Article

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Phonological activation of distractor pictures in sign production

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Abstract

In this study, we investigated how activation unfolds in sign production, examining whether signs that are not produced have their representations activated by semantics (cascading of activation). Deaf signers were tested in the picture-picture interference task. Presented with a pair of overlapping pictures, participants named the green picture (target) and ignored the red picture (distractor). In Experiment 1 we varied whether target and distractor pictures had similar signs. Signs were produced faster with sign-related compared to unrelated picture pairs. The facilitation observed with sign-related pairs replicates the one obtained in speaking with sound-related pairs (e.g., *bed-bell*), a finding cited in support of cascading of activation. In Experiment 2 we focused on sign iconicity anticipating that cascading of activation would lead to a facilitatory effect of iconicity. Consistent with this prediction, distractor pictures with iconic signs induced faster responses. Altogether, our results reveal that cascading of activation is a fundamental aspect of language processing at play not only in speaking, but also in signing.

It has taken the human brain million years of evolution to become a sophisticated system capable of computing language using speech articulation and auditory recognition. Nevertheless, human brains exhibit the impressive ability to naturally adopt sign languages that are based on hand configuration and movement in production and visual input in recognition. This remarkable language plasticity raises the question of the extent to which brain mechanisms supporting spoken language would also underlie sign language, a question only recently language scientists have started to investigate. Here, we address it from the perspective of language production, specifically examining whether widespread activation – a key feature in spoken word selection – extends to sign processing.

There is no direct correspondence between the meaning a speaker wants to communicate and the words in a language, since specific words may not exist for some meanings, or more than a single word can adequately express certain meanings. In consideration of this basic fact of language, all theories of spoken word production have assumed that multiple words are simultaneously activated when speakers attempt to produce a word (Caramazza, 1997; Dell, 1986; Levelt, Roelofs, & Meyer, 1999). For example, "my sister Suzanne," "my only sister," "Suzanne," "my sister," or "her" are all appropriate expressions and their words could be activated when talking about this sister. All theories further assume that the word receiving the strongest activation is selected, which normally corresponds to a word adequately expressing the intended meaning. The way in which the notion of multiple word activation has been specifically implemented depends on further assumptions theories make on word representations. In theories assuming that meaning interfaces directly with word phonology (Caramazza & Miozzo, 1997), the phonology of multiple words must be activated. In theories positing lemmas – an intermediate level of representation between meaning and word phonology that encodes word grammatical features (e.g., Levelt et al., 1999) – spreading of activation can be limited to lemmas or further reach word phonology. Here, the term *full cascading* is used to refer to activation spreading to the phonology of multiple words, while the term *discrete cascading* refers to the hypothesis that activation of multiple words stops at the lemma level and that beyond this point only the phonology of the word selected for production is activated, at least in normal circumstances.

Various results have been cited in support of full cascading in spoken word production, including those obtained in psycholinguistic studies (e.g., Morsella &

Miozzo, 2002; Navarrete & Costa, 2005; Peterson & Savoy, 1998; Vitevitch, 2002), from analyses of speech errors produced by normal speakers (Goldrick & Blumstein, 2006), or from studies of brain-damaged individuals with specific language impairments (Rapp & Goldrick, 2000). Furthermore, studies with bilinguals have shown that multiple words are simultaneously activated not only in the language in use but also in the other language (Colomé & Miozzo, 2009; Costa, Caramazza, & Sebastián-Gallés, 2000). Moreover, full cascading proved essential to successfully reproduce a variety of empirical results with computational models of spoken word production (e.g., Chen & Mirman, 2012; Dell & O'Seaghdha, 1992; Oppenheim, Dell, & Schwartz, 2010). Although individual results cited in support of full cascading have not been spared criticism, they collectively form a body of evidence making full cascading very plausible and likely to be a characterizing feature of spoken word selection.

What words are co-activated on each instance depends on various factors. Many of these words are semantically related to the intended word – e.g., *brother, girl,* or *family* for the target word *sister*. Their activation arises from activation spreading to related concepts within the semantic systems and subsequently cascading to word phonology. Other co-activated words are phonologically related – e.g., *sinister* or *mister* for the target word *sister* – as a result of activation spreading across words part of the same 'phonological neighborhood' (Sadat, Martin, Costa, & Alario, 2014; Vitevitch, 2002). Were there cascading of activation in sign production, co-activated signs would not be similar in terms of sounds, sharing instead features of hand movement and configuration. This prediction was tested in Experiment 1.

A second prediction of full cascading, which was tested in Experiment 2, relates to iconicity, defined as the correspondence between a sign and the perceptual-motor features of the referent (Taub, 2001). Such correspondence is present, with varying degree of faithfulness, in iconic signs and absent in non-iconic signs (Fig. 1). For example, the sign *key* is iconic in American, Swedish, Estonian and Turkish sign languages because it reproduces the hand-turning action associated with key (http://www.spreadthesign.com/). Iconic signs were produced faster than non-iconic signs in two picture naming studies, one conducted with deaf signers (Vinson, Thompson, Skinner, & Vigliocco, in press), the other with proficient bimodal bilinguals (speakers who acquired sign language as L2; Baus & Costa, in press). While pictures are assumed to activate perceptual and action-related features of the concepts, the activation of those features embedded in iconic signs is assumed to activate components of the signs associated with these features, thus facilitating sign selection for production. The effects of iconicity might not be limited to target signs, but extend to all of the signs activated in production. However, if iconic signs are more strongly activated, they should be more likely than non-iconic signs to be among the co-activated signs. This specific prediction of full cascading was tested in Experiment 2.

