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## The effect of iconicity in the mental lexicon of hearing non-signers and proficient signers: evidence of cross-modal priming

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The present study investigated the priming effect of iconic signs in the mental lexicon of hearing adults. Non-signers and proficient British Sign Language (BSL) users took part in a cross-modal lexical decision task. The results indicate that iconic signs activated semantically related words in non-signers' lexicon. Activation occurred regardless of the type of referent because signs depicting actions and perceptual features of an object yielded the same response times. The pattern of activation was different in proficient signers because only action signs led to cross-modal activation. We suggest that non-signers process iconicity in signs in the same way as they do gestures, but after acquiring a sign language, there is a shift in the mechanisms used to process iconic manual structures.

**Keywords:** iconicity; sign language; gesture; cross-modality; priming

Manual communication has undergone intensive scrutiny over the past years with researchers proposing a clear distinction between two types of hand gesticulation. Gestures, first, take place during ongoing speech and convey important information not always encoded in the acoustic signal (McNeill, 1992). Natural sign languages, in contrast, are independent from speech and have the same expressive power as spoken languages because of their conventionalised structure and degree of systematization (Stokoe, 1960). While there are important differences between signs and gestures, there are also strong similarities. Iconicity, the ability to incorporate physical features of a referent into their structure, is a prevalent feature in both signs and gestures. In fact, many signs overlap in form and meaning with some of the co-speech gestures used by speakers (e.g., signers and speakers are likely to represent the concept of *eating* by bringing a hand to the mouth). These similarities have implications for hearing adults learning a sign language as a second language (L2). At first exposure to a sign language, learners are capable of recognising the meaning of a large number of signs despite their inexperience with a language in the manual-visual modality. In the same way that English speakers with no knowledge of French can understand the meaning of the word *banque*, non-signers are capable of recognising signs with clear mappings with their referent (i.e., iconic signs). A potential explanation behind this could relate to speakers' experience in processing and producing iconic gestures during speech.

Based on evidence that iconic gestures activate semantically related words (Yap, So, Yap, Tan, & Teoh, 2011), the present study investigated patterns of activation in non-signers' mental lexicon after viewing iconic signs for the first time. It was also explored whether activation varies as a function of the type of iconicity (i.e., signs depicting actions or perceptual features of an object). Lastly, it investigated whether proficient L2 signers showed a different pattern of activation from non-signers when processing iconic signs.

The role of iconicity has been an important focus of attention in much sign language research. With some exceptions (Ortega, Sumer, & Ozyürek, 2014; Thompson, Vinson, Woll, & Vigliocco, 2012), most studies suggest that iconic signs are not favoured during first language acquisition because young children lack the world knowledge to associate manual symbols with their referent (Meier, Mauk, Cheek, & Moreland, 2008; Newport & Meier, 1985; Orlansky & Bonvillian, 1984). In contrast, it has been consistently reported that iconicity facilitates sign learning in adult non-signers. Lieberth and Gamble (1991) taught a group of hearing adults with no knowledge of a sign language a set of iconic and arbitrary signs and then tested their ability to recall them at two points in time. Over a short period (10 minutes), participants were able to recall the meaning of both types of sign with equal ease, but over an extended period (two weeks), iconic signs were recalled significantly better. Campbell, Martin, and White (1992) replicated these findings by administering a forced choice recognition task to non-signers and

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beginner signers. During the training phase, participants were shown a series of iconic and arbitrary signs and were asked to remember them as accurately as possible. During the testing phase, a list including previously seen and novel signs was presented and participants had to discriminate old from novel signs. Both groups of participants were significantly better at recalling and naming iconic over arbitrary signs regardless of their different experiences with a sign language. More recently, the effect of iconicity in translation tasks by adult signers and non-signers was investigated (Baus, Carreiras, & Emmorey, 2012). The study reports that non-signers were significantly faster at translating iconic than arbitrary signs, whereas proficient signers were slower at translating the iconic sign equivalents. These results were interpreted as evidence that clear sign-referent mappings facilitate recall in the early stages of sign acquisition but have a detrimental effect in proficient signers. Specifically, the authors argue that in non-signers ‘iconicity appears to strengthen the link between a sign’s form and its representation in conceptual memory’ (p. 8). The negative effect observed in proficient signers was explained as iconic signs having multiple meaning associations causing slower reaction times due to a larger number of available translations. Together these studies demonstrate that individuals with no prior exposure to a sign language interpret and recall iconic signs more easily than arbitrary signs but after gaining proficiency in a sign language the relevance of iconicity diminishes.

A plausible explanation behind non-signers’ preference for recalling iconic signs may relate to their similarity with iconic gestures. Gestures are a fundamental aspect of human communication and are present in all ages and cultures. They may have deictic functions and refer to objects in the immediate environment by pointing (Kita, 2003), or they can have conventionalised forms within a culture, like the emblem ‘thumbs-up’ (McNeill, 1992). Some gestures also involve re-enactment of an action (e.g., mimicking the action of drinking), or they can represent visual properties of objects (e.g., tracing the shape of a ball; Kita, 2000; McNeill, 1992). The common misconception that gestures and signs are equivalent structures may lie in that pointing, emblems and iconicity are also common features in all sign languages. Signs and gestures, however, have significant differences at the structural and processing level. Both types of manual structures can encode physical attributes of their referent (iconicity), but a clear distinction is that while gestures are holistic units without sub-lexical organisation (McNeill, 1992), signs consist of meaningless phonological constituents, e.g., handshape, location, movement and orientation (Brentari, 1999; Stokoe, 1960). With regards to processing, signers decompose the building blocks of signs to retrieve a cohort of potential candidates for lexical access (Baus, Gutiérrez-Sigut, Quer, & Carreiras, 2008;

Carreiras, Gutiérrez-Sigut, Baquero, & Corina, 2008; Dye & Shih, 2006). In contrast, gestures are processed as holistic entities in parallel with ongoing speech to integrate information from two distinct modalities into a unified message (Kelly, Creigh, & Bartolotti, 2010; Ozyürek, Willems, Kita, & Hagoort, 2007). The differences at the structural and processing level clearly show that despite some superficial similarities, gestures lack phonological organisation and are dependent on speech for interpretation. Nonetheless, because non-signers can access the meaning of iconic signs without having any knowledge of a sign language, it is plausible to suggest they do so by processing their iconic features.

