.g., Friederici, 2005; MacSweeney, Capek, Campbell, & Woll, 2008) and infants (e.g., Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002; Gervain, Macagno, Cogoi, Peña, & Mehler, 2008; Mercure et al., 2020; Peña et al., 2003). While the comparison between speech and sign ought to be interpreted with caution, as it obtains across different studies with different age groups (newborns vs. six-month-olds), the comparison is warranted by the fact that (a) the groups are arguably matched for their experience with the relevant linguistic modality; and (b) the data sets were re-analyzed to contrast the effect of reduplication, specifically. The early amodal tuning of human brains to language is also evident in the selective preference of six-month old hearing infants for signs (relative to pantomimes Krentz &

Corina, 2008) and their engagement in manual babbling (Petitto, Holowka, Sergio, & Ostry, 2001).

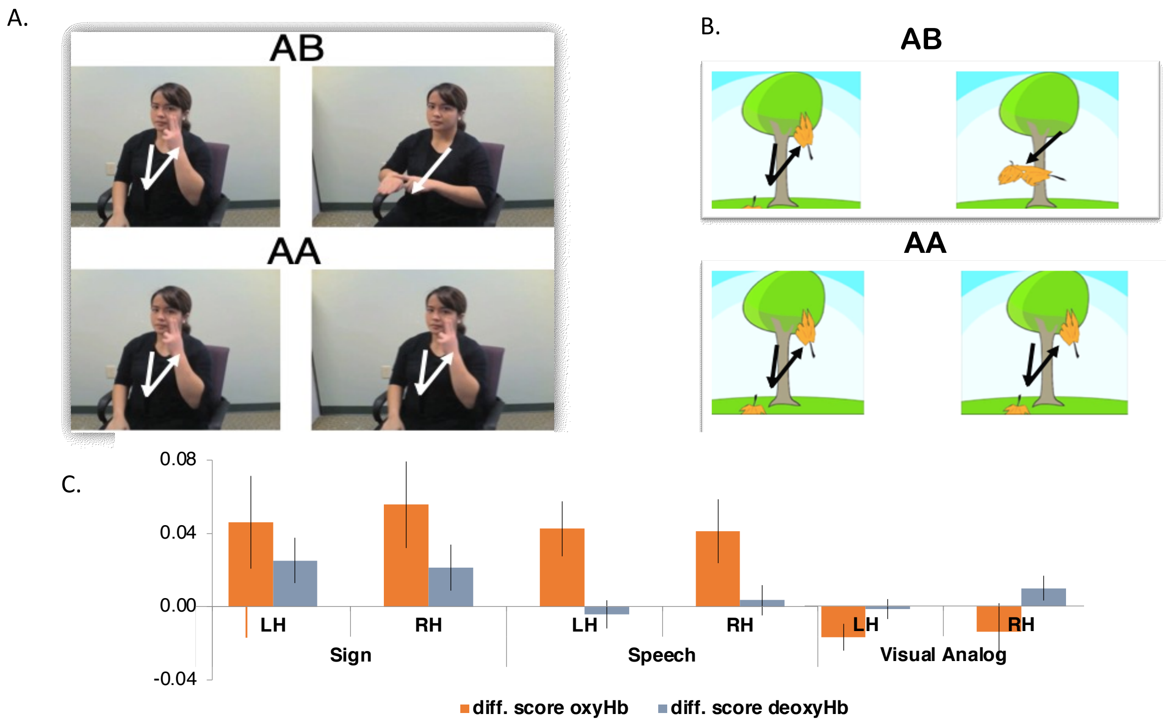


Figure 1. Infants' response to linguistic vs. nonlinguistic reduplication. Panels A-B provide still images of the linguistic signs and nonlinguistic visual controls; Panel C presents responses to the reduplication rule (responses to reduplication minus non-reduplication controls) in linguistic stimuli (sign and speech) and nonlinguistic controls (visual analogs). Images and data are from Berent et al., 2021b)

Together, these findings suggest that the infant language system is equipotential—it can extract phonological rules from either speech or signs. Phonological knowledge, then, is not inherently confined to a single linguistic modality already early on in development.

