Modality-dependent and -independent factors in the organisation of the signed language lexicon: Insights from semantic and phonological fluency tasks in BSL

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Abstract

We used fluency tasks to investigate lexical organisation in Deaf adults who use British Sign Language (BSL). The number of responses produced to semantic categories did not differ from reports in spoken languages. However, there was considerable variability in the number of responses across phonological categories, and some signers had difficulty retrieving items. Responses were richly clustered according to semantic and/or phonological properties. With respect to phonology, there was significantly more clustering around the parameters "handshape" and "location" compared to "movement". We conclude that the BSL lexicon is organised in similar ways to the lexicons of spoken languages, but that lexical retrieval is characterised by strong links between semantics and phonology; movement is less readily retrieved than handshape and location; and phonological fluency is difficult for signers because they have little metaphonological awareness in BSL and because signs do not display the onset salience that characterises spoken words.

KEYWORDS: British Sign Language; semantic fluency tasks; phonological fluency tasks; sign language phonology

INTRODUCTION

Studies of the mental lexicon have traditionally focused on spoken languages, which exploit the auditory modality. Within this context, a word is a mapping between a set of sounds (the phonological form) and a meaning (the semantic form). For example, hearing the form “cat” conjures up a particular mental image in speakers of English because they have learnt the link between the sequence of sounds /k/, /æ/, /t/ and the concept of CAT. Words are organised in the mental lexicon according to both meaning and phonology (Levelt, 1989).

Signed languages are natural languages that show many, if not all, of the same linguistic features as spoken languages, despite their transmission via a different modality. Furthermore, brain imaging studies show that signed languages are processed in the same neural regions as spoken languages (MacSweeney, Capek, Campbell & Woll, 2008). However, the phonological form of signs is very different to that of spoken words. Whereas spoken words consist of sequences of sounds that unfold over time, signs are composed of manual and facial elements that are organised with considerable simultaneity (Sandler & Lillo-Martin, 2006; also termed “multidimensional organisation”, Riche, Bellugi, Emmorey, Bettger, & Klima, 1993, and “vertical processing”, Brentari, 2002). Their manual phonological form is composed of three parameters: the configuration of the hand (“handshape”), the place of articulation (“location”) and the movement of the hand and its fingers (“movement”) (Sandler & Lillo-Martin, 2006). In addition, many signs are accompanied by a silent oral component (“mouthing”), which in some cases is related to the lip pattern made by the equivalent English word. For example, the phonological form of the sign CAT[1] in British Sign Language (BSL) consists of both hands being held with fingers slightly bent and then being pulled away from cheeks (see figure 1). The signer might

[1] Here and throughout we use the established sign linguistics convention of putting English glosses for signs in capitals.

choose to simultaneously mouth all or part of the lip pattern of the English phonology, /kæt/. The three manual parameters are not just descriptive devices – they have neurological validity (MacSweeney et al, 2008) and psychological validity, as shown by signers' "tips of the fingers" states (Thompson, Emmorey & Gollan, 2005), and in gating (Emmorey & Corina, 1990) and priming studies (Carreiras, Gutierrez-Sigut, Baquero & Corina, 2008).

INSERT FIGURE 1 ABOUT HERE

A second way in which signed and spoken languages differ is in the greater iconicity in signed languages. For example, in the BSL sign CAT, the hands moving away from the cheek represent the animal's whiskers. The visual modality affords many opportunities for such visually-motivated mappings between form and meaning, and researchers are increasingly investigating the effects of iconicity on signed language processing (see Perniss, Thompson & Vigliocco, 2010, for a review).