Overwhelming empirical evidence has shown that speech and gestures are not independent but rather form part of a complex, highly integrated system that convey important semantic and pragmatic information of a multi-modal utterance (Kelly et al., 2010; Kita & Özyürek, 2003; McNeill, 1992). The effect gesture has in speech has been observed during syllabic articulation (Gentilucci & Dalla Volta, 2008), sentence processing (Ozyürek et al., 2007) and neural activation (Dick, Goldin-Meadow, Hasson, Skipper, & Small, 2009). The close links between gesture and speech have also been found at the lexical level, given that gestures aid word retrieval (Krauss, 1998; Yap et al., 2011). For instance, Yap and colleagues (2011) asked participants to take part in a lexical decision task in which they had to discriminate real from non-words. Target words (e.g., *bird*) could be preceded by an iconic gesture to which they were semantically related (e.g., flapping hands) or unrelated (e.g., tracing a square with the fingers). Words were identified significantly faster when they were preceded by semantically related gestures. These findings support previous claims that iconic gestures are important for speech production because they activate conceptual features of a referent to retrieve its linguistic label (de Ruyter, 1998; Krauss, Chen, & Chawla, 1996). Considering the scenario in which hearing non-signers have contact for the first time with a conventionalised sign language, it cannot be expected that they will process iconic signs through phonological decomposition as deaf signers (Baus et al., 2008; Dye & Shih, 2006; Gutiérrez, Müller, Baus, & Carreiras, 2012) because they lack a visual phonological system and a signed lexicon. Instead, non-signers would be expected to exploit their experience of processing iconic gestures by using the visual image generated by iconic signs (de Ruyter, 1998, 2007; Krauss, 1998; Krauss et al., 1996). To that effect, interpretation of iconic signs would lead to activation of semantically related words across modalities.

Iconic signs are not a homogenous group. The term ‘iconicity’ has been widely used as an umbrella term to encompass signs depicting features of a concept. However, signs make links with their referent in multiple ways. Figure 1 shows that in British Sign Language (BSL), for

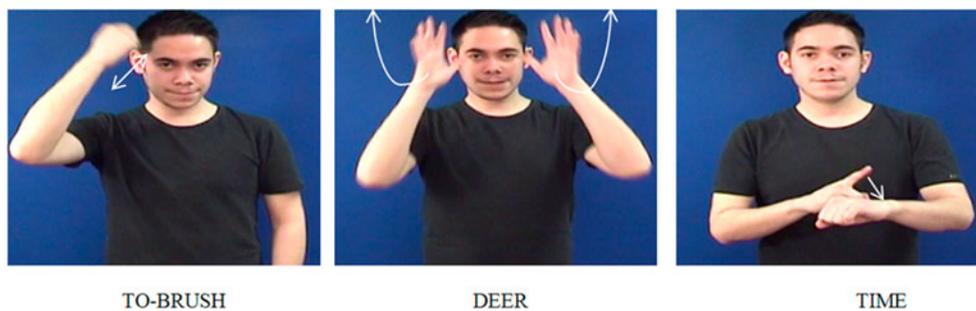


Figure 1. BSL signs with different sign-referent associations. The sign TO-BRUSH mimes the action of a person brushing his hair, the sign DEER depicts a deer's antlers and the sign TIME is produced by pointing at an imaginary watch.

instance, iconic signs can be pantomime of an action (e.g., TO-BRUSH),<sup>1</sup> they can depict a part of a referent (e.g., DEER), or they can represent a concept associated with an object (e.g., TIME) (Mandel, 1977; Taub, 2001). In addition, iconic elements can be incorporated in a sign as a whole (Klima & Bellugi, 1979) or in one of its phonological components (Cuxac, 1999; Johnston & Schembri, 2007; Pietrandrea, 2002; van der Kooij, 2002). The inferences required to see the links between different types of iconic signs and their referent vary in complexity and thus vary in accessibility for non-signers. This is captured in the notion that non-signers have access to the meaning of only those signs with transparent links to their referent (Klima & Bellugi, 1979). For instance, signs depicting body movement would be expected to be understood faster and more accurately than signs depicting objects because the former can be easily mapped to motoric representations (i.e., the sign TO-BRUSH resembles the action of brushing, but the sign DEER is an abstract representation of a deer's antlers). In addition, adults have experience performing such actions and in many instances, the gestures associated with them are highly conventionalised and thus easier to recognise. The transparent links between actions and their referent have a clear impact during child development. Young hearing children are more accurate at interpreting signs depicting actions than signs depicting features of an object (Tolar, Lederberg, Gokhale, & Tomasello, 2008). It is yet to be investigated whether action signs are mapped to their referent more easily by adults than perceptual signs.

