The hands and mouth do not always slip together in British Sign Language: Dissociating articulatory channels in the lexicon

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Abstract

We investigate the extent of integration between the hands and mouthing for lexical signs in British Sign Language, using picture naming and translation tasks that are sensitive to semantic similarity effects in lexical retrieval. Semantic errors in sign forms due to semantically related contexts were more common in translation from English than in picture naming, while semantic errors in mouth patterns were sensitive to semantic context only in picture naming, and not in translation from English. These results are consistent with an account whereby mouthing is accessed through a largely separable channel from manual components of the sign lexicon, rather than being bundled with manual components and incorporated into the sign language lexicon despite its original relationship to English. Effects did not differ between Deaf and hearing native signers, suggesting that stronger links between orthography and phonology in the hearing group do not play a role.

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

Introduction

Signed language production involves the simultaneous use of multiple articulators; not only the two hands themselves, but also other articulators such as the body, face, and the mouth have both lexical and grammatical functions (e.g., to convey adjectival or adverbial information, or to mark negation, yes-no questions or relative clauses). In addition to mouth patterns that can be used to express adjectival or adverbial information, many lexical signs are associated with specific mouth patterns which are integral to a specific sign and are time-locked to production of the sign's manual component (i.e., the movement of the hands, Boyes Braem & Sutton-Spence, 2001). These mouth patterns are of two types: those originating within the sign language system, and those derived from a spoken language. The former, sometimes termed "mouth gestures", use abstract vocal properties (e.g., inhalation/exhalation, mouth shape, or articulation) to reflect properties of the manual signs themselves (Woll & Sieratzki, 1998). The latter, instead (often termed "mouthings"), are derived from the pronunciation of words in a spoken language. Sometimes mouthings are used to distinguish between ambiguous sign forms (for example, the British Sign Language (BSL) signs BREAKFAST and LUNCH[1] are distinguished only by English-derived mouthings), but they are also commonplace in nonambiguous signs, occurring very frequently in spontaneous conversation, and are often considered to be part of the signs themselves (see Boyes Braem & Sutton-Spence, 2001, for further discussion)[2].

However, there is little evidence concerning the precise nature of the link between mouthings and manual elements of lexical signs in language production, and the nature of the systems underlying their retrieval and production. It is certainly the case that the two must diverge at some point, because they rely upon different articulatory systems (hands vs. mouth). Our primary question concerns the extent to which these representations are linked before this divergence takes place. On one hand, mouthings might reflect the activation of representations based on a spoken language, which are accessed relatively independently from the sign language representations driving the manual component of signs. As such they would be incidental to the retrieval of the manual form, rather than being integrated before phonological and especially phonetic encoding.. On the other hand, although mouthings historically originated as a borrowed form from the surrounding spoken language, they may have become fully embedded within the sign language production system and thus completely integrated with the manual component of signs.

In order to test these two alternatives, we employed a lexical retrieval task targeting the semantic level of representation: cyclic semantic blocking (Kroll & Stewart, 1994). In this task, participants repeatedly name objects presented in contexts of other objects that are either semantically related or unrelated to each other. In spoken languages, speakers are slower to name pictures when they are presented in the context of semantically related items, an

[1] Signs in BSL are customarily represented as English glosses in capital letters.

[2] For example, in a set of 300 lexical signs produced by Deaf BSL signers for use in a lexical norming study (Vinson, et al. 2009), more than 90% included mouthing, although the sign models were given only general instructions to produce the signs as naturally as possible, and no mention was made of mouthing. This is likely an overestimate of the rate at which mouthing occurs in discourse (these signs were produced in isolation) but gives an impression of the importance of mouthing.

effect that can be explained by increased semantic competition during lexical retrieval (Damian, Vigliocco & Levelt, 2001). The same kind of semantic interference is also observed when bilingual participants are presented with a word in L2, and must translate it into L1 (Vigliocco, Lauer, Damian & Levelt, 2002), thus illustrating that the same kind of semantic competition occurs when lexical retrieval is based on translation rather than picture naming. Crucially, a different pattern is observed for word naming. When participants are presented with semantically related or unrelated blocks of words, and are asked to name them in the same language (i.e., read them), the effect of semantically related contexts is facilitatory (faster word naming for semantically related than unrelated blocks), in contrast to picture naming and translation (Damian et al., 2001).