Experiment 1: Phonologically related signs

Is full cascading also at play in sign production? To examine this question we sought to replicate, with signs, the facilitation effect obtained in speaking with the picture-picture interference task, a result that has been interpreted as implying full cascading. Participants in this task are presented with pairs of overlapping pictures and instructed to use a specific cue (e.g., picture colors) to decide which picture to name or ignore. Morsella and Miozzo (2002) reported faster naming responses when the two pictures had phonologically similar names (*bed*-*bell*) compared to unrelated names (*bed*-*dog*). The facilitation effect Morsella and Miozzo found in English disappeared when the task was replicated in Italian, a language in which the picture names were unrelated. The latter result confirms that the facilitation found in English derives from the phonological similarities of the picture names rather than pictorial or semantic differences in the materials. Having been replicated in multiple studies (Kuipers & La Heij, 2009; Meyer & Damian, 2007; Navarrete & Costa, 2005; but see Jescheniak, Oppermann, Hantsch, Wagner, Madebach, & Schriefers, 2009), the facilitation induced by phonologically similar distractor pictures appears to be a robust phenomenon. The facilitation observed in the picture-picture interference task can be explained by assuming, in line with full cascading, that distractor pictures activate their phonology. With phonologically similar pairs, the phonology of target pictures receives extra activation from the distractor pictures, thus causing faster naming responses. In the picture-picture interference task carried out in Experiment 1, we aimed to determine if parameters of signs corresponding to the distractor pictures are activated, a finding implying full cascading in sign production.

Linguistic analyses on sign articulation in natural languages have revealed four major phonological parameters that are probably universal: handshape, location of the sign relative to the body, movement of the hand, and orientation (Battison, 1978; Sandler & Lollio-Martin, 2006; Stokoe, Casterline, & Croneberg, 1965). These parameters vary cross-linguistically in number and typology, and are combined according to language-specific and language universal constraints giving rise to the whole inventory of signs in a given language. A rigorous definition of sign similarity was proposed in prior studies (Baus, Gutierréz-Sigut, Quer, & Carreiras, 2008; Corina & Hildebrandt, 2002; Meyers, Lee, & Tsay, 2005) and also used in Experiment 1. Analyses of errors involving signs have also shown that sign production is sensitive to similarity defined in terms of shared parameters (Hohenberger, Happ, & Leuninger, 2002; Newkirk, Klima, Pedersen, & Bellugi, 1980; Pyers, Gollan, & Emmorey, 2009; Thompson, Emmorey, & Gollan, 2005). This conclusion is further supported by results showing that signing a picture's name is facilitated by the concurrent presentation of a sign sharing some of the phonological constituents (Corina & Hildebrandt, 2002; Baus et al. 2008).

Deaf signers of Italian Sign Language (ISL; *Lingua Italiana dei Segni*) were presented in Experiment 1 with two overlapping colored pictures – one green, the other red – and instructed to name the green picture by producing its sign. The overlapping pictures forming the phonologically related pairs had signs sharing some parameters. Pictures were re-matched to create unrelated picture pairs that served as baseline against which phonologically related pairs were compared. For example, the target picture *tree* was paired with the distractor picture *hat* (the signs *tree* and *hat* are similar in location and movement), and with the unrelated distractor picture *bell*. Experiment 1 was replicated with hearing Italian speakers who verbally named the pictures. The reason for this replication was twofold. First, because different pictures were paired in related and unrelated conditions, we have to control for pictorial and semantic differences between conditions. Second, all of our deaf participants were, with varying degrees of proficiency, bilingual speakers of (spoken) Italian. Although we avoided pairing pictures with names sounding similar in Italian, the replication would control for the possible contribution of the (spoken) Italian names of pictures. The lack of an effect of sign similarity with Italian speakers would ensure a proper balance of the stimuli used to test full cascading in sign language.

Participants

The 24 deaf participants (mean age=17 years; range=15-25; SD=2.4) attended a boarding school for deaf students in Northern Italy, where ISL is used for teaching and is students' primary and preferred language. Participants had some knowledge of spoken Italian, acquired especially for purposes of reading and writing. The 24 hearing participants and Italian speakers were university students (mean age=20 years; range=19-23; SD=1.8) who participated for course credits. They reported no hearing deficits or knowledge of a sign language.