Based on the finding that iconic gestures activate semantically related words through the shared links to the conceptual system (Krauss, 1998; Krauss et al., 1996), a lexical decision task was administered to a group of hearing adults with no knowledge of any sign language and to a group of proficient BSL signers. Following a similar paradigm as that of Yap and colleagues (Yap et al., 2011), participants were asked to discriminate between words and non-words preceded by conventionalised iconic signs (as opposed to iconic gestures). For non-signers, it was predicted that presentation of iconic signs would

activate semantically related words. Additionally, because some signs map the iconic properties of their referent more clearly than others, it was also explored whether different types of iconic signs would lead to different rates of lexical activation. More specifically, if comprehension of signs depicting perceptual features of an object is more cognitively taxing because of their less transparent links with their referent (e.g., DEER is less transparent than TO-BRUSH), faster response times would be expected in words preceded by action signs. Proficient signers, in contrast, have developed a signed lexicon so it may be that they rely less on iconicity than hearing non-signers to access the meaning of signs. In fact, iconicity may have a negative effect due to their multiple associated meaning as shown in a recent translation task (Baus et al., 2012). For these reasons, proficient signers are expected to exhibit a different pattern of lexical activation from non-signers.

## Methodology

### Participants

The non-signing group consisted of 21 hearing native speakers of English (nine female, mean age = 27.87 years) with no knowledge of BSL. The group of proficient signers consisted of 21 hearing native speakers of English (14 female, mean age = 31.50 years) who had achieved the British National BSL Level 2 certification. A one-sample *t*-test on participants' self-reported years of BSL experience revealed that there was no significant difference on their length of exposure to BSL [mean: 5.20 years;  $t(20) = 0.567$ ,  $p = 0.387$ ]. Both groups of participants were right-handed and reported having normal or corrected vision.

### Stimuli

The stimuli for this study came from a set of 300 individual BSL signs recorded by a native signer against a blue screen and without mouthing patterns so as to avoid giving cues of the meaning of the sign. The video clips of individual signs were shown with their closest English translation to a different group of 15 hearing non-signers

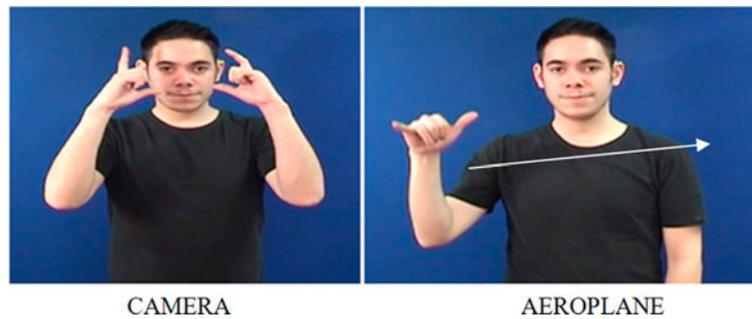


Figure 2. The BSL sign CAMERA (left) is an action sign because it represents body motion associated with an object. The sign AEROPLANE (right) is a perceptual sign because it depicts the shape of an object.

to rate them for their degree of iconicity in a 7-point Likert scale (1 being highly arbitrary and 7 highly iconic). The ratings of all signs were averaged across participants to obtain the mean iconicity rating for the 300 signs. Based on these ratings, a 3.5 cut-off point was set to divide arbitrary from iconic signs. Only items with mean iconic rating of 3.5 or higher were used in the experiment. From this cohort, two researchers independently selected signs that depicted body motion (*action* signs) or physical features of an object (*perceptual* signs; see Figure 2). Intercoder disagreements (5% of the signs) were discussed until full agreement was reached. The final experimental stimuli consisted of a total of 28 action and 28 perceptual signs with mean iconicity ratings of 6.32 (SD = 0.35) and 5.17 (SD = 0.96), respectively. An independent sample *t*-test revealed that there was a significant difference in iconicity ratings between both sign groups [ $t(27) = 9.765$ ,  $p < 0.001$ ]. This measure of iconicity was interpreted as actions signs having more transparent links to their referents than signs incorporating perceptual characteristics of objects, and as a result, they would lead to greater lexical activation (i.e., greater semantic priming).

Each sign in the action and perceptual condition was matched with a semantically related word from the Edinburgh Associative Thesaurus (Kiss, Armstrong, Milroy, & Piper, 1973). To date, there is no empirical data on semantic associations across modalities (word-gesture/sign). It was therefore assumed that the BSL sign would have the same effect on semantically related words as its English translation. In other words, it was assumed that the BSL sign CAMERA would activate the semantically related word 'photo' in the same way as in the spoken modality the word 'camera' activates the word 'photo'. The semantically related words in each condition were controlled for length and frequency. The mean length of words in the action condition was 4.68 (SD = 0.81) and 4.18 (SD = 1.21) for perceptual signs. A paired sample *t*-test showed that there was no significant difference in the number of letters between both conditions [ $t(27) = 1.537$ ,  $p = 0.136$ ]. The word 'frequency' values were collected from the MRC Psycholinguistic Database (Wilson, 1988).

The mean frequency values for the words in the action and perceptual condition were 81.00 (SD = 105.95) and 82.93 (SD = 77.15), respectively. An independent sample *t*-test showed that there was no significant difference between the frequencies of both word groups [ $t(53) = 0.004$ ,  $p = 0.990$ ]. Action and perceptual signs were also paired with a semantically unrelated word. These were the semantically related words used in the other sign condition (i.e., the semantically related words in the action condition were the semantically unrelated words for the perceptual condition and vice versa). Lastly, signs were matched with nonsense pseudowords (e.g., *twark*) to allow participants to make the lexical decision. These words were drawn from ARC non-word database (Rastle, Harrington, & Coltheart, 2002). See Appendix 1 for a full list of experimental items.