Here we use the cyclic naming paradigm with BSL signers. In one session, signers were asked to name pictures, in another they were asked to translate English prompt words into BSL. If mouthings and the manual component of signs are fully integrated, a single lexico-semantic representation should be retrieved, hence semantic effects on mouthings and manual components should pattern together. Importantly, this should be the case both when signers are naming pictures as well as when they translate from English to BSL. If however, BSL manual production and mouthing are separable, with the latter being based on the English production system to some extent, we should see a dissociation of these two error types in the word translation task. This is because in the picture task, both manual and mouthing semantic errors should be more likely in semantically related contexts than unrelated contexts (reflecting lexical competition at the semantic level, in line with results of picture naming tasks in spoken languages (Damian et al., 2001; Vigliocco et al., 2002). In the word task, however, semantic interference should be stronger for manual semantic errors, while mouthing errors should resist the effects of semantic context, in line with the results of word naming (Damian et al., 2001) whereby the orthographic-phonological mapping in English permits retrieval to avoid semantic competition. In other words, the translation task should be more like word reading for mouthing, but more like picture naming for manual sign production.

In addition to native deaf signers, we investigated hearing BSL signers who learned BSL natively from Deaf parents. For this group of signers (who are bimodal bilinguals) we reasoned that the manual and mouthing components may be less integrated than for native Deaf signers. This is because mouthing can be more closely linked to English phonology. Moreover, for these individuals, the link between orthography and phonology should be stronger. If so, we would expect hearing signers to show the same pattern of results as Deaf signers in the picture naming task, but exhibit more resistance to semantic interference in word naming.

Method

Subjects

Eight native Deaf BSL signers (four women; average age 23.4, SD = 5.9) and seven hearing native BSL signers (average age 26.1, SD=6.2) participated in the study. All of the hearing signers were employed as BSL-English interpreters at the time of testing. Subjects were paid £20 for their participation.

Materials and Design

Twenty-five items were chosen, with the following restrictions: they had to be clearly picturable, and named with a single word in English and a single BSL sign. Where possible, visually dissimilar pictures were selected for each category. Items came from five semantic categories: animals {dog, snake, mouse, sheep, spider}, artefacts {comb, drill, saw, scissors, spanner}, clothing {belt, glove, shirt, shoe, sock}, fruit {apple, banana, cherry, grape, melon} and vehicles {aeroplane, bicycle, boat, bus, skateboard}. Pictures were obtained from Snodgrass and Vanderwart (1980) or created in similar style.

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

Dependent measures of interest were semantic errors in either the manual modality (i.e., participant mistakenly produced a sign or part of a sign that was semantically related to the correct target sign), or the mouthing modality (i.e., participant mistakenly produced an English mouth pattern or part of a mouth pattern that was semantically related to the correct target mouth pattern). These were analyzed using factorial ANOVA investigating the effects of Group (Deaf, hearing) x Task (picture, word) x Block Type (semantically related, unrelated) treating subjects as random factors.

Procedure

Participants were told that the experiment investigated sign production, and that they would see a series of pictures or words. For each trial, they were start with their hands flat on a desktop, and then produce the BSL sign as quickly as possible, returning to the desktop before the next trial. Each experimental session started with a series of untimed naming trials: a single picture or English word would appear on the screen, and participants were asked to produce their BSL sign for each one. This was to ensure that the items

were familiar, and in the event of ambiguity, they could decide on their preferred sign before the experiment began. All instructions were given in BSL.

After this was a series of 25 practice trials, one repetition of each item, presented at the same rate as the experimental trials. Participants had an opportunity to ask questions before starting the experimental trials. Each trial began with a 500ms blank screen, followed by a fixation cross displayed for 1000ms. The picture or word appeared immediately thereafter, remaining on the screen for 2000ms. A 1000ms blank screen ended each trial. Participants were given the opportunity to take breaks after each block of 25 trials. All trials were recorded using a digital video camera, and transferred to desktop computers for analysis.

The word and picture tasks were conducted in separate sessions separated by at least a week. All participants performed the word task before the picture task.

Results

Manual production

Sign productions were individually analyzed frame-by-frame, and divided into the following response categories.

Correct signs: Participant produced the target sign without any kind of disfluency or inaccuracy. Most trials were correct (95.2% of all trials), reflecting the ease of this task.

Semantic errors: Erroneous productions that were from the same semantic category as the target word (219 instances; 1.46% of all trials). This included partial errors where the target was identifiable.[3]

Purely phonological errors: Erroneous productions that were semantically unrelated to the target word but shared some elements of its form (30 instances; 0.02%).

Other errors: These included dysfluencies of various kinds including subtly incorrect movements or delayed movements of the non-dominant hand (2.11%), and errors of other kinds such as unrelated lexical errors, blends and perseverations (370 instances; 0.56%).

