The Hands and Mouth Do Not Always Slip Together in British Sign Language: Dissociating Articulatory Channels in the Lexicon

David P. Vinson, Robin L. Thompson, Robert Skinner, Neil Fox and Gabriella Vigliocco

Psychological Science 2010 21: 1158 originally published online 19 July 2010
DOI: 10.1177/0956797610377340

The online version of this article can be found at:
http://pss.sagepub.com/content/21/8/1158

Published by:
SAGE
http://www.sagepublications.com

On behalf of:
Association for Psychological Science

Additional services and information for Psychological Science can be found at:

Email Alerts: http://pss.sagepub.com/cgi/alerts

Subscriptions: http://pss.sagepub.com/subscriptions

Reprints: http://www.sagepub.com/journalsReprints.nav

Permissions: http://www.sagepub.com/journalsPermissions.nav
The Hands and Mouth Do Not Always Slip Together in British Sign Language: Dissociating Articulatory Channels in the Lexicon

David P. Vinson, Robin L. Thompson, Robert Skinner, Neil Fox, and Gabriella Vigliocco
University College London

Abstract
In contrast to the single-articulatory system of spoken languages, sign languages employ multiple articulators, including the hands and the mouth. We asked whether manual components and mouthing patterns of lexical signs share a semantic representation, and whether their relationship is affected by the differing language experience of deaf and hearing native signers. We used picture-naming tasks and word-translation tasks to assess whether the same semantic effects occur in manual production and mouthing production. Semantic errors on the hands were more common in the English-translation task than in the picture-naming task, but errors in mouthing patterns showed a different trend. We conclude that mouthing is represented and accessed through a largely separable channel, rather than being bundled with manual components in the sign lexicon. Results were comparable for deaf and hearing signers; differences in language experience did not play a role. These results provide novel insight into coordinating different modalities in language production.

Keywords
lexical retrieval, production, sign language, mouthing, semantic competition

Received 6/17/09; Revision accepted 12/16/09

In contrast to the single-articulatory system of spoken languages, sign-language production involves the simultaneous use of multiple articulators beyond the two hands. The body, face, and mouth all can have lexical and grammatical functions (e.g., conveying adjectival or adverbial information, marking negation). In addition to mouth patterns expressing adjectival or adverbial information, many lexical signs are associated with specific mouth patterns that are integral to a specific sign and are time locked to production of the sign’s manual component (i.e., hand movement; Boyes Braem & Sutton-Spence, 2001). These mouth patterns are of two types: those originating within the sign-language system and those based on spoken language.

Mouth patterns originating within the sign-language system, sometimes termed “mouth gestures,” use abstract vocal properties (e.g., inhalation and exhalation, mouth shape, articulation) to reflect properties of the manual signs themselves (Woll & Sieratzki, 1998). Mouth patterns based on spoken language, often termed “mouthings,” are derived instead from the pronunciation of words in a spoken language. These mouthings often distinguish between ambiguous sign forms. For example, the British Sign Language (BSL) signs for EAT and MEAL have the same manual form, but they are distinguished by English-derived mouthings. However, such mouthings are also commonly associated with nonambiguous signs that occur in spontaneous conversation. In linguistic theory, some researchers consider mouthings to be part of the signs themselves, but other researchers consider mouthings to be an incidental consequence of language contact and not part of the sign lexicon (see Boyes Braem & Sutton-Spence, 2001; Nadolske & Rosenstock, 2007; Sutton-Spence, 1999; Sutton-Spence & Day, 2001).

Despite the ubiquity of mouthings, researchers know little about how mouthings are linked to manual elements of lexical
signs, and how retrieval of mouthings and manual components is orchestrated in sign production. The simultaneous occurrence and synchronization of mouthings and manual components suggest shared lexical representations, at least at a semantic level. Although mouthings historically originated as borrowed forms from the surrounding spoken language, they may have become fully embedded within the sign-language production system, thus being completely integrated with signs’ manual components. Under this view, closely related signs like EAT and MEAL would have different representations in the BSL lexicon. These lexical sign representations would serve as the basis for retrieval of both manual phonology and mouthing phonology. This view is consistent with lexical-retrieval models derived from spoken-language research (e.g., Levelt, Roelofs, & Meyer, 1999), in which one lexical representation drives retrieval of phonology for language production.