In sum, each sign in the action and perceptual conditions were shown four times: with a semantically related word, with a semantically unrelated word and with two different nonsense words making a total of 224 sign-word pairs. Signs were paired with two different pseudowords so that participants had to reject a target word the same number of times that they accepted a real word. The experiment was divided into two blocks with a break in between. Each block consisted of 56 sign-pairs from the action condition and 56 pairs from the perceptual condition making a total of 112 sign-word pairs in each block. Blocks contained equal number of action and perceptual signs as well as equal number of related and unrelated sign-word pairs. Ten participants saw Block 1 first and Block 2 second, and the rest of participants saw the blocks in reversed order.

### Procedure

Participants were tested individually on a portable computer in a quiet room. The programme E-prime v. 2.0.8.90 (Schneider, Eschman, & Zuccolotto, 2002) was used to display trials and measure reaction times. The procedure was as follows: first, a fixation point appeared in the centre of the screen for 500 ms. This was followed by the

video clip of the iconic sign (e.g., TO-SLAP) which lasted 2000 ms. Immediately after the video stopped playing, a lower case target word in black letters over white background appeared in the middle of the screen for 1500 ms. Participants were instructed to pay close attention to the sign and decide whether the word that followed was a real English word (e.g., *hand*) or not (e.g., *twark*). It was emphasised that they could not focus only on the words and ignore the signs because they were going to be tested on the signs shown. Participants were asked to press as quickly and accurately as possible the key 'J' with their right (dominant) hand if the word was real and the 'F' key with their left (non-dominant) hand if the target was a nonsense word. Trials were presented in pseudo-randomised order so as to avoid repetition of consecutive experimental items.

Reaction times were recorded in milliseconds from the onset of the target word. On the total raw data-set, incorrect responses (2.0%) and responses 2.5 standard deviations away from the mean (2.2%) were classed as outliers and removed from the analysis.

## Results

A  $2 \times 2 \times 2$  design was used with group as between-subjects factor (non-signers vs. proficient signers) and type of iconicity (action vs. perceptual) and semantic relatedness (related vs. unrelated) as within-subjects factor. A mixed-design analysis of variance (ANOVA) by participant ( $F_1$ ) and by item ( $F_2$ ) revealed that there was a main effect of type of iconicity [ $F_1(1,39) = 18.669, p < 0.001, \eta^2 = 0.324; F_2(1,54) = 3.723, p = 0.050, \eta^2 = 0.065$ ] with words being recognised faster when they were preceded by action signs (mean = 579.100 ms, SE = 9.161) than when they were preceded by perceptual signs (mean = 590.514 ms, SE = 9.437). There was also a main effect of relatedness [ $F_1(1,39) = 14.560, p < 0.001, \eta^2 = 0.272; F_2(1,54) = 6.952, p = 0.011, \eta^2 = 0.114$ ]. Semantically related sign-word pairs led to faster response times (mean = 579.131 ms, SE = 9.343) than semantically unrelated pairs (mean = 590.483, SE = 9.437). There was a significant main effect of group in the per item analysis [ $F_1(1,39) = 0.897, p = 0.349, \eta^2 = 0.022; F_2(1,54) = 21.024, p < 0.001, \eta^2 = 0.280$ ] with proficient signers responding faster (mean = 570.062, SE = 3.760) than non-signers (mean = 594.443, SE = 3.760). None of the two-way interactions were significant [ $F_1 < 1; F_2 < 1$ ]. There was, however, a significant three-way interaction in the per participant analysis [ $F_1(1,39) = 3.228, p = 0.043, \eta^2 = 0.076; F_2(1,54) = 1.279, p = 0.263, \eta^2 = 0.023$ ]. No main effects or interactions were found in the error analysis. Based on the three-way interaction, we analysed response times per group separately.

For non-signers, we performed a 2 (related vs. unrelated)  $\times$  2 (actions vs. perceptual) repeated measures

ANOVA by participants ( $F_1$ ) and by items ( $F_2$ ). The analysis revealed a main effect of type of iconicity in the by-participant analysis [ $F_1(1, 19) = 5.751, p = 0.027, \eta^2 = 0.232; F_2(1, 27) = 1.310, p = 0.262, \eta^2 = 0.046$ ]. Participants were faster at identifying words paired with action signs (mean = 589.776 ms, SE = 4.896) than words paired with perceptual signs (mean = 599.11 ms, SE = 6.389). There was a main effect of relatedness [ $F_1(1, 19) = 10.896, p = 0.004, \eta^2 = 0.364; F_2(1, 27) = 8.306, p = 0.008, \eta^2 = 0.235$ ]. Real words were recognised faster when they were preceded by semantically related signs (mean = 586.10 ms, SE = 12.466) than when they were paired with unrelated signs (mean = 601.075 ms, SE = 13.255). The interaction between type of iconicity and relatedness was not significant [ $F_1 < 1; F_2 < 1$ ] (see Figure 3). No main effects or interactions were found in the error analysis.

These results support the hypothesis that iconic signs activate semantically related words in hearing non-signers. However, contrary to the initial prediction, it appears that the more direct mappings in action signs do not generate larger facilitation effects because action and perceptual signs yielded similar reaction times in the semantically related condition.