Little is yet known, however, about how the mental lexicon is organised in signers. In this study we investigated the organisation of the BSL lexicon using a probing technique that has proved particularly valuable in studies of spoken languages: the verbal fluency task. The task requires participants to produce as many words as they can in a given time (usually a minute) that fall into a certain semantic category (e.g. "animals", "food") or that begin with a certain sound or letter (e.g. "s", "f", "a"). The semantic version of the fluency task tests participants' semantic organisation. It is assumed that if participants are able to retrieve different animal or food items, their lexicon is organised taxonomically, with different animals organised under a super-ordinate category "animal", and likewise for food items. Furthermore, responses tend to be produced in temporal clusters which are closely semantically related, for example, the subcategories "pets", "zoo animals" and "birds" (for “animals”), or “fruit”, “meat” and “desserts” (for “food”), indicating that words that are closely semantically related are stored together in the lexicon (Gruenewald & Lockhead, 1980). Put another way, if semantic memory is considered to consist of associative links between nodes, where nodes correspond to category members, then a cluster is a set of nodes that are strongly associated (e.g. Kail & Nippold, 1984).

Not all members of a cluster are readily retrievable (links between their nodes are weaker), and so if the participant is to retrieve “as many items as they can” (as per the task demands), then the best strategy when search within a cluster slows down is to switch to a new semantic field in the attempt to retrieve a new cluster of words. Indeed, a reliable characteristic of semantic fluency is that response rate declines over time (Gruenewald & Lockhead, 1980; Kail & Nippold, 1984), and the number of words produced, or “fluency”, is a function not only of the number of items recovered from each cluster, but also of the number of switches to new clusters (Troyer, Muscovitch & Wincour, 1997).

Phonological (i.e. sound or letter) fluency is harder than semantic fluency, with both adults (Harrison, Buxton, Husain & Wise, 2000) and children (Koren, Kofman & Berger, 2005; Sauzéon, Lestage, Raboutet, N’Kaoua, & Claverie, 2004) generating fewer responses and making more errors. Phonological fluency is considered to require a more strategic search, and therefore to be more dependent on executive functions such as cognitive flexibility and set-shifting (Sauzéon, et al, 2004). Just as for semantic fluency, responses tend to be clustered, e.g. for the category “s”, rhyming “sand” and “stand” might occur one after the other, and response rate declines over time. For both semantic and phonological categories, not only are task-congruent clusters produced (i.e. semantic clusters within semantic categories and phonological clusters within phonological categories) but also task-*in*congruent clusters (i.e. semantic clusters produced within phonological categories, and vice versa), although these are rarer (Abwender, Swan, Bowerman & Connolly, 2001). Task-incongruent clusters are interpreted as reflecting an intentional, executive strategy on the part of the speaker (Abwender et al, 2001).

In the present study we adapted the verbal fluency task for BSL, which is the first time, to the best of our knowledge, that the task has been reported in any signed language (a recent study by Marshall, Rowley, Mason, Herman & Morgan (2013) reports just semantic fluency data for deaf children who use BSL). We make three sets of predictions. The first set concerns predicted similarities between fluency in signed and spoken languages, the second concerns predicted differences, and the third concerns predictions that are specific to signed languages.

Our first set of predictions concerns aspects of performance that are predicted to be comparable between signers and speakers. In particular, we predict that the following "signatures" of verbal fluency in spoken language exist for BSL too.

1. A greater number of responses for semantic compared to phonological categories.
2. Clustering within semantic and phonological categories, with each category containing both task congruent and task incongruent clusters.
3. A decline in response rate over time.

We predict that the types of semantic clusters for BSL will be very similar to those found for spoken languages and particularly for spoken English, given that users of both languages operate in the same dominant British culture and are likely to be just as familiar with foods and animals. Indeed, in Marshall et al (2013) deaf signing children produced very similar responses to those reported for English-speaking hearing children.