Methods

Materials. Each of the 32 pictures selected as targets was paired with a sign-related distractor picture and a sign-unrelated distractor picture. Furthermore, each of 32 distractors pictures was paired with two target pictures. Pictures forming related pairs had signs sharing at least one parameter, while unrelated picture pairs shared no parameters. Appendix A lists the pictures used in each condition, along with the parameters shared by sign-related pairs. Paired pictures were neither semantically related, nor had similar sounding names in spoken Italian. Related and unrelated picture pairs were matched for iconicity ratings ($t<1$) obtained from 10 Italian speakers who served as raters. Raters were presented with an object name and a video of its sign, and asked to indicate to what extent the sign reproduced “visual characteristics of the object or aspects of actions associated with it,” using a 7-point scale (1=completely different; 7=very similar). We also selected 32 filler pictures (16 targets and 16 distractors). Each filler target-picture was paired with two filler distractor-pictures, thus creating a total of 32 filler picture-pairs. These filler picture-pairs were only shown to signing participants. Instead, speaking participants were presented with 64 picture pairs resulting from matching 32 target pictures with 32 distractor pictures. Half of these picture pairs (sound-related; N = 32) were formed by pictures with Italian names sharing at least the first two phonemes (mean number of identical onset phonemes = 2.5); the other half of picture pairs (sound-unrelated) had Italian names that were phonologically different (see list in Appendix B). We expected to replicate the facilitation effect reported in previous studies, a finding suggesting that naming engendered a similar ‘depth of processing’ in the condition testing sign similarity. The pictures of Experiment 1 were line drawings from different databases (Alario, & Ferrand, 1999; Bonin, Peereman, Malardier, Méot, & Chalard, 2003; Dell’acqua, Lotto, & Job, 2000). Lines were colored green (targets) or red (distractors). One picture was superimposed on top of another. Picture pairs were divided into two blocks of equal number of trials. Each block started with 4 warm-up pairs that, along with fillers, were excluded from analyses. Picture pairs were presented in one of 8 pseudorandom orders that prevented related pairs from appearing in consecutive trials or pictures to be re-presented before at least 2 intervening trials.

Procedure. Familiarization, stimuli presentation, and response recording varied slightly between signers and speakers. Signers started the experiment by viewing each target picture along with its videoed signs. They were instructed to use these signs to identify the green pictures as fast and accurately as possible, while ignoring the red, overlapping pictures. The task was practiced by naming 2 warm-up pairs 6 times. At the beginning of a naming trial, the instruction "Press z + m" appeared on the center of the screen. Soon after the two keys were pressed with the index fingers, a picture pair appeared on the central region of the screen previously covered by the instructions. Pictures remained on view until one of the two keys was released from the keyboard. The inter-trial interval was set at 1.5 s and started when the second key was released from the keyboard. Naming latencies corresponded to the time interval between picture appearance and the release of the first key. Once the signing of the green pictures was completed, participants signed the distractor pictures. No time limits were imposed on these responses that were collected to control for the signs used for distractor pictures. Stimulus presentation and response times (RTs) were controlled by E-Prime 2 (Psychology Software Tools, Inc., Sharpsburg, PA). All of the signs were video recorded.

Speakers began the experiment viewing each target picture with its names written beneath and were instructed to use these names for their spoken responses. Instructions emphasized response speed and accuracy. The stimuli used for practicing the naming task were those presented to signers. Each experimental trial started with a fixation point (+) presented on the center of the screen for 750 ms and immediately followed by a blank interval that varied randomly in duration (200, 400, 600 or 800 ms). Next, picture pairs appeared until the spoken response began, or for a maximum of 2.5 s. The screen remained blank during the inter-stimulus interval for 1.5 s from picture disappearance. Finally, a question mark appeared and participants started a new trial by pressing the spacebar. Naming latencies were measured from picture onset to the beginning of spoken responses. To determine name agreement, participants also named the distractor pictures using the procedure described above for signers, except this time responses were spoken. Stimulus presentation and response recording were controlled by DMDX software (Forster & Forster, 2003).

Naming latencies and accuracy were determined off-line using the CheckVocal software (Protopapas, 2007).

The same procedure was used for scoring manual and spoken responses. Responses treated as errors and therefore excluded from RT analyses included: (a) incorrect signs/names; (b) responses produced with disfluencies, repairs, or hesitations; (c) extremely fast (<200 ms) or long (>2.5 s) responses.

Results

Agreement was overall high with the signs (mean=89%; range=48-100%) and the spoken names (mean=97%, range=89–100%) that participants used to identify the distractors. Responses from two signing participants were discarded because of high error rates (>25%). After the exclusion of these participants, errors accounted for 1.7% of signed responses, while errors occurred with 3.8% of spoken responses. Error rates did not differ across conditions for either type of responses (ts<1). Crucial differences were found in the latencies of signed and spoken responses to picture pairs varying in sign similarity (Fig. 2). Signed responses were 24 ms faster for sign-related picture pairs (mean = 861 ms; SD = 167) than unrelated picture pairs (mean = 885 ms; SD = 172), a significant difference in both the by-subjects analysis ($t1(21)=4.40$, $p<.001$) and the by-items analysis ($t2(23)=2.24$, $p<.05$). By contrast, identical mean latencies (751 ms) were found between spoken responses to picture-pairs with related vs. unrelated signs (ts<1). Finally, replicating previous findings, speaking participants responded 20 ms faster to sound-related than unrelated picture-pairs (mean (SD): 744 (69) vs. 764 (76); $t1(23)=2.21$, $p<.05$; $t2(31)=1.17$, $p=.09$).

The sign-similarity effect found with signers provides a first indication of full cascading in sign production. The lack of sign effects with speakers is unsurprising given the extraneousness of these participants to sign distinction, nevertheless important for showing that materials used to test sign-relatedness effects were accurately balanced. Finally, the sound-similarity effect found with spoken responses demonstrates that picture distractors activated (spoken) phonology. The latter result reveals that distractors were similarly processed by signers and speakers, since with both participants we found evidence of phonological activation (either of words or signs).