For proficient signers, a 2 (related vs. unrelated)  $\times$  2 (actions vs. perceptual) repeated measures ANOVA by participants ( $F_1$ ) and by items ( $F_2$ ) was carried out. The by-participant analysis revealed a significant main effect of type of iconicity [ $F_1(1, 19) = 12.066, p = 0.003, \eta^2 = 0.388; F_2(1, 27) = 2.664, p = 0.114, \eta^2 = 0.090$ ]. Words paired with action signs yielding faster response times (mean = 563.914, SE = 12.446) than words paired with perceptual signs (mean = 576.102, SE = 13.169). There was no main effect of relatedness [ $F_1(1, 19) = 3.279, p = 0.090, \eta^2 = 0.147; F_2(1, 27) = 1.074, p = 0.309, \eta^2 = 0.038$ ]. Semantically related (mean = 566.914,

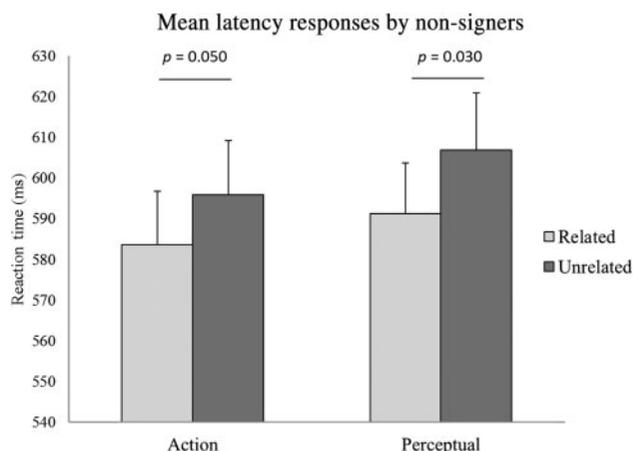


Figure 3. Mean response times in ms for target words preceded by related and unrelated BSL sign for hearing non-signers. Bars represent standard error.

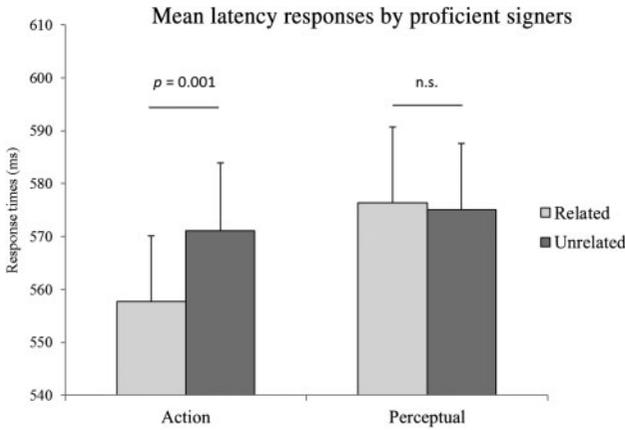


Figure 4. Mean response times in ms for target words preceded by related and unrelated BSL sign for hearing proficient signers. Bars represent standard error.

SE = 13.197) and unrelated pairs (mean = 573.685, SE 12.501) yielded similar response times. There was a significant two-way interaction between type of iconicity and semantic relatedness in the by-participant analysis [ $F_1(1, 19) = 5.277, p = 0.033, \eta^2 = 0.217; F_2(1, 27) = 2.200, p = 0.150, \eta^2 = 0.075$ ]. Pairwise *t*-tests after Bonferroni corrections revealed that in the action condition, semantically related pairs yielded faster response times (mean = 556.322, SE = 12.463) than semantically unrelated pairs (mean = 571.505, SE = 12.84;  $t(19) = 3.302, p = 0.004$ ). In the perceptual condition, in contrast, the difference in response times between semantically related (mean = 576.340, SD = 14.339) and unrelated pairs (mean = 575.863, SD = 12.599) did not reach significance [ $t(19) = 0.080, p = 0.937$ ]. The analysis also revealed that words associated with semantically related action signs were detected significantly faster than words preceded by semantically related perceptual signs [ $t(19) = 3.983, p = 0.001$ ]. In contrast, semantically unrelated words preceded by action signs were identified at the same rate as words preceded by semantically unrelated perceptual signs [ $t(19) = 0.917, p = 0.371$ ] (see Figure 4). The error analysis revealed no significant main effects or interaction.

These data suggest that iconic signs do not activate the mental lexicon of proficient signers in the same way as non-signers, given that semantic relatedness was irrelevant in the activation of target words in the perceptual condition. Critically, while the distinction between different types of iconicity did not affect lexical activation in hearing non-signers, it had an effect on proficient signers. More specifically, only action signs caused cross-modal lexical activation. The different pattern of results between non-signers and proficient signers is interpreted as evidence that knowledge of a sign language affects the mechanisms of processing iconic signs.

Following up on the previous analyses, we calculated the magnitude of the priming effect for action and perceptual signs (Response Time (RT) unrelated condition – RT related condition = effect size) in non-signers and signers. Table 1 shows the mean response times for each condition per group with the differences between unrelated and related conditions. For non-signers, a paired samples *t*-test revealed that the magnitude of the priming effect between action and perceptual signs did not reach significance [ $t(19) = 0.614, p = 0.547$ ]. For proficient signers, however, the magnitude of the priming effect was significantly different [ $t(19) = 2.297, p = 0.033$ ]. From these data, it is possible to confirm that action and perceptual signs activate semantically related words to the same extent in hearing non-signers. In the case of proficient signers, cross-modal activation only occurs with action and not perceptual signs.

**General discussion**

This study set out to investigate patterns of cross-modal lexical activation in hearing non-signers and proficient signers after viewing conventionalised iconic signs. Based on studies showing that iconic gestures activate semantically related words (de Ruiter, 1998; Krauss, 1998; Krauss et al., 1996; Yap et al., 2011), it was predicted that iconic signs would have a similar effect in the lexicon of non-signers because they would also activate representations in the conceptual system and lead to lexical activation. It was also speculated that signs depicting

Table 1. Mean response time (standard error in parentheses) and magnitude effect across conditions per group.