2. *Adults possess amodal linguistic principles*

That infants can extract phonological rules from signs is highly informative, but perhaps not utterly surprising. After all, we know that infants can acquire both spoken and signed languages, and infants' brains also show considerable plasticity (e.g., Olulade et al., 2020). Accordingly, the ability of sign-naïve infants to extend their phonological system to signs is no guarantee that adults can do the same. But existing empirical evidence suggests that adults, too, can spontaneously project what they know about their *spoken* language to the phonology of signs, even when they are utterly naïve to a sign language.

These studies exploited the fact that repetition (e.g., XX) is structurally ambiguous (e.g., Berent et al., 2016; Inkelas, 2008), much like ambiguous visual figures, or ambiguous syntactic structures (e.g., *visiting relatives can be annoying).* In all these cases, a single stimulus is amenable to two competing parses (i.e., interpretations, Table 1).

Table 1. The competing linguistic parses of repetition:

Linguistic level	Semantic function	Parse		Expected response
Phonology	No	Identity	XX	XX<XY
Morphology	Yes	Reduplication	{X}Xc	XX>XY

In the case of linguistic repetition, one parse treats the two syllables as purely phonological (formally, XX); repetition has no bearing on meaning, much like the English *banana* has no morphological link to *bana.* But repetition can also indicate a systematic change in meaning. For example, in Manam, the word *panana* ('to chase') is formed from *pana* ('to run'; Lichtenberk, 1983). Similarly, the Hawaiian word *hoe* 'to paddle' gives rise to *hoe-hoe* 'to paddle continuously' (Elbert & Pukui, 2001). This (morphological) interpretation of repetition is called reduplication. Formally, reduplication is parsed as {X}Xc, where the second syllable X is a copy of the base {X}.

The distinction between these two parses—(phonological) identity and (morphological) reduplication—matters because the two parses demonstrably elicit opposite reactions (for linguistic explanation, see Berent et al., 2016). When the repetition is purely phonological, participants avoid XX (relative to XY). But when the repetition is linked to a change in meaning (e.g., morphological plurality), participants actively prefer it (relative to XY). And since the stimulus itself is unchanged, this change in responses can only arise from participants' abstract linguistic knowledge, rather than sensorimotor demands, which are identical across the unchanged stimuli.

Critically, these linguistic principles apply to both speech and signs. This conclusion is supported by two lines of evidence. One is the similarity in the responses of speakers and signers to repetition in their native language modality (in speech and signs, respectively). The second line of evidence shows that speakers can project linguistic principles from their spoken L1 to signs—cross-modally.

a. Repetition in speech and sign elicits similar unimodal projections

Consider first the responses of speakers and signers to linguistic repetitions in unfamiliar stimuli (e.g., pseudowords) in their native language modalities (e.g., speech, for English speakers)—this is a test of the projection of linguistic knowledge ***unimodally***. Here, participants were presented with two printed words, corresponding to novel linguistic forms: XX and XY, and asked to choose among them. Speakers (of Hebrew or English) were presented with (novel) spoken stimuli (e.g., *slaflaf* vs. *slafmat*); signers (of American Sign Language (ASL) were presented with (novel) signs. In each case, the stimuli consisted of bare phonological forms, as repetition was not associated with any meaning.

We asked whether linguistic experience with morphological reduplication in participants' native language would lead speakers to spontaneously parse these novel bare forms morphologically, as reduplication. If it does, then speakers of languages with rich reduplicative morphologies ought to prefer repetition; speakers of non-reduplicative morphologies should not.

Hebrew and ASL provide their respective speakers with ample experience with morphological reduplication. For example, Hebrew uses reduplication to mark diminution (e.g., *kelev,* 'dog'→*klavlav* 'puppy'), and ASL likewise uses reduplication to form nouns from verbs (e.g., sit→chair). So when presented with novel phonological forms, speakers of Hebrew and ASL ought to spontaneously interpret repetition morphologically (as reduplication, hence XX>XY). English, by contrast, is not rich with morphological reduplication, so for English speakers, we expected a phonological parse (i.e., identity, hence, XX<YX).