However, mouthings and manual production must diverge at some point, because they rely on different articulators (hands vs. mouth). Thus, mouthings might reflect the activation of representations based on a spoken language, with these representations being accessed relatively independently from manual sign-language representations. As such, mouthings could be incidental to manual-form retrieval, rather than being integrated before phonological encoding. This possibility reflects the fact that bilinguals who know sign languages and spoken languages (bimodal bilinguals) need not suppress one language while producing another. Such a view is held by some sign lexicographers (e.g., Johnston & Schembri, 2007), who consider related signs that are disambiguated only by mouthings as one lexical sign (e.g., EAT, MEAL). These lexicographers believe that such signs reflect a single representation in the sign lexicon that is more general than the English words “eat” and “meal.” Mouthings would thus reflect English phonology, rather than being part of the sign lexicon.

Language experience (and hearing status) may be critical in shaping the relationship between manual components and mouthing patterns. This association may be stronger for native BSL signers who are deaf than for native BSL signers who are not deaf. This is because mouthings by hearing signers may be more closely linked to English phonology as a result of hearing signers’ spoken English production, and it may also be due to more frequent use of code blending (simultaneously producing signed and spoken language; Emmorey, Borinstein, Thompson, & Gollan, 2008).

Here, we report the first empirical investigation of the association between manual components and mouthing patterns of signs, and of the role of language experience in shaping these associations. We employ cyclic naming, a lexical-retrieval task targeting semantic representations (Kroll & Stewart, 1994). Our assumption is that semantic representations are the most obvious level at which manual components and mouthing patterns may be coupled, whereas the modalities would diverge at phonological and phonetic levels. This assumption derives from the view that semantics is largely shared across modalities (e.g., spoken and written), and is possibly shared in spoken languages between speech and gestures accompanying speech (e.g., Bernardis & Gentilucci, 2006).

When performing cyclic naming, participants repeatedly assign names to pictures of objects, or translate prompt words from their second language to their first language; the stimuli are presented in blocks of items that are either semantically related or semantically unrelated to each other. In spoken languages such as English and Dutch, speakers are slower and more error prone in naming pictures presented in the context of semantically related items than speakers of other languages are; this effect is explained by increased semantic competition during lexical retrieval (Damian, Vigliocco, & Levelt, 2001). Similar semantic interference also occurs when bilingual participants are shown a word in their second language and must translate it into their first language (Vigliocco, Lauer, Damian, & Levelt, 2002). This interference illustrates that the same kind of semantic competition occurs when lexical retrieval is based on translation rather than picture naming.

It is crucial to note that a different pattern is observed for word naming. When participants are presented with semantically related or semantically unrelated blocks of words to read aloud, semantically related contexts facilitate naming (i.e., participants name words faster in semantically related blocks than in semantically unrelated blocks), in contrast to picture naming and translation (Damian et al., 2001). This finding can be explained in terms of interaction between orthography and semantics, possibly in tandem with the use of a sublexical route between orthography and phonology.

In one session, signers were asked to name pictures; in another session, signers were asked to translate written English words into BSL. If mouthings and the manual components of signs are fully integrated for deaf signers, a single lexico-semantic representation should be retrieved; hence, semantic effects on mouthings and manual components should show a similar error pattern. It is important to note that this should occur when signers are naming pictures, and also when they translate from English to BSL. If, however, manual production of BSL and mouthing are separable, with mouthing being based on the English production system, these errors should dissociate in the word-translation task. This is because in the picture-naming task, both manual semantic errors and mouthing semantic errors should be more likely to occur in semantically related contexts than in semantically unrelated contexts. Such errors would reflect lexical competition at the semantic level, in line with the results of picture-naming tasks in spoken languages (Damian et al., 2001; Vigliocco et al., 2002). In the word-translation task, however, semantic interference should be stronger for manual semantic errors, and mouthing errors should resist the effects of semantic context. This latter result for mouthing errors would resemble the effects that occur in word-naming tasks (Damian et al., 2001), in which the orthographic-phonological mapping in English should reduce or eliminate semantic competition. In essence, the word-translation task should be more like word reading for mouthing, but more like picture naming for manual production.