Condition	Mean response times per group	
	Non-signers	Signers
Action related	583.146 (13.22)	561.451 (12.91)
Action unrelated	594.985 (13.50)	576.818 (13.17)
Difference		11.839
Perceptual related	589.05 (14.04)	582.86 (13.71)
Perceptual unrelated	607.16 (14.16)	582.965 (13.82)
Difference		18.110

referents with different mappings (i.e., signs depicting actions or perceptual features of objects) would facilitate activation in different degrees. Proficient hearing signers were expected to have a different pattern of lexical activation because they have developed a manual lexicon and should process iconic signs through a different mechanism. In order to test these predictions, a cross-modal lexical decision task was implemented to a group of hearing non-signers and a group of hearing proficient BSL signers. The results showed that iconic signs activated semantically related words in hearing non-signers regardless of their inexperience with BSL. However, the distinction between action and perceptual signs was irrelevant because semantically related words were activated at the same rate by both types of signs. The results also show that iconic signs did not affect the mental lexicon of proficient signers in the same way as non-signers because only action signs activated semantically related words.

Cross-modal sign-word activation has been reported in bilingual deaf and hearing signers with an established manual vocabulary (Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011; Ormel, Hermans, Knoors, & Verhoeven, 2011; Shook & Marian, 2012). The non-signing participants of the present study, however, had no knowledge of BSL, thus the mechanism by which iconic signs activated their lexicon must be different from that of proficient signers. The results from the present study suggest that the capacity to activate semantically related words is not restricted to iconic gestures because iconic signs also displayed the same effect. The explanation put forward here is that experience in processing iconicity in gestures caused lexical activation during the recognition of iconic signs.

Overwhelming evidence has demonstrated that gestures are a fundamental component of human communication and that speakers of all ages and cultures simultaneously integrate information from the verbal and manual signal to decode the meaning of a multi-modal utterance (Kelly et al., 2010; Ozyürek et al., 2007). Iconic gestures, in particular, play a prominent role during naturalistic interaction because they facilitate the exchange of complex information (Campisi & Özyürek, 2013) and clarify lexical ambiguity (Holler & Beattie, 2003). Addressees are sensitive to iconic gestures because they have to decode them to capture information not always present in the acoustic signal. Relevant to this study is the finding that gestures facilitate lexical retrieval (Krauss, 1998) and importantly, that iconic gestures prime words because of 'the tight semantic link between iconic gestures and words' (Yap et al., 2011, p. 108). The present data draw parallels with the gesture literature in that iconic signs lead to lexical activation in non-signers.

The processing mechanism of iconic gestures and how they spread activation to words in the mental lexicon is

not yet fully understood. However, research has generated a number of proposals supporting the idea they do so by mediation of the conceptual system. The Image Activation Hypothesis, for instance, proposes that iconic gestures help to maintain the visual characteristics of a referent, while the linguistic system performs a search of a lexical item (de Ruiter, 1998). The Lexical Retrieval Hypothesis, on the other hand, argues that iconic gestures activate conceptual information which in turn leads to activation of semantically related words through cross-modal priming (Krauss, 1998; Krauss et al., 1996). These hypotheses suggest that iconic gestures ground in physical reality the spatial features of a concept, while the linguistic system searches for its label. Despite some differences in their theoretical grounding, both hypotheses support the notion that iconic gestures activate conceptual features of a referent and this leads to lexical activation. Decoding the meaning of iconic gestures is a key component of human communication, and given their structural similarities with iconic signs, we argue that any iconic manual symbol taps into the conceptual system of hearing non-signers causing lexical activation. In other words, manual structures with iconic links with their referent (gestures and signs alike) activate semantically related words by mediation of the conceptual system.

We also investigated the impact of different types of iconicity during lexical activation. Iconicity is not a categorical property but rather lies in a continuum, with some iconic signs being easier to understand by non-signers than others (Klima & Bellugi, 1979). It was expected that comprehension of action signs would be favoured by non-signers because of their direct mappings with their referent (i.e., the sign TO-BRUSH resembles the act of brushing, but the sign DEER is just an abstract representation of a deer's antlers). The iconicity ratings by non-signers supported the assumption that the links between both types of signs and their referents were more transparent for action signs than signs encoding perceptual features of an object. Thus, it was predicted that the clearer mappings between action signs and their referents would lead to faster activation of semantically related words. Our data did not support this prediction because semantically related words preceded by action signs yielded similar response times as words preceded by perceptual signs. These findings, we argue, give additional credence to the hypothesis that, regardless of their referent, iconic signs are processed as gestures because non-signers rely on their visual features to assign them a meaning.

Gestures are a crucial component of every communicative interaction because they make significant contributions towards the understanding of a message. However, gestures are intrinsically ambiguous, and their meaning is heavily dependent on co-occurring speech (Beattie & Shovelton, 1999; McNeill, 1992). For example, the