Semantic errors 2x2x2 ANOVA (Group x task x block type) on number of semantic manual errors revealed a main effect of block type ($F(1,13)=27.394$, $p<.01$); participants made more errors in semantically related blocks than in unrelated blocks. There was also a main effect of task ($F(1,13)=6.942$, p.021): more semantic errors in the word task than in the picture task. These main effects were modulated by an interaction ($F(1,13)=5.801$, p.032); the effects of semantic blocking were greater in the word task than in the picture task.

[3] We also distinguished between mixed errors (errors sharing elements of both meaning and form with the target) and purely semantic errors (sharing meaning only) but collapsed them both into a single category for analyses reported here, as they did not differ.

Importantly, the main effect of group was not significant ($F<1$), nor were any of the interactions involving group (all $F<1.4$, $p>.25$).

Table 1: Manual errors: number of semantic errors as a function of task, block type and group.

	Picture task		Word task	
Group	Related	Unrelated	Related	Unrelated
Deaf	44	9	63	9
Hearing	25	7	52	10

Other errors For erroneously-produced signs that were not semantically related to the target sign, ANOVA revealed no main effects or interactions (all $F<1.6$, $p>.20$).

Table 2. Manual errors: number of Other errors as a function of task, block type and group.

	Picture task		Word task	
Group	Related	Unrelated	Related	Unrelated
Deaf	37	40	58	44
Hearing	56	46	44	45

Mouthing production

Mouthing productions were individually analyzed frame-by-frame, independently from analysis of manual productions.

Participants produced a mouth pattern of some kind on 79.9% of trials, but tendencies to produce mouthing differed drastically between individuals. Eleven subjects (five hearing, six Deaf) produced mouthing on more than 95% of trials in both picture and word tasks. One hearing subject virtually never mouthed (less than 10% of all trials), and another Deaf subject seldom mouthed (less than 25% of all trials). Finally, two subjects (one Deaf, one hearing) mouthed much more in the picture task than in the word task (72 and 99% vs 35% and 50% respectively).

Trials with mouthing were then further divided into the following response categories.

Correct mouthing: Participant produced a mouth pattern that visually corresponded to production of the English word (10,019 instances; 71.77% of all naming trials).

Semantic errors: Participant produced a mouth pattern that visually corresponded to a different English word in the same category as the target word (70 instances; 0.43%)

Hesitations and stutters: Participant hesitated before producing a mouth pattern or stuttered, repeating all or some of the mouth pattern (522 instances; 3.27%)

Reduced forms: Participant produced a mouth pattern that is an incomplete version of the English word, e.g. "sizz" for "scissors" (706 instances; 4.43%). Many of these should not actually be considered erroneous utterances, as many mouth patterns exhibit such characteristics in everyday speech.

For the analyses involving particular categories of mouthing, the four subjects who exhibited low levels of mouthing overall were excluded, leaving six Deaf and five hearing subjects for analysis.

Semantic mouthing errors 2x2x2 ANOVA on proportion of semantic errors was carried out. The main effects of task ($F(1,9)=2.692$, $p=.135$) and block type ($F(1,9)=2.000$, $p=.191$) were not significant. However, there was a significant task x block type interaction ($F(1,9)=6.085$, $p=.036$). In the picture task, there were more errors for semantically related blocks (1.0%) than unrelated blocks (0.5%). In the word task, however, there was no such effect (related: 0.3%, unrelated, 0.4%). This was different from manual errors for which a greater semantic blocking effect was observed in the word task.

Again, neither the main effect of group nor any interactions involving group reached significance (task x group $F(1,9)=2.692$, $p=.135$; all other $F<1$).

Table 3. Mouthing errors: number of semantic errors as a function of task, block type and group.

	Picture task		Word task	
Group	Related	Unrelated	Related	Unrelated
Deaf	18	9	5	4
Hearing	9	4	8	7

Reduced forms 2x2x2 ANOVA on proportion of reduced forms was carried out. The main effect of group approached significance ($F(1,9)=3.979$, $p=.077$) reflecting a tendency for Deaf subjects to use reduced forms more often than hearing subjects. None of the other main effects or interactions was significant (all $F<1.2$, $p>.3$); intersubject variability was extensive enough to mask any possible effects here.

Table 4. Mouthing: number of reduced forms as a function of task, block type and group.