Results were in line with these predictions. We found that, when participants' L1 had a productive reduplicative morphology, participants indeed preferred repetition (XX>XY), and this was the case regardless of whether their L1 was spoken (e.g., Hebrew) or signed (ASL). English speakers, by contrast, showed a reliable repetition aversion (XX<XY).

These results support two conclusions. First, responses to repetition dissociate from the sensorimotor demands of the stimulus. A single (spoken) stimulus (e.g., *slaflaf*) can elicit conflicting responses (aversion vs. preference) for speakers of English and Hebrew, respectively, whereas two radically different sensory stimuli (spoken vs. signed repetition) elicit the same responses, i.e., preference, in Hebrew and ASL signers, respectively. These results suggest that responses are governed by abstract principles. Second, these principles depend on the grammatical (morphological) properties of L1. Speakers of rich reduplicative morphologies spontaneously parse doubling in bare phonological forms as reduplication (as {X}Xc); speakers of non-reduplicative morphologies parse the same inputs as phonological identify (as XX). Critically, this holds regardless of L1 modality.

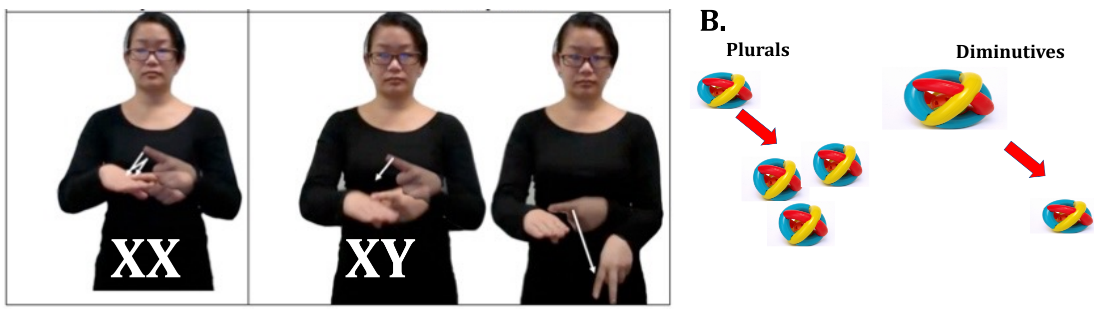
b. Speakers project linguistic principles from their spoken L1 to signs cross-modally

In a second line of experiments, we showed that participants project knowledge of their spoken language to novel ASL signs—***cross-modally***. Critically, these projections arise spontaneously, despite the fact that these participants are sign-naïve—they have no command of a sign language.

In one set of experiments, repetition expressed plurality. For example, participants were shown the base X with one ball, and then asked to choose a name for a set of balls (see Figure 2A-B); the options were XX or XY (as in the phonological condition). Now, however, doubling potentially signaled a ***morphological*** change, i.e., plurality. We asked whether experience with morphological plurality in one's spoken language would lead speakers to project a morphological (reduplicative) parse to signs.

To address this question, we administered these experiments to speakers of various languages—all with productive plural morphologies (English, Hebrew, and Malayalam). In each case, speakers preferred signs with repetition (XX) to signs without repetition (XY), suggesting that speakers of all these languages relied on a morphological parse (Berent et al., 2021a; Berent et al., 2016; Berent et al., 2020).

A. **B.**



C.