Finally, language experience could matter. For hearing signers, the link between English orthography and phonology should be even stronger because of the full availability of English phonology both in perception and production. If this is
the case, we would expect hearing signers to show the same pattern of results that deaf signers show in the picture-naming task, but exhibit more resistance to semantic interference in the word-translation task than deaf signers do.

### Method

#### Subjects

Eight native BSL signers who were deaf (all from Deaf families; 4 women and 4 men; average age = 23.4 years, SD = 5.9) and 7 native BSL signers who were not deaf (all from Deaf families; 3 women and 4 men; average age = 26.1 years, SD = 6.2) participated in the study. All of the hearing signers worked as BSL-English interpreters at the time of testing. Subjects were paid £20 for their participation.

#### Materials and design

We chose 25 items that could be clearly illustrated; each item had a single-word English name and a single-sign BSL name. Items came from five semantic categories: animals (dog, snake, mouse, sheep, spider), artifacts (comb, drill, saw, scissors, spanner), clothing (belt, glove, shirt, shoe, sock), fruit (apple, banana, cherry, grape, melon), and vehicles (airplane, bicycle, boat, bus, skateboard). Pictures were obtained from Snodgrass and Vanderwart (1980) or created in a similar style. If possible, visually dissimilar pictures were selected for each category.

Five semantically related sets of items were prepared by selecting all five members of a given category; five semantically unrelated sets of items were prepared by randomly selecting one member from each category. Blocks of 25 trials each were created by randomly selecting from the items in a set without replacement, five times successively, so that each item would appear in a cycle of five trials before any item appeared again. Two blocks were created for each set of items; each block had a different pseudorandom order of trials. The order of blocks was randomized for each subject. The same design was used for both the picture-naming tasks and the word-translation tasks.

#### Procedure

Participants were told that the experiment investigated sign production, and that they would see a series of pictures or words. At the start of each trial, participants placed their hands flat on a desktop; then they produced the BSL sign for the picture or word they were shown as quickly as possible. Each session started with untimed naming trials: A picture or an English word appeared on the screen, and participants were asked to produce the BSL sign for each one. This procedure was to ensure that the items were familiar, and when encountering sign synonyms, subjects could decide on their preferred sign before the experiment began. Instructions were given in BSL, and 25 practice trials were presented before the experimental trials began.

Each trial began with a 500-ms blank screen, followed by a fixation cross lasting 1,000 ms. The picture or word appeared immediately thereafter for 2,000 ms. A 1,000-ms blank screen ended each trial. Participants were given the opportunity to take breaks after each block of 25 trials. There were a total of 20 blocks (500 trials total) for each of the two tasks (word translation and picture naming) per subject. The word-translation task and the picture-naming task were conducted in separate sessions at least a week apart. All participants performed the word-translation task before the picture-naming task.

#### Scoring

All trials were recorded using a digital video camera, and the recordings were transferred to desktop computers for analysis. Manual productions were individually analyzed frame by frame by a native signer. Trials were classified as correct utterances, semantic errors, or nonsemantic errors. In correct utterances, the target sign was produced without any kind of disfluency or inaccuracy. In semantic errors, a sign from the same semantic category as the target sign was produced (e.g., signing APPLE when BANANA was the correct response). This category included partial errors in which the target was identifiable. Nonsemantic errors included disfluencies, such as subtly incorrect movements, delayed movements of the nondominant hand, and use of the nondominant hand to produce a one-handed sign; semantically unrelated lexical errors; blends; and perseverations.