gesture of tracing a square with two fingers will convey entirely different concepts if it co-occurs with the phrases 'it was a small window' or 'he won't hear anyone else's opinion'. Despite the iconic gesture encoding crucial information for the interpretation of a message, speech is central to deduce the intended meaning. In other words, the information encoded in co-occurring speech will influence the meaning of iconic gestures. This has implications on the order of occurrence of gestures and speech during communicative interactions. In naturalistic settings, iconic gestures almost always occur before or accompanying the co-expressive word; they are rarely initiated after (Morrel-Samuels & Krauss, 2001). This sequence allows iconic gestures to tap on conceptual representations of the referent and activate plausible lexical interpretations. In the present study, non-signers may have activated a range of lexical items that could be plausible interpretations of the iconic signs, and as a consequence, words that were semantically related to these interpretations were also activated. Target words were presented immediately after the iconic signs; therefore, semantically related associates remained active which explains why related targets were detected faster than semantically unrelated. The process to interpret gestures appears to follow the same route regardless of their referent given that action and perceptual signs yielded the same reaction times. If we accept that iconic gestures do not have a fixed meaning and that their interpretation is context-dependent and subject to co-occurring speech (Beattie & Shovelton, 1999; McNeill, 1992), it could be anticipated that both types of iconic signs are processed following the same mechanism. It is the speech content and not degree of transparency what determines the meaning of iconic gestures. The present data suggest that regardless of the type of referent, iconic signs lead to the activation of multiple lexical items that can potentially be associated with a given sign, and these in turn activate semantically related words.

Our results also show that type of iconicity had a different effect in lexical activation in proficient signers. Namely, words preceded by semantically related perceptual signs did not lead to faster lexical retrieval. The significant interaction between type of iconicity and semantic relatedness clearly shows that signs depicting perceptual features of an object did not have the same effect on word activation as action signs. While semantically related words paired with action signs were identified significantly faster than unrelated words, semantically related words paired with perceptual signs remained unaffected. A possible explanation behind these differences might relate to perceptual signs being associated with more than one meaning.

The negative effect on lexical recognition due to words having multiple meanings has been attested in signed and spoken languages (Baus et al., 2012; Rodd, Gaskell, &

Marslen-Wilson, 2002). In order to evaluate this possibility, additional data were collected. Five hearing learners of BSL (same level as the proficient signers in the study) were shown the signed stimuli and were asked to provide all the meanings they could associate with them. It was decided to do this with sign L2 learners instead of deaf signers because the latter would have a much broader knowledge of BSL and thus would not reflect the knowledge of proficient L2 learners. The average number of meanings for action signs (mean = 2.43) and signs depicting perceptual features of a referent (mean = 2.32) were not significantly different [ $t(27) = 0.361, p = 0.721$ ]. Closer inspection of the data showed that the words associated with action signs were polysemes, i.e., they were extensions of the core meaning of the sign (e.g., the sign TO-EAT included responses like *eat, dinner, breakfast, lunch, nibbles* as associate meanings). In contrast, signs depicting perceptual features of an object included many homonyms, i.e., signs with the same phonological form but with different unrelated meanings (e.g., the sign DRESS was also glossed as *torso, body, clothes*). After removing the words that were extension of the core meaning of the BSL signs, the number of meanings associated with action signs (mean = 1.25) was significantly different to the number of meanings associated with perceptual signs [mean = 1.61,  $t(27) = 2.287, p = 0.03$ ]. This analysis shows an important difference between both types of iconic signs: while action signs were often associated with words within the same semantic domain, perceptual signs included significantly more unrelated meanings to the BSL prime. However, even though this analysis indicates that there is a more dense lexical neighbourhood for perceptual than action signs, it remains unclear why perceptual signs did not lead to cross-modal activation.

It may be that for perceptual signs, participants selected one of the possible meanings of the sign that was not the intended for the task. For instance, the sign BUTTERFLY was paired with the semantically related word 'net'. However, the phonological form of this sign is the same as the sign ANGEL. It is plausible that during the task, participants selected an alternative meaning of the sign (e.g., ANGEL) and this led to activation of words within this semantic domain (e.g., 'Heaven') and not in the semantic domain intended in the task (e.g., 'net'). The lack of mouthing patterns or contextual information to disambiguate these signs may have led participants towards a different meaning not relevant to the experimental trial (e.g., 'Heaven' as opposed to 'net'). In order to assess this possibility, we looked at the preferred meaning for the stimulus materials by the five sign L2 learners mentioned above. We calculated the proportion of participants that provided the intended meaning of the task as their first choice and found that the proportion for actions signs (mean: 0.88, SD = 0.14) was significantly

higher than for perceptual signs [mean: 0.75;  $t(28) = 2.049$ ,  $p = 0.05$ ]. This suggests that the absence of cross-modal activation in perceptual signs could be attributed to their denser lexical neighbourhoods and to participants selecting a meaning not relevant to the task. Importantly, these analyses show that rather than processing the iconic features of signs to assign them a meaning, proficient signers associate manual forms with a specific meanings and this leads to more constrained lexical activation (i.e., activation only of words associated with one of the specific meanings of the sign).

In light of the different patterns of activation, it is possible to suggest that non-signers and proficient signers process iconic signs through significantly different mechanisms. While the flexibility of allocating meaning to iconic gestures (signs) helped non-signers in the task, signers' knowledge of the finite number of meanings of iconic signs had a detrimental effect. That is, many signs are iconic in nature, but unlike gestures, they are not randomly assigned to any referent with overlapping features; they are constrained by the rules of a linguistic system. Sign learners may be aware of the form-meaning links between sign and referent via iconicity, but they have now established clear links to the permissible referents that an iconic sign can be mapped to (e.g., in BSL, tracing the shape of a butterfly's wings is not a permissible form of BUTTERFLY, and similarly, the manual form of BUTTERFLY cannot mean AEROPLANE). Iconic gestures, on the other hand, can have a wide range of forms and meanings and these associations are mainly driven by the content of the ongoing speech.