Experiment 2: Effect of iconicity

The evidence of cascading emerged in Experiment 1 has implications for defining what signs are activated in production. In fact, this finding leads to anticipate that signs that easily activate phonology have a greater opportunity to be co-activated. We tested this prediction varying the iconicity of the picture distractors presented in the picture-picture interference task. Our prediction was in part motivated by the findings from signed picture naming we reviewed in the Introduction that showed faster responses for iconic than non-iconic signs (Baus & Costa, in press; Vinson et al., in press). To the extent that the advantage for iconic signs reflects a stronger activation of phonology, we can anticipate an equally stronger activation of the phonology of distractors whose signs are iconic. Furthermore, in line with accounts proposing that a greater activation of distractor phonology leads to a faster exclusion of the distractor response and therefore a faster selection of the target response (Finkbeiner & Caramazza; 2006; Miozzo & Caramazza, 2003; Mahon, Costa, Peterson, Vargas & Caramazza, 2007), signed responses would be faster for distractor with iconic signs.

The advantage Vinson et al. (in press) found with the production of iconic signs was obtained comparing pictures with iconic vs. non-iconic signs. Although different pictures were used, it was not controlled that the pictures were comparable for other variables than iconicity that could have affected visual and semantic processing. These uncontrolled variables – rather than iconicity – could have been the responsible for the differences reported by Vinson et al. (in press) in signed picture naming. A control of these variables is typically undertaken by replicating the task with hearing speakers lacking knowledge of sign language (Note). This control was introduced by Baus and Costa (in press), who tested proficient bimodal bilinguals. However, we should be cautious in extending effects of iconicity observed with bimodal bilinguals to deaf signers, as previous results have showed that some variables (e.g., frequency; Emmorey, Petrich, & Gollan, 2012) have stronger effects with bimodal bilinguals, and that bimodal bilinguals are quite sensitive to iconicity while acquiring sign language (Campbell, Martin, & White, 1992; Lieberth, & Gamble, 1991; Ortega & Morgan, in press; Poizner, Bellugi, & Tweney, 1981). In line with these considerations, we deemed important to replicate the advantage for iconicity found in signed picture naming. Specifically, we recorded the signed response latencies given by deaf signers to iconic and non-iconic picture distractors. We also controlled that spoken response latencies were comparable between distractor pictures with iconic and non-iconic signs.

Participants

Deaf signers (N = x; mean age=x years; range=x-y; SD=y) and hearing speakers (N = x; mean age=x years; range=x-y; SD=y) were from the same samples as in Experiment 1. None of the participants in Experiment 2 were also tested in Experiment 1.

Methods

Materials and procedure. Iconicity ratings were obtained for a large sample of object signs from 10 hearing English speakers using the procedure described in Experiment 1. We selected x pictures with iconic signs having iconicity ratings greater than x. A second group of x pictures had non-iconic signs and iconicity ratings lower than x. Pictures with iconic and non-iconic signs were used as distractors. Each of the x pictures selected as target was paired with one iconic and one non-iconic picture distractor. The target and distractor pictures forming each pair were semantically unrelated and had phonologically unrelated signs sharing no parameters in ISL or phonologically unrelated spoken names in Italian. The list of target-distractor pairs used in Experiment 2 is shown in Appendix C. Only one change was introduced in the procedure of Experiment 1. Participants of Experiment 2 were asked to sign (or name) the distractor pictures as fast and accurately as possible in the control of sign (name) agreement carried out with distractor pictures. Response latencies were collected to establish whether an iconicity advantage appeared with signed or spoken picture naming.

Results

The signs and spoken names participants used to identify the picture distractors demonstrated high agreement (means: x vs. y). Accuracy was comparably high in the picture-picture interference task with signed and spoken responses (means = x and y) and across conditions (ts<1). Crucial differences were found between response modalities with RTs (Fig. 3). While signed responses were faster with iconic vs. non-iconic distractor pictures (means: x vs. y; t1(x)=x, p<.x; t2(x)=x, p<.x), no differences appeared with spoken responses (means: x vs. y; ts<1). In other words, while signed responses revealed a sizable effect of iconicity that, as we anticipated, was facilitatory, the lack of effects with spoken responses ruled out that results with singed responses could reflect differences in the materials. Parallel differences emerged between response modalities with distractors pictures. Only signers named iconic distractor pictures faster than non-iconic distractor pictures (means: x vs. y; t1(x)=x, p<.x; t2(x)=x, p<.x; speakers: means: x vs. y; t<1). The results with spoken responses along with the control with spoken responses demonstrate advantages in the production of iconic signs, thus corroborating previous findings (Baus & Costa, in press; Vinson et al., in press).

We explained the faster responses for picture distractors with iconic signs as reflecting the speed with which alternative responses could be excluded and assuming faster rejection with strongly activated distractors. Exclusion mechanisms have been proposed to explain various forms of interference induced in spoken word production by the simultaneous presentation of words or picture distractors, and specifically to account for the finding of reduced interference with strongly activated distractors (Finkbeiner & Caramazza; 2006; Miozzo & Caramazza, 2003; Mahon, Costa, Peterson, Vargas & Caramazza, 2007). This is a problematic finding for alternative accounts of interference that do assume exclusion processes (e.g., Piai, Roelofs, & Schriefers, 2012; Starreveld, La Heij, & Verdonschot, 2013). The faster responses we observed when distractor pictures had iconic signs is better explained within accounts proposing exclusion mechanisms.