Manual productions were analyzed separately from manual productions by a native signer, who individually analyzed mouthing productions frame by frame. Trials in which the mouth was not visible were excluded. The remaining trials were classified as no mouthing, correct utterances, semantic errors, or reduced forms. No mouthing occurred when the participant did not produce any mouth pattern. In correct utterances, the participant’s mouth pattern visually corresponded to his or her production of the English word. In semantic errors, the participant’s mouth pattern visually corresponded to a different English word from the same category as the target word (e.g., a mouth pattern like “cherry” was produced when “grape” was the correct response). This category included partial mouth patterns or corrections in which the initial mouthing could be identified. In reduced forms, the participant’s mouth pattern was an incomplete version of the English word (e.g., “sizz” for “scissors”). Many of these mouthings may not have been erroneous utterances, as many mouthings exhibit such characteristics in everyday conversation. Nonsemantic errors included visible hesitations before producing a mouth pattern, stuttering, and substitution errors that were semantically unrelated to the target.

For both manual production and mouthing production, a subset of trials was independently scored by a different rater to test reliability. The dependent measures of interest were semantic errors$^{3}$ in either the manual modality or the mouthing modality. These errors were analyzed using factorial analyses of variance (ANOVA$s$) to investigate the effects of group (deaf
Errors on Hands and Mouth

1161

Results

Manual production

Most trials (95.5%) were coded as correct utterances (this proportion reflected the overall ease of this task); 219 trials (1.57%) were coded as semantic errors, and 400 trials (2.67%) were coded as errors of other types. Interrater reliability (judged on 1,000 trials: 250 from each of two subjects in each of the two tasks) was 98% on semantic errors, and 96% considering all scoring categories (most disagreement was about the subcategories to which nonsemantic errors should be assigned).

Semantic errors. A 2 × 2 × 2 ANOVA (Group × Task × Block Type) on the number of semantic errors (see Fig. 1) revealed a main effect of block type, $F_1(1, 13) = 31.040, p < .01, \eta^2_p = .705; F_2(1, 24) = 53.962, p < .01, \eta^2_p = .692$. Participants made more errors in semantically related blocks than in semantically unrelated blocks. There was also a main effect of task, $F_1(1, 13) = 7.878, p = .015, \eta^2_p = .377; F_2(1, 24) = 6.421, p = .018, \eta^2_p = .211$. Participants made more semantic errors in the word-translation task than in the picture-naming task. These main effects were modulated by an interaction, $F_1(1, 13) = 8.029, p = .014, \eta^2_p = .382; F_2(1, 24) = 7.750, p = .01, \eta^2_p = .244$. The difference

![Fig. 1. Average number of manual semantic errors per subject in the picture-naming and word-translation tasks. Responses made by deaf subjects and hearing subjects were coded separately in semantically related and semantically unrelated blocks. Error bars reflect standard errors of the mean.](https://example.com/figure1.png)
between semantically related and semantically unrelated blocks was greater for words than for pictures.

It is important to note that neither the main effect of group nor any interactions involving group were significant in the subjects analysis (all $F$’s < 1). By items, only the main effect of group was significant, $F_2(1, 24) = 4.423, p = .046, \eta^2_p = .156$, and the Group × Block Type interaction approached significance, $F_2(1, 24) = 3.401, p = .078, \eta^2_p = .124$; all other $F_2$’s < 1.

Nonsemantic errors. For erroneously produced signs not semantically related to the target sign, an ANOVA revealed no main effects or interactions, all $F_1$’s and $F_2$’s < 1.7, $p$s > .20 (see Fig. 2).