	L1 Structure		Response to signs	
L1	***Morphology***	***Semantics***	***Plural***	***Diminutive***
English, Malayalam	Yes	Plural	XX>XY	XX=XY
Hebrew		Plural & Diminutive	XX>XY	XX>XY
Mandarin	No		XX=XY	XX=XY

Figure 2. Cross modal projections. In these experiments, speakers who were sign-naïve were asked to choose between two signs—XX and XY (A); reduplication (AA) indicated either plurals or diminutives (B). Speakers' responses to plurals and diminutive in signs (C) varied systematically, depending on whether their L1 has productive morphology and whether this morphology marks plurals or diminutives. Data from Berent et al., 2021a; Berent et al., 2016; Berent et al., 2020

But what principles led participants to project this parse to signs—did they rely on their knowledge of their rich spoken language morphology, or on iconicity? To find out, we turned to speakers of Mandarin—a language with no productive plural morphology (Berent et al., 2020). If responses to signs are only driven by iconicity, then the same result ought to emerge for speakers of Mandarin. This, however, is *not* what we found. Unlike English, Hebrew and Malayalam speakers, Mandarin speakers did not prefer to express plurality by repetition (Figure 2C). This suggest that the representation of ***signs*** depends on the morphological structure of speakers' ***spoken*** L1, rather than iconicity.

Another challenge to the iconicity explanation is presented by Hebrew speakers. Hebrew, recall, uses repetition to express diminution (*kelev 'dog', klavlav* 'puppy')—the opposite of iconicity (where "more", in form, ought to express "more", semantically). We next asked whether Hebrew speakers would be able project this knowledge from their spoken language morphology to signs. So in this second set of studies, we presented participants with a situation in which repetition (in form) marked semantic diminution (Figure 2B). This is similar to how Hebrew works, except that the experimental stimuli were all novel ASL ***signs*** (X=a large ball, XX=a small ball).

Results showed that Hebrew speakers preferred to express diminution by repetition in signs (Berent et al., 2021a; Berent et al., 2016), just as they do for their spoken language morphology (Berent et al., 2017). As expected, this was *not* the case for speakers of languages with non-diminutive- (English, Malayalam) and non-productive (Mandarin) morphologies; Berent et al., 2021a; Berent et al., 2020, Figure 2C).

Altogether, then, these results suggest that, when sign-naïve speakers first encounter signs, they do not view signs as nonlinguistic stimuli, akin to dance or pantomime. Rather, speakers appear to spontaneously project to signs linguistic principles from their spoken L1 (for a complete formal account of these linguistic principles and the precise conditions on cross-modal transfer, see Berent et al., 2021a).

These results obviously do not imply that their knowledge of the relevant sign language (ASL) is complete, identical to that of signers, nor do they negate the effect of modality (for discussion, see Berent et al., 2021a). But these findings do suggest that speakers can partly encode the phonological structure in signs, and they do so by recruiting grammatical principles from their spoken language.

3. *Conclusions and implications*

In this commentary, we have reviewed evidence suggesting that phonological knowledge may be partly amodal. We showed that the language system of young infants appears to be equipotential, inasmuch as it supports the extraction of phonological rules across language modalities. We also showed that speakers and signers rely on common phonological principles, and that speakers who are sign-naïve can spontaneously project those linguistic principles from their spoken L1 to signs.

Several conclusions follow from these findings. First, if one wishes to unveil what kind of representations constrain sign processing, one cannot automatically consider sign-naïve speakers as “linguistic blank slates”. This recommendation challenges the widespread practice of using non-signers as “controls” for the linguistic knowledge in signers. To the extent non-signers can project some of their knowledge to signs, this approach may be too conservative, as it systematically underestimates the true role of linguistic knowledge in signers.

Second, some aspects of phonology could be broader in scope than what researchers typically presume. Phonology, then, may not be fully tied to any particular sensory modality—speech or sign. To be clear, this conclusion does not deny that other aspects of phonology are potentially embodied (e.g., Caselli et al., 2022; Hayes et al., 2004; Sandler, 2018). The challenge to future research, then, is to sort out the precise contribution of embodiment and abstraction, rather than treat abstraction and embodiment as mutually exclusive hypotheses, a matter of “either or”.

Finally, this amodal view of phonology carries translational implications. If some aspects of phonology can apply across language modalities, then it is conceivable that signers' knowledge of ASL could serve them well in the acquisition of spoken language phonology and reading (e.g., Krentz & Corina, 2008; McQuarrie & Abbott, 2013; Petitto et al., 2016a}). Exploring these possibilities requires that we revisit the assumption that phonological knowledge is entirely modality-specific.

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