	Picture task		Word task	
Group	Related	Unrelated	Related	Unrelated
Deaf	132	123	214	196
Hearing	97	85	156	148

Relation between manual and mouth errors

An interesting question concerns the relationship between manual semantic errors and mouthing semantic errors. A straightforward prediction from the hypothesis under which mouthing is integrated into the sign lexicon is that mouthing errors and manual errors should tend to occur on the same trials and seldom dissociate from each other. If both are derived from retrieval of a single lexico-semantic representation, and semantic competition leads to mis-selection of a related representation, the two modalities should be very tightly linked when it comes to semantic errors.

As shown in Table 5, however, there were strong dissociations between errors in the two modalities. There were 190 manual semantic errors which also had some kind of mouthing, and only 70 trials in which mouthing substitutions occurred. Crucially there were only 19 instances of trials in which both types of errors occurred together, a very low proportion if the two types of errors are meant to arise from mis-selection of a single, shared lexical representation. Further, many of these errors in one modality were accompanied by correct utterances in the other (34 correct manual production accompanied by mouthing substitution errors, and 72 correct mouthing production accompanied by manual semantic errors), events which should not occur if the two modalities share a lexico-semantic representation.

Table 5. Number of trials in each mouthing category as a function of the type of manual production.

	Manual production		
Mouthing production	Semantic error	Non-semantic error	Correct response
Substitution	19	17	34
Correct	72	206	9741
Other errors	99	138	991
No mouthing	29	39	2563

Discussion

The main findings from the experiment are as follows. First, broadly speaking, 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), which highlight the role of semantic competition during lexical retrieval processes.

The lack of substantive differences in the effects of semantic contexts for Deaf and hearing signers strongly points to commonality in processes despite the differences in the groups' English language experience (i.e., Deaf signers experience little or no auditory input from English). The possible differences between the ways Deaf and hearing signers learn English did not have consequences for their sign retrieval in the word translation study, nor did it have consequences on the degree to which their mouthing was affected by the task and semantic blocking manipulations. This suggests that Deaf signers may also have strong associations between English orthography and phonology although this would not be based on sound, but rather on the mouth and tongue actions that correspond to production of English words. Evidence for this 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 English rhymes that do not share orthography (Hanson & McGarr, 1989). Deaf children also can show awareness of spoken phonology (syllables, rhymes and pronunciation of nonsense words; Sterne & Goswami, 2000).[4]

Most important, however, is the extent to which manual and mouthing errors exhibited different patterns of performance across tasks. In the manual channel, semantically-related contexts led to greater likelihood of semantic errors in the English word condition than in picture naming. On the other hand, semantic errors in mouth patterns were sensitive to semantic context only in picture naming, and not at all in the English word condition. This latter finding suggests that the presence of English orthography provided resistance in the mouthing channel to semantic competition in lexical retrieval. This can be attributed to the reliable mapping between orthography and mouthing (if not overtly articulated phonology) during naming in BSL. Also relevant here is the extremely limited co-occurrence of mouthing and manual semantic errors as illustrated in Table 5. These errors should have been much more closely yoked if they arise due to retrieval of the same lexico-semantic representation.

At a theoretical level, this pattern of results provides strong evidence against an account of the BSL lexicon under which mouthings are fully isolated from their English origins and instead are fully integrated into the sign lexicon, diverging only during retrieval of phonological features and not before. Were this to be the case, the same effects of semantic blocking should have occurred for manual and mouthing errors in both picture naming and translation from English, because both production modes are accessed via retrieval of a single lexico-semantic representation. Instead, results favor separate representations at this level for manual and mouthing production components of lexical signs, with mouthing being based on the English production system to some extent. This would suggest that the mouthing system in BSL comes about via the bilingual status of signers who read and speak English (or at least have learned English phonological awareness), and is not just historically based upon English vocabulary.

Of course, these findings apply only to those 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 an fMRI study by Capek et al. (2008), where comprehension of signs accompanied by mouthings generated activations similar to comprehension of speechreading (i.e., seeing but not hearing English words), while comprehension of signs accompanied by vocal gestures generated activations more similar to comprehension of manual signs that were not accompanied by any mouth movement.

[4] There are various ways in which phonological awareness can come about in the absence of auditory input. It is likely that a very substantial role is played by visual exposure to spoken English. In many cases this is supplemented by explicit instruction in education, not only in order to facilitate actual production of a spoken language (e.g. communicating with hearing non-signers), but also in contexts of teaching literacy. A variety of different approaches are used (for an overview see Friedman Narr, 2006).

Acknowledgments

This research was supported by Economic and Social Research Council Grant (ESRC) RES000230038, by ESRC Grant RES620286001 to the Deafness, Cognition, and Language Research Centre, and by a Wellcome Trust VIP award. Special thanks to Tyron Woolfe for his help with implementing and running the initial study with Deaf participants.

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