**Mouthing production**

Participants produced mouthings on 79.9% of trials (11,317 mouthings; 2,361 trials with no mouthing), but tendencies to produce mouthings varied between individuals. Eleven subjects (5 hearing, 6 deaf) produced mouthings on more than 95% of trials in both picture-naming tasks and word-translation tasks. One hearing subject produced mouthings on less than 10% of all trials, and 1 deaf subject produced mouthings on less than 25% of all trials. Two subjects (1 deaf, 1 hearing) produced more mouthings for pictures than for words (99% and 72% vs. 50% and 35%, respectively). Although this difference indicates that mouthings and manual components can
Errors on Hands and Mouth

1163

Dissociate, it may suggest only that it is possible to suppress articulation in one channel (akin to covert speech, e.g., McGuigan, 1978) and does not necessarily address the question of shared semantic representations. Trials on which mouthing did occur are more informative because they show how mouthing errors are affected by the semantic manipulation.

Among trials with mouthing, 10,019 (71.77%) resulted in correct utterances, 70 (0.43%) resulted in semantic errors, 522 (3.27%) resulted in other kinds of errors, and 706 (4.43%) resulted in reduced forms. Interrater reliability (judged on the same trials as was manual production) was 100% on semantic errors and 91% considering all categories (most disagreements being related to classification of reduced forms vs. disfluencies). For the following analyses, the 4 subjects who exhibited low levels of mouthing overall were excluded, leaving 6 deaf and 5 hearing subjects for analysis.

Semantic errors. A 2 × 2 × 2 ANOVA on the proportion of semantic errors was conducted (see Fig. 3; item analyses included only those 22 items with at least one error across conditions). The main effects of task, $F(1, 9) = 2.692, p = .135, \eta^2_p = .230; F(1, 21) = 7.140, p = .014, \eta^2_p = .254$, and block type, $F(1, 9) = 2.000, p = .191, \eta^2_p = .182; F(1, 21) = 7.542, p < .01, \eta^2_p = .400$, were significant only by items.

Fig. 3. Average proportion of semantic mouthing errors per subject in the picture-naming and word-translation tasks (considering only trials on which mouthing occurred). Responses made by deaf subjects and hearing subjects were coded separately in semantically related and semantically unrelated blocks. Error bars reflect standard errors of the mean.
However, there was a significant Task × Block Type interaction, $F(1, 9) = 6.085, p = .036, \eta^2_p = .402$; $F_2(1, 21) = 4.529, p = .045, \eta^2_p = .177$. In picture-naming tasks, significantly more errors occurred in semantically related blocks (1.01%) than in semantically unrelated blocks (0.48%) despite the small number of errors overall. In the word-translation tasks, however, there was no such effect (related: 0.33%; unrelated: 0.41%). This effect was different than the effect for manual errors, in which a greater semantic blocking effect was observed for the word-translation tasks.

Neither the main effect of group nor any interactions involving group reached significance by subjects, $F(1, 9) = 2.692, p = .135, \eta^2_p = .230$, for the Task × Group interaction; all other $F$s $< 1$; however, by items, the Group × Task interaction was significant, $F_1(1, 21) = 14.007, p < .01, \eta^2_p = .400$, and the main effect of group also approached significance, $F_2(1, 21) = 3.143, p = .091, \eta^2_p = .130$.

**Reduced forms.** A $2 \times 2 \times 2$ ANOVA on the proportion of reduced forms was carried out (see Fig. 4). The main effect of group was significant by items and approached significance by subjects, $F(1, 9) = 3.979, p = .077, \eta^2_p = .307$; $F_2(1, 24) = 25.815, p < .01, \eta^2_p = .518$. This effect reflected a tendency for deaf subjects to use reduced forms more often than hearing subjects.

**Fig. 4.** Average proportion of incomplete mouthings (reduced forms) per subject in the picture-naming and word-translation tasks (considering only trials on which mouthing occurred). Responses made by deaf subjects and hearing subjects were coded separately in semantically related and semantically unrelated blocks. Error bars reflect standard errors of the mean.
Table 1. Number of Trials in Each Mouthing Category as a Function of the Type of Manual Production

<table>
<thead>
<tr>
<th>Mouthing category</th>
<th>Manual production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Semantic error</td>
</tr>
<tr>
<td>Semantic error</td>
<td>19</td>
</tr>
<tr>
<td>Correct</td>
<td>72</td>
</tr>
<tr>
<td>Nonsemantic error</td>
<td>99</td>
</tr>
<tr>
<td>No mouthing</td>
<td>29</td>
</tr>
</tbody>
</table>

subjects did. None of the other main effects or interactions was significant by subjects (all \(F_s < 1.2, ps > .3\)), although the main effect of task, \(F(1, 24) = 16.905, p < .01, \eta^2_p = .413\), and the Task × Group interaction, \(F(1, 24) = 23.214, p < .01, \eta^2_p = .492\), were significant by items.