However, there are differences between signed and spoken languages that are predicted to affect the organisation of the lexicon, and therefore to give rise to differences in performance between signers and speakers. Our second set of predictions concerns three such expected differences:

1. *Close links between phonology and semantics*. Certain handshapes and locations in BSL can bear meaning, and so can be considered to be morphemes (Sutton-Spence & Woll, 1999). For example, the "I" handshape[2], which consists of a closed fist with just the little finger extended, bears negative meaning in most (but not all) signs, e.g. BAD, WRONG, AWFUL, POISON, ILL and REJECT (SHEEP and SIX are two examples where the meaning is not negative). Similarly, the forehead is the location for many signs to do with thinking and knowing, e.g. THINK, KNOW, UNDERSTAND, CLEVER, DREAM and IDEA, itself iconically motivated by the location of the brain (although not all signs located at the forehead relate to thinking and knowing, e.g. NAME and MUMMY). We predict that this feature of BSL will be reflected in a high degree of semantic clustering for phonological categories.
2. *Manual homonyms*. In BSL, many pairs (or groups) of signs share the same manual components (i.e. handshape, movement and location), but have different mouthings to disambiguate their meanings. We might therefore expect homonyms to cluster together in signers' responses. Although not all homonyms share semantics, many do (as in LION/TIGER, see figure 2, or AUDIOLOGY/RADIO), and so the production of homonym clusters is likely to contribute to semantic clustering.
3. *Fingerspelling*. Some words of English, particularly low frequency items, do not have an established sign in BSL. Just as users of a spoken language do, signers who

[2] Many handshapes are named after the letter they represent in the one-handed American fingerspelling alphabet. This is the convention in sign language linguistics and we follow it here. However, the reader should note that when we ask signers to produce signs that contain, for example, the "I" handshape, we are not asking them to produce the signed translations of English words that begin with "I", rather BSL signs that contain that handshape. The actual name of the handshape is irrelevant to the task.

> wish to communicate about referents for which there is no established form in their lexicon borrow from another language. In the case of signers, one way to borrow is to represent English words by fingerspelling their written form with the manual alphabet. Low frequency items, e.g. MONGOOSE, are more likely to be fingerspelled (i.e. m-o-n-g-o-o-s-e). Hence we might expect borrowing, in the form of fingerspelling, in sign fluency tasks. In addition, a few short high frequency fingerspellings have become lexicalised (e.g. e-g-g for EGG, h-a-m for HAM, b-b for BAKED BEANS).

It is well-recognised that some differences between the BSL lexicon and the lexicons of spoken languages – strong form-meaning links, large numbers of homonyms, and fingerspelling – exist (Brien, 1992; Sutton-Spence & Woll, 1999). The question we ask in this study is whether they have a demonstrable effect on signers' lexical organisation.

INSERT FIGURE 2 ABOUT HERE

The final set of predictions are specific to signed languages because they concern the phonological parameters of sign, and, in particular, the type of phonological clustering that we expect to find in our data. Marshall et al. (2013), in their study of semantic fluency in deaf child signers, did not study phonological clustering within the responses, and ours is the first study to investigate this. A growing literature on lexical access in signed languages, using tasks other than fluency tasks, consistently reports the role of phonology in sign language processing, and we therefore predict clustering according to all three parameters. What we are unable to make are precise predictions regarding which parameter(s) will show the most clustering, as no clear picture arises from the existing literature on other lexical access tasks. Such studies report, instead, mixed findings.

In a “tip of the finger” (analogous to “tip of the tongue”) study, signers were more likely to retrieve a target sign's handshape and location than to retrieve its movement (Thompson et al, 2005). Similarly, in a gating study, location and handshape were recognised first, with movement last (Emmorey & Corina, 1990). In contrast, Orfanidou, Adam, McQueen and Morgan (2009) investigated misperceptions in a sign-spotting task, and specifically instances where nonsense signs were reported as real signs. They reported that movement and handshape were more likely to be misperceived than location. Baus, Gutiérrez-Sigut, Quer and Carreiras (2008) found in a picture-sign interference task that target signs were named more quickly when they shared either handshape or movement with their distractors, but were named more slowly when they shared location.