General Discussion

ISL signs were produced faster when distractor pictures had similar signs (Experiment 1). Faster naming responses were not observed in a replication of the picture-naming task with Italian speakers lacking knowledge of ISL. This contrasting pattern of results makes us confident that the differences we found with signed responses reflected sign similarities rather than other aspects of the materials. The effect of sign similarity parallels the effect of sound similarity previously observed in several studies on the picture-picture interference task (Kuipers & La Heij, 2009; Meyer & Damian, 2007; Morsella & Miozzo, 2002; Navarrete & Costa, 2005). The facilitation effect of ~20 ms found with signs is comparable in magnitude to the effects obtained in speaking, a result further underscoring cross-modality similarities with the facilitation effect. The similarity effect obtained in the picture-picture interference task with spoken words has been considered as demonstrating full cascading as opposed to discrete cascading. The parallel findings with signs suggest that full cascading is also at play in sign production, and thus activation spreading from semantics is not restricted to the sign that is effectively produced but also to the cohort of contextually activated signs. From a neurocognitive perspective, this means that connections between brain regions processing semantics and motor aspects of signs function in broadly similar ways as those linking the brain regions involved in semantics and the processing of word sounds. It is interesting in this context that evidence of full cascading was also found in writing (Bonin, Roux, Barry, & Canell, 2012; Buchwald, & Falconer, 2014; Roux & Bonin, 2012), a finding that along with those obtained with spoken words and signs makes it plausible to consider full cascading a universal feature of language processing.

Our findings add to previous studies on sign language production that replicated results originally observed in speaking (for a review see Corina, Gutierrez, & Grosvald, 2014). An example comes from tip-of-the-fingers, in which fragments of target signs can be produced, analogously to what is found in tip-of-the-tongues (Thompson et al., 2005). However, not all results have been replicated in sign production. One notable exception concerns spontaneous errors, specifically the appearance of stranding errors with words (Garrett, 1975) but not signs (Honenberger et al., 2002; Newkirk, 1980). These errors consist in position exchanges that make stems stranded from their suffixes, as in the slip *talking Turkish* → "turking talkish." A further example concerns the implicit priming paradigm Myers, Lee, and Tsay (2005). Charting the similarities and differences in tasks demanding the production of spoken words vs. signs would prove useful to understand aspects of language processing that are universal from the ones that are modality-specific. Furthermore, differences could provide important cues to determine how modality-specific constraints would shape language production processing.

The implications of our results are not restricted to the dynamics of lexical processing in sign production, extending also to the representation of signs accessed in language production. As mentioned in the Introduction, theories on language production in speaking have proposed alternative accounts of the architecture of the lexical system. A main point of debate has concerned whether semantics directly contacts representations encoding word sounds (Caramazza & Miozzo, 1997) or whether there is an intermediate level formed by lemmas that encode word grammatical features and mediate access to word sounds (Dell, 1986; Levelt et al., 1999). Similar questions hold in sign production. Even in the context of sign production, the alternative accounts differ crucially on full cascading – i.e., whether activation would spread to the phonological representations specifying parameters associated with hand movements. Accounts assuming direct semantic-phonology interface are forced to predict full cascading, so the findings suggesting full cascading we obtained in picture-picture interference task confirms a strong prediction of this type of accounts. In theory, activation can spread in different ways within accounts assuming lemmas, but while our evidence strongly suggests spreading of activation from lemmas to phonological representations, it makes spreading of activation restricted to selected lemmas (discrete cascading) an untenable alternative.

By implicating full cascading, our results raise further questions about activation in sign production: What signs are activated in addition to the one actually selected for production? How far does activation spread within the language system? What are the consequences of full cascading? Cues for answering these questions are provided by our results.

We found in Experiment 2 that iconicity not only reduced interference in the picture-picture interference task but also facilitated signed naming, the latter result extending previous findings with deaf speakers (Vinson et al., in press) and bimodal bilinguals (Baus & Costa, in press). Together, the findings of Experiment 2 suggest that iconic signs are more strongly activated than non-iconic signs, thus facilitating sign selection or the exclusion of non-target signs. More generally, the iconicity effects observed in Experiment 2 contribute to understanding the composition of co-activated signs. As a consequence of their comparatively high activation, iconic signs have high probabilities of being among the signs co-activated in production. Iconicity also makes the composition of activated signs different in signing and speaking, where we found no effects of iconicity (see also Baus & Costa, in press). Research on speaking has made clear that the composition of co-activated words is a major factor in determining lexical selection – both correct and erroneous (Gordon, 2002; Sadat et al., 2014; Ziegler, Muneaux, & Grainger, 2003). Having established that iconicity determines which signs are activated, aspects of lexical selection affected by co-activation can be better characterized in sign processing.