Relation between manual errors and mouthing errors

The critical question concerns the relationship between manual semantic errors and mouthing semantic errors. A straightforward prediction if mouthing is integrated into the sign lexicon is that mouthing semantic errors and manual semantic errors should co-occur. This is because both modalities depend on retrieving a single lexico-semantic representation, which is selected incorrectly in semantic errors. Table 1 illustrates the breakdown of different mouthing categories for different categories of manual productions.

There were 190 manual semantic errors in which there was also some kind of mouthing, and only 70 mouthing semantic errors. It is crucial to note that only 19 of these trials contained both types of errors together (10 in the word-translation task and 9 in the picture-naming task; all of these errors reflected the same slip on hands and mouth). This is a very low proportion if the two kinds of errors arise from retrieval of the same lexico-semantic representation. Further, many of these errors in one modality were accompanied by correct utterances in the other modality: There were 34 correct manual productions with mouthing semantic errors, and 72 correct mouthing productions with manual semantic errors. These discrepancies should not occur if the two modalities share a lexico-semantic representation.

Discussion

The manipulation of semantic context had consequences for production in BSL: Semantically related contexts led to more semantic errors in signing. As no such effect was observed for other sorts of manual errors, this finding fits well with results from studies of spoken languages (e.g., Damian et al., 2001; Kroll & Stewart, 1994; Vigliocco et al., 2002).

When it comes to the differences between deaf and hearing signers, none of the group comparisons was significant, and those comparisons approaching significance (i.e., Task × Group interaction in mouthing semantic errors and main effect of group for reduced forms) did not involve the crucial semantic-relatedness manipulation. The lack of substantive differences in semantic effects for deaf and hearing signers points strongly to commonality in processes. Namely, deaf signers showed the same effects of association between orthography and phonology as hearing signers did. These effects occurred despite the differences in each groups’ English-language experience, and despite the fact that deaf signers may not have learned English via auditory input. Support for some common processes comes from studies of phonological awareness in deaf signers. For example, deaf adult signers (American college students) have been shown to possess sufficient phonological awareness to produce pairs of English rhyming words that do not share orthography, such as “tie-sky” and “blue-through” (Hanson & McGarr, 1989). Deaf children also can show awareness of spoken phonology (syllables, rhymes, and pronunciation of nonsense words; Sterne & Goswami, 2000).

Whereas this previous literature demonstrates that deaf signers can exploit links between written orthography and spoken phonology only in overt, metalinguistic tasks, our work goes beyond these studies by showing that such links also affect automatic processes in language production (see also Transler & Reitsma, 2005). There are various ways in which phonological awareness can occur in the absence of auditory input (or reduction of auditory input). It is likely that a substantial role is played by visual exposure to spoken English. In many cases, this exposure is supplemented by explicit educational instruction, not only in order to facilitate actual production of a spoken language (e.g., communicating with hearing nonsigners), but also in contexts of teaching literacy (for an overview of different approaches, see Friedman Narr, 2006). Finally, many deaf signers (including some of our participants) do not have complete hearing loss: They receive some auditory input (residual hearing capacity or hearing aids) that could support the acquisition of some spoken-language phonology.