This study is one of the first attempts to evaluate the impact of different types of iconicity during sign processing in hearing adults with different levels of sign language proficiency. The distinction between action signs and signs depicting perceptual features of a referent did not show a significant effect in non-signers because the way they process iconicity allowed for flexibility during the interpretation of iconic signs. In contrast, the results from proficient signers clearly show that a signed lexicon affected the way in which they processed iconic signs. This is caused by proficient signers not relying on speech to interpret their meaning. After acquiring a sign language, hearing adults develop specific links between an iconic manual form and the conceptual system and meanings are allocated in a systematic way (i.e., the meaning of iconic signs is not flexible as in iconic gestures). The different patterns of activation between action and perceptual signs are evidence that cross-lexical activation in proficient signers is constrained by linguistic mechanisms, with signs with multiple unrelated meaning leading to reduced facilitation effects. Given that the present study replicates previous findings regarding the negative effect of iconicity in proficient signers (Baus et al., 2012), future research should include exhaustive information on the stimulus

materials such as number of translation, neighbourhood density and frequency to shed light on the factors that facilitate or hinder sign processing.

The present study shows that in the same way that L2 learners can understand the meaning of foreign words because of their phonological and semantic overlap with words in their own lexicon (e.g., *bank* and *banque*), non-signers can also recognise a large number of iconic signs because of their similarities with their own gestures. Given that both iconic manual structures exhibit similar behavioural responses in non-signers' mental lexicon, it is possible to suggest that iconic gestures act as some form of 'cognates' within the manual modality at the early stages of sign language learning. Our study also suggests that lexical representation in hearing sign language learners is initially established via the gestural system. After exposure to a conventionalised sign language, however, learners modify the processing mechanism of the manual signal because they have established systematic links between signs and the conceptual system. This study strengthens the arguments for the gestural origin of a manual linguistic system and points at crucial processing differences between signs and gestures. It also contributes towards our understanding of how language learning takes place and how existing information is exploited as footing to develop new knowledge.

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### Note

1. By convention, block capitals are used to represent the English gloss of a sign.

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### Appendix 1. List of sign-word pairs per block

	Sign gloss	Iconicity	Related	Un-related	Nonsense1	Nonsense2
Block 1						
1	CAMERA	Action	photo	net	fap	knush
2	INJECT	Action	needle	teeth	rop	thafe
3	STIR	Action	spoon	buckle	gourn	slont
4	JUGGLE	Action	clown	deaf	cep	creum
5	KEY	Action	lock	carrot	snurf	ren
6	SLAP	Action	hand	talk	twark	sout
7	MARCH	Action	army	bird	swod	speem
8	PULL	Action	push	pond	lan	stould
9	TIE	Action	neck	forest	bamth	fub
10	CORKSCREW	Action	wine	wheel	stroob	tud
11	VIOLIN	Action	string	face	wof	trewt
12	SKI	Action	snow	fly	ceeb	spresh
13	CANOE	Action	rapids	watch	fince	slome
14	HAMMER	Action	nail	clothes	spirpe	slunt
15	BOX	Perceptual	square	heavy	rilm	fusk
16	RHINO	Perceptual	mud	food	flob	stilch
17	CLOUD	Perceptual	sky	pull	reuth	trebe
18	RAKE	Perceptual	grass	fuel	splon	vapse
19	AEROPLANE	Perceptual	fly	light	biefen	knurke
20	DRESS	Perceptual	girl	hair	wef	ciff
21	MOON	Perceptual	sun	paint	tarbam	crolt
22	HOUSE	Perceptual	garden	smell	cluft	croice
23	AERIAL	Perceptual	tv	tin	pud	sem
24	SICK	Perceptual	ill	break	poy	gern
25	PILLOW	Perceptual	bed	animal	pebe	spom
26	TREE	Perceptual	wood	cards	slart	flane
27	TURTLE	Perceptual	sea	letter	brulk	plail
28	BOTTLE	Perceptual	beer	shirt	hup	clut

## Appendix (Continued)

	Sign gloss	Iconicity	Related	Un-related	Nonsense1	Nonsense2
Block 2						
1	BUTTERFLY	Perceptual	net	photo	knush	fap
2	CROCODILE	Perceptual	teeth	needle	thafe	rop
3	BELT	Perceptual	buckle	spoon	slont	groun
4	HEARING AID	Perceptual	deaf	clown	creum	cep
5	RABBIT	Perceptual	carrot	lock	rem	snurf
6	GOSSIP	Perceptual	talk	hand	bothe	stave
7	BINOCULARS	Perceptual	bird	army	sout	twark
8	DUCK	Perceptual	pond	push	stould	lan
9	DEER	Perceptual	forest	neck	fub	bamth
10	BICYCLE	Perceptual	wheel	wine	tud	stroob
11	SMILE	Perceptual	face	string	trewt	wof
12	HELICOPTER	Perceptual	fly	snow	spresh	ceeb
13	CLOCK	Perceptual	watch	rapids	slome	fince
14	CLOTHES PEG	Perceptual	clothes	nail	slunt	spirpe
15	EAT	Action	food	square	fusk	rilm
16	WEIGH	Action	heavy	mud	stilch	flob
17	PUSH	Action	pull	sky	pib	gral
18	LIGHTER	Action	fuel	grass	vapse	splon
19	LIGHT BULB	Action	light	fly	trebe	reuth
20	BRUSH	Action	hair	girl	ciff	wef
21	DRAW	Action	paint	sun	crolt	tarbam
22	PERFUME	Action	smell	garden	croice	cluft
23	CAN	Action	tin	tv	sem	pud
24	DROP	Action	break	ill	gern	poy
25	CRAWL	Action	animal	bed	spom	pebe
26	CARDS	Action	cards	wood	flane	slart
27	WRITE	Action	letter	sea	gral	pib
28	IRON	Action	shirt	beer	clut	hup