Up to this point, we have referred to phonological representations in rather general terms. However, the iconicity effect found in Experiment 2 constrains hypotheses about the information activated by non-selected signs. One possibility is that non-selected signs only activate purely linguistic representations encoding features of hand shape and movement that are exclusively related to language and accessed for purposes of language processing. Crucially, hand features associated with actions or reproducing visual characteristics of objects would be extraneous to this kind of linguistic representations, essentially precluding iconicity effects to appear. The iconicity effects we found in the picture-picture interference task reveal instead that non-selected signs activate information accessible not only in language but also in action. In this respect, sign production appears to resemble speech production, for showing the activation of aspects related to the planning and implementation of articulatory gestures (Baese-Berk, & Goldrick, 2009; Goldrick & Blumstein, 2006; Buchwald & Miozzo, 2011). It should be clarified that our result do not imply that signs would not activate a language-specific representation, revealing instead that activation would spread beyond this representation reaching more 'peripheral' representations articulatory in nature. Furthermore, our results do not imply that visual objects would activate features related to actions prevalently in signers rather than speakers. Neuroimaging evidence has revealed activation, in picture naming, in brain areas engaged in action and motor control (Grafton, Fadiga, Arbib, & Rizzolatti, 1997; Miozzo, Hauk, Pulvermüller, in press; Rueschemeyer, van Rooij, Lindemann, Willems, & Bekkering, 2010). Even if action-related information would be activated, iconicity effects might not appear with speakers in the picture-picture interference task because such information would not affect spoken word production.

In conclusion, cascading of activation is a processing feature not only of a language system based on an oral articulator and the product of evolution but also of sign languages that depend on a hand articulator as an alternative output device. This pervasiveness reveals cascading of activation as a feature fundamental for a proper functioning of human language. However, the motor system itself might have favored the appearance of cascading of activation, being evolved as a system capable of simultaneously processing multiple alternative responses (Castiello, 2005) – a skill maybe refined by the acquisition and prolonged practice of sign language.

Note. Spoken naming latencies are available in Szekely et al. (2004) for 60 of the 92 pictures tested by Vinson et al. (in press). We used the iconicity ratings available from Vinson et al. (in press) to create two group of 30 pictures, one composed of pictures with iconic signs (iconicity ratings > x), the other of pictures with non-iconic signs (iconicity ratings < x). Pictures with iconic signs were named faster than those with non-iconic signs (x vs. y; t(x)=y, p = .05, one tail). Although naming latencies are available from only a sample of the pictures tested by Vinson et al. (in press) and probably not from the identical stimuli they administered, these results underscore the importance of a proper control of the pictorial stimuli.

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Appendix A

Sign-related and unrelated target-distractor pairs presented in Experiment 1. Target pictures are shown in uppercase. Italian names are in bracket. ✓ indicates shared parameters (H = handshape, L = location, M = movement, O = orientation).

	TARGET PICTURES		DISTRACTOR PICTURES							
			SIGN-UNRELATED		SIGN-RELATED		Shared Parameter			
							H	L	M	O
1	ELEPHANT	[elefante]	motorbike	[moto]	glass	[bicchiere]	✓			
2	CLOTHESPIN	[molletta]	table	[tavolo]	bird	[uccello]			✓	
3	POTATO	[patata]	helicopter	[elicittero]	violin	[violino]			✓	
4	BICYCLE	[bicicletta]	snake	[serpente]	broom	[scopa]	✓	✓		
5	BUS	[autobus]	skyscraper	[grattacielo]	bottle	[bottiglia]	✓	✓		
6	DOOR	[porta]	mushroom	[fungo]	book	[libro]	✓	✓		
7	HOUSE	[casa]	racket	[racchetta]	saw	[sega]	✓	✓		
8	IRON	[ferro da stiro]	umbrella	[ombrello]	suitcase	[valigia]	✓	✓		
9	LIGHTHOUSE	[faro]	key	[chiave]	ambulance	[ambulanza]	✓	✓		
10	TRAIN	[treno]	fork	[forchetta]	rifle	[fucile]	✓	✓		
11	WHEEL	[ruota]	violin	[violino]	sun	[sole]	✓	✓		
12	CAT	[gatto]	saw	[sega]	fiore	[flower]	✓		✓	
13	EGG	[uovo]	hat	[cappello]	squirrel	[scoiattolo]	✓			✓
14	ICE-CREAM	[gelato]	rifle	[fucile]	racket	[racchetta]	✓			✓
15	SCREWDRIVER	[cacciavite]	volcano	[vulcano]	mushroom	[fungo]	✓			✓
16	TREE	[albero]	bell	[campana]	hat	[cappello]	✓			✓
17	STAMP	[francobollo]	glass	[bicchiere]	volcano	[vulcano]		✓	✓	
18	PYRAMID	[piramide]	ambulance	[ambulanza]	table	[tavolo]	✓	✓	✓	
19	ROAD	[strada]	suitcase	[valigia]	skyscraper	[grattacielo]	✓	✓	✓	
20	ANTENNA	[antenna]	bird	[uccello]	helicopter	[elicottero]	✓	✓		✓
21	CART	[carrello]	piano	[pianoforte]	motorbike	[moto]	✓	✓		✓
22	CLOUD	[nuvola]	flower	[fiore]	factory	[fabbrica]	✓	✓		✓
23	CLOWN	[pagliaccio]	broom	[scopa]	pig	[maiale]	✓	✓		✓
24	COMPUTER	[computer]	crayfish	[gambero]	piano	[pianoforte]	✓	✓		✓
25	ERASER	[gomma]	squirrel	[scoiattolo]	match	[fiammifero]	✓	✓		✓
26	FISHING ROD	[canna]	book	[libro]	umbrella	[ombrello]	✓	✓		✓
27	FIST	[pugno]	sun	[sole]	pitcher	[caraffa]	✓	✓		✓
28	HOOK	[gancio]	factory	[fabbrica]	crayfish	[gambero]	✓	✓		✓
29	PAINT BRUSH	[pennello]	pitcher	[caraffa]	snake	[serpente]	✓	✓		✓
30	PLUG	[spina]	pig	[maiale]	fork	[forchetta]	✓	✓		✓
31	SPIDER	[ragno]	match	[fiammifero]	bell	[campana]	✓	✓		✓
32	SWORD	[spada]	bottle	[bottiglia]	key	[chiave]	✓	✓		✓