Mixed findings have also been reported by primed lexical decision studies. Although priming has been found when prime and target pairs are phonologically similar, the type of phonological similarity differs across studies. Dye and Shih (2006) found that facilitatory priming occurred only when prime and target signs shared both location and movement, whereas Carreiras et al (2008) found facilitatory priming only for handshape, and then only when target signs were non-signs. Carreiras et al (2008) also found *inhibitory* priming for location, although this time the effect was limited to real signs. Conversely, Corina and Hildebrandt (2002) investigated movement and location and found no evidence of phonological priming for either parameter.

Hence, although there is evidence to suggest that phonological parameters differ in the roles they play in sign access, the existing experimental data (and particularly those from primed lexical decision tasks) at present resist a straightforward explanation. Nor do theoretical models of sign phonology offer an easy answer. The two major models of sign language phonology – the Prosodic Model of Brentari (1998) and the Hand Tier Model of Sandler

(1989) – differ in how they conceive of the relationship between movement and the other parameters. Brentari divides phonological features into two types: inherent features, which are realised simultaneously and comprise all the aspects of handshape and location, and prosodic features, which are dynamic and therefore comprise all aspects of movement. Sandler (1989), in contrast, separates handshape from location and movement. Given contradictions within the theoretical and experimental literature, and that no other study has used a method of relatively free generation of signs (as opposed to the production of specific signs required by the studies of Emmorey & Corina, 1990, Thompson et al, 2005, and Baus et al, 2008), there is no theoretical basis for making predictions as to whether handshape, location or movement clusters will be most numerous in our data. In this sense our study is exploratory.

MATERIALS AND METHODS

Participants

Data were collected from 30 participants for semantic fluency (12 male; aged 21-60, mean = 39.23, SD = 12.92) and a subset of 15 participants for phonological fluency (7 male, aged 20-60, mean = 38.80 years, SD = 12.53). The group sizes differ because after piloting both tasks on 15 participants, changes were made to the phonological categories and to the instructions[3], but the semantic task remained unchanged. We are therefore able to include the pilot participants and report findings for a larger group for the semantic task.

Participants were recruited through the researchers' own contacts, deaf clubs and the participant recruitment database at the ESRC Deafness, Cognition and Language Research Centre. BSL has substantial regional variation, and we recruited our participants from South

[3] Specifically, we increased the number of phonological categories from 3 to 6 because of variability in the number of responses across categories, and we clarified the instructions by adding examples.

East England to minimise variation as far as possible. All participants use BSL as their preferred form of communication and report using it every day. Of the 30 participants, 18 are native signers who acquired BSL from deaf parents. 12 participants were born to hearing parents, and of those, 10 learnt BSL before the age of 3. Two participants, from the group whose data are reported just for the semantic fluency task, had a later age of BSL acquisition (5 and 8 years). However, comparing their data to the rest of the group indicated no obvious differences in number or types of responses, so they are included here. The subset of 15 participants in the phonological fluency tasks consisted of 13 native signers, and 2 non-native signers who had learnt BSL before the age of 3.

Stimuli

We used two semantic and six phonological categories. The semantic categories were “food” and “animals”, which are the most widely-used categories in the spoken language literature. The phonological categories were as follows:

Handshape (see figure 3): “I” – the fist with the fourth (little) finger extended; “G” – the fist with the first (index) finger extended; “claw 5” – all five fingers apart and slightly bent.

Location: “above the shoulders”; “on the palm of the non-dominant hand”

Movement: “two hands, both hands moving”