Across both groups of signers, manual and mouthing errors exhibited different patterns across tasks. For manual production, semantically related contexts led to increased semantic errors for word-translation tasks compared with picture-naming tasks. On the contrary, mouthings showed semantic effects only in picture-naming tasks, and not in the word-translation tasks. This latter finding suggests that the presence of English orthography provided resistance in the mouthing channel to semantic competition in lexical retrieval. This resistance can be attributed to the reliable sublexical mapping between orthography and mouthing (if not overtly articulated phonology) during naming in BSL. It seems, however, that sublexical processing must occur in tandem with lexical processing.

It is important to note that cases in which the same semantic error occurred on the hands and the mouth at the same time were equally frequent for pictures (9 instances) and for words...
(10 instances). If mouth patterns in the word task were strictly produced by a direct link between orthography and phonology, such errors should have been much less common in the word task (in which semantic representations were not involved). Further, the presence of semantic effects in word-naming tasks (e.g., Damian et al., 2001) reveals some activation of lexical representations, rather than just purely reflecting a direct mapping between orthography and phonology. We therefore conclude that mouthings in the word-naming tasks reflected both transparent mappings between orthography and phonology, and access to English lexical representations. Although these results clearly indicate a dissociation between lexical retrieval for mouthings and manual components of signs, we must also note that the present findings do not generalize beyond mouthings that are derived from English words; mouth gestures related to properties of BSL signs are much more likely to be tightly integrated into the sign lexicon. Some evidence compatible with a possible dissociation between mouthings and mouth gestures comes from a functional magnetic resonance imaging study by Capek et al. (2008); in that study, comprehension of signs accompanied by mouthings generated activations similar to comprehension of speech reading (i.e., seeing but not hearing English words), but comprehension of signs accompanied by mouth gestures generated activations similar to comprehension of manual signs that were not accompanied by any mouth movement.

Our results provide the first strong evidence against an account positing that mouthings are fully integrated into the BSL sign lexicon (except for divergences during retrieval of phonological features). If integrated, comparable effects of semantic blocking should have occurred for manual errors and mouthing errors in both picture-naming tasks and English-translation tasks, because both production modes are accessed by retrieving a single lexico-semantic representation. Instead, our results favor separate representations at this level for manual components and mouthings of lexical signs, with mouthings being based on the English-production system. This suggests that mouthing in BSL develops because bilingual signers read and speak English (or at least have learned English phonological awareness), and mouthing in BSL is not just historically based on English vocabulary. Such mouthings can thus be considered less a part of the sign-language system and more like code blends (see Emmorey et al., 2008).

Finally, our results have implications for reading and literacy. Evidence for phonological recoding in silent reading by hearing subjects (De Jong, Bitter, van Setten, & Marinus, 2009) suggests an important role of phonology in orthographic development (and thus literacy). For deaf children, it has been argued that orthographic representations cannot be fully developed without sufficient exposure to spoken-language phonology (Hermans, Knoors, Ormel, & Verhoeven, 2008). We suggest that mouthing during sign-language production reflects some degree of activation of the phonology of spoken language, especially via visual and articulatory experience. Thus, mouthing can contribute to the development of orthographic representations (and hence literacy) for deaf children.

Acknowledgments
This research was supported by Economic and Social Research Council (ESRC) Grant RES000230038; ESRC Grant RES620286001 to the Deafness, Cognition, and Language Research Centre; and a Wellcome Trust VIP award.

Declaration of Conflicting Interests
The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Notes
1. Signs in BSL are represented by English capital letters.
2. We use the term Deaf with an uppercase D to refer to those people who use a sign language and identify as members of the Deaf community, in contrast to deaf, which refers only to hearing status.
3. For deaf signers (the first group tested), we also measured signing latencies using an infrared device that detected when subjects’ hands moved up from the desktop to initiate sign production. Responses were extremely fast (350–400 ms) and insensitive to our experimental manipulations. The speed of these responses suggested that these measures did not reflect processes of lexical retrieval, but only non-meaningful upward movement, possibly because signers could lift their hands to begin signing whether or not they were actually ready to produce a sign. We therefore discontinued the use of this measure for hearing signers and focused solely on errors.

References
Errors on Hands and Mouth