Appendix B

Sound-related and unrelated target-distractor pairs presented in Experiment 1 to Italian speakers. Target pictures are shown in uppercase. Underlined segments indicate onset phonemes shared by Italian picture names in sound related pairs.

	SOUND-RELATED PICTURE PAIRS		SOUND-UNRELATED PICTURE PAIRS	
	English Names	Italian Names	English Names	Italian Names
1	ANGEL-carrot	ANGELO-carota	ANGELO-anchor	ANGELO-ancora
2	ARC-button	ARCO-bottone	ARC-bow	ARCO-arco
3	BARREL-pencil	BOTTE-matita	BARREL-button	BOTTE-bottone
4	BOX-bench	SCATOLA-panchina	BOX-ladder	SCATOLA-scala
5	BRANCH-anchor	RAMO-ancora	BRANCH-frog	RAMO-rana
6	CANDLE-leaf	CANDELA-foglia	CANDLE-kangaroo	CANDELA-canguro
7	CANDY-pipe	CARAMELLA-pipa	CANDY-horse	CARAMELLA-cavallo
8	CELERY-hand	SEDANO-mano	CELERY-chair	SEDANO-sedia
9	CHAIN-cow	CATENA-mucca	CHAIN-dog	CATENA-cane
10	CHEF-kite	CUOCO-aquilone	CHEF-heart	CUOCO-cuore
11	DRAWER-banana	CASSETTO-banana	DRAWER-castle	CASSETTO-castello
12	DRILL-heart	TRAPANO-cuore	DRILL-tractor	TRAPANO-trattore
13	DUCK-moon	ANATRA-luna	DUCK-pineapple	ANATRA-ananas
14	EAGLE-bowl	AQUILA-birillo	EAGLE-Kite	AQUILA-aquilone
15	FIREPLACE-frog	CAMINO-rana	FIREPLACE-carrot	CAMINO-carota
16	FISH-castle	PESCE-castello	FISH-pear	PESCE-pera
17	GARBAGE CAN-truck	BIDONE-camion	GARBAGE CAN-bowl	BIDONE-birillo
18	GUN-horse	PISTOLA-cavallo	GUN-pipe	PISTOLA-pipa
19	HELM-knife	TIMONE-coltello	HELM-tiger	TIMONE-tigre
20	HANDCUFFS-dog	MANETTE-cane	HANDCUFFS-pencil	MANETTE-matita
21	MUMMY-cigarette	MUMMIA-sigaretta	MUMMY-cow	MUMMIA-mucca
22	PANDA-tractor	PANDA-trattore	PANDA-bench	PANDA-panchina
23	RABBIT-nose	CONIGLIO-naso	RABBIT-knife	CONIGLIO-coltello
24	SEAL-pineapple	FOCA-ananas	SEAL-leaf	FOCA-foglia
25	SHIP-tiger	NAVE-tigre	SHIP-nose	NAVE-naso
26	SHIRT-bow	CAMICIA-arco	SHIRT-truck	CAMICIA-camion
27	STORK-ladder	CICOGNA-scala	STORK-onion	CICOGNA-cipolla
28	SHOVEL-kangaroo	PALA-canguro	SHOVEL-peacock	PALA-pavone
29	SWEATER-chair	MAGLIONE-sedia	SWEATER-hand	MAGLIONE-mano
30	SYRINGE-peacock	SIRINGA-pavone	SYRINGE-cigarette	SIRINGA-sigaretta
31	WHALE-onion	BALENA-cipolla	WHALE-banana	BALENA-banana
32	WOLF-pear	LUPO-pera	WOLF-moon	LUPO-luna

Appendix C

Target-distractor picture pairs presented in Experiment 2. Target pictures are shown in uppercase. The signs of distractor pictures varied for iconicity (iconic vs. non iconic). Italian names are in bracket.

	TARGET PICTURES		DISTRACTOR-PICTURE SIGNS			
			ICONIC		NON-ICONIC	
1	X	[X]	X	[X]	X	[X]

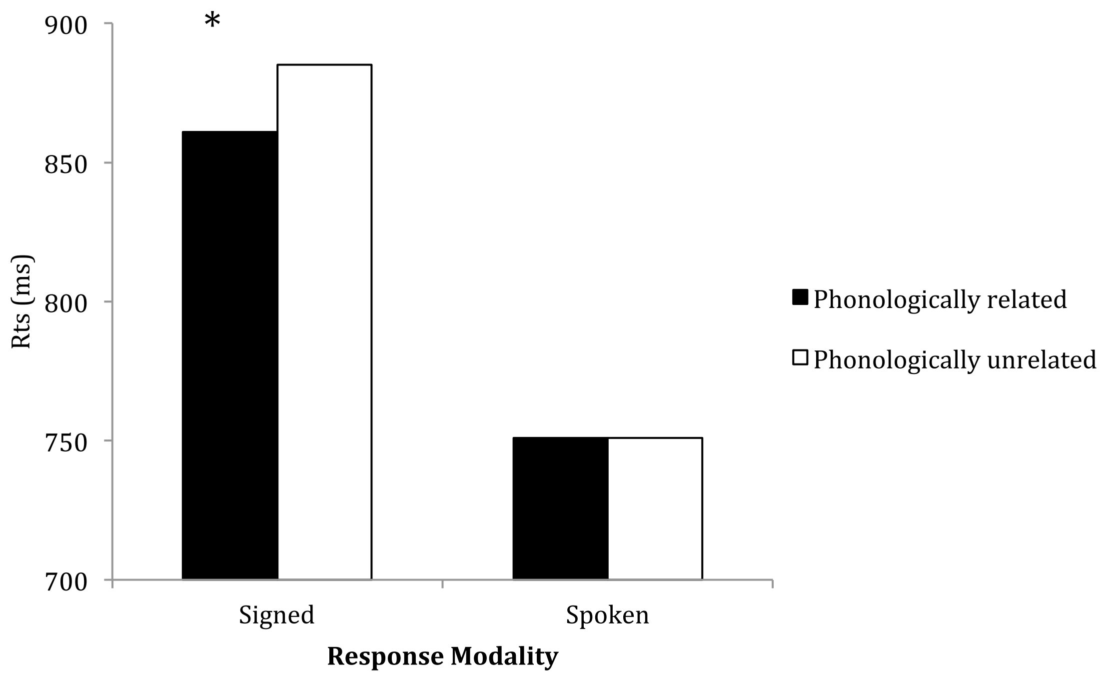

Figure 1. Signed and spoken responses to target pictures presented with overlapping distractor pictures. Target-distractor pictures had signs that were either similar (phonologically related) or different (phonologically unrelated). Signed responses were significantly faster with phonologically related than unrelated distractors (as indicated by *). No effects of sign similarity were found with spoken responses.

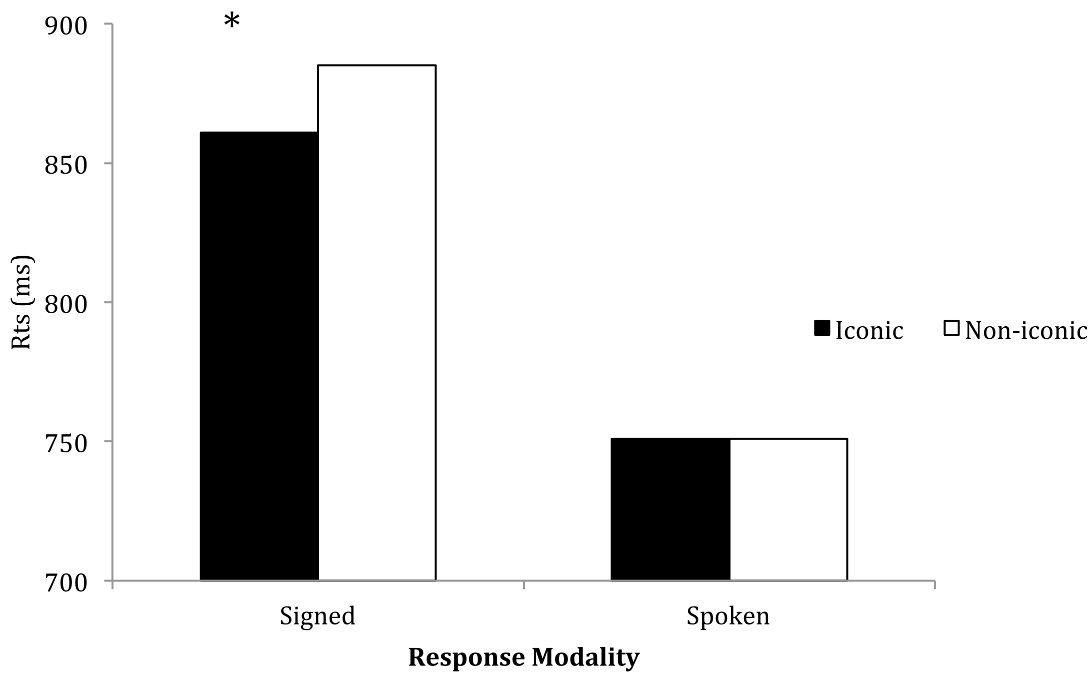

Figure 2. Signed and spoken responses to target pictures presented with overlapping distractor pictures. Distractor pictures had signs that were either iconic or non-iconic. Signed responses were significantly faster with iconic than non-iconic distractors (as indicated by *). No effects of iconicity were found with spoken responses.