INSERT FIGURE 3 ABOUT HERE

We deliberately selected a range of phonological categories, given that fluency tasks have never before been used in a signed language. There are no published frequency counts for BSL of the sort that are available to guide research design in some spoken languages. There is, however, a BSL/English dictionary (Brien, 1992) with signs organised according to handshape. Three handshape categories were chosen to represent a range of frequencies: the dictionary presents 167 signs for “G”, 78 for “claw 5”, and 29 for “I”[4]. Despite these differences in frequency, all three handshapes offer signers possibilities to retrieve clusters of semantically-related signs. As discussed previously, “I” has a negative meaning in many signs (23 out of the 29 listed in the dictionary). “Claw 5” offers a wider set of meanings. It is used as a classifying element in certain established signs, e.g. “bent legs” in SPIDER and BEETLE, or to indicate the extent of large spheroid objects such as the foods AUBERGINE and MELON (Brien, 1992). The fingertips can be used to represent many small dots, as in FRECKLES and CHICKEN POX. While those meanings are visually iconic, “Claw 5” also has a non-iconic symbolic function, for example in signs relating to strong emotion, such as ANNOYED, WORRY, COMPLAIN and FURIOUS. “G” also offers a wide set of meanings, including a classifying element in established signs, e.g. a person in signs such as MEET, and long thin objects in the signs UNDERGOUND TRAIN and ROCKET. It is a size and shape specifier in the signs WINDOW and PICTURE, where it traces the outline of the referent. “G” also has a major role in deictic signs where it is used to point to referents, as in the signs EYE and THROAT, and is used in pronouns such as YOU and HIM.

Two locations were chosen – a very broad location of “above the shoulders” (which comprises a number of more specific locations, including the forehead, nose, cheek, mouth, and neck) and the narrower location of “palm of the non-dominant hand”. Although there are no frequency counts for signs at these two locations, our intuition is that “above the shoulders” is the location of many more signs than “palm of the non-dominant hand”. The “above the shoulders” location often carries rich iconic meaning. For example DEAF and HEARING AID are signed at the ear, CROWN and HAT at the top of the head, and SEE and GLASSES at the eye. (There are many other signs where the location is *not* iconic, as in

[4] These figures might seem low, but the BSL dictionary represents only a sample of the BSL lexicon and does not include all homonyms, so the actual number of lexical items available for each category is higher.

AFTERNOON at the chin, NAME at the forehead and SISTER at the nose). "Palm of the non-dominant hand" does not have such specific iconicity, although it can have a classifying function of "surface" in signs such as STAMP (where the hand represents the envelope) and BUTTER (where the hand represents the surface of the object being buttered).

Finally, we also chose a movement category, "two-handed movement". Signs can be one-handed or two-handed. The phonological constraints on signs are such that when both hands move, they have the same movement, and move either synchronously or in an alternating fashion (Sutton-Spence & Woll, 1999). Because the BSL Dictionary does not organise signs by movement it is less easy to calculate how many signs contain this type of movement, and we did not do so. However, our intuition is that this type of movement is common, and signs within this category include BROTHER, COMMUNICATION, DIFFERENT and SAME. There are possible links between this type of movement and meaning. In the sign MEET, for example, movement represents movement: two G hands move towards one another, representing the movement of two people. In the signs COMMUNICATION, WAR and ARGUE, the alternate movement arguably represents (metaphorically) to-and-fro movement.

Procedure

Instructions were delivered in BSL by the experimenter (second author, a Deaf native signer). The instructions for the two semantic categories were straightforward: "Please tell me the names of as many animals/food items as you can. Be as quick as possible. You have one minute. Ready? Go". No examples were given. Similar instructions were given for the phonological categories, with the second author demonstrating the particular handshape, location and movement categories. In addition, three examples were given for each category, because piloting showed that signers found this part of the task very difficult and unintuitive.

The order in which the eight categories were presented was counterbalanced. Participants were filmed so that their responses could be timed and coded at a later stage.

Analysis of responses

Responses were glossed using the equivalent English word, and fingerspelled items were identified. We also recorded the number of seconds after the start of the minute each response was produced. The total number of responses in the full minute and for each quadrant of the minute (i.e. 1-15s, 16-30s, 31-45s and 46-60s) were calculated.

Semantic categories

In coding responses for semantic categories (i.e. "food" and "animals") we followed existing literature. Responses were scored as correct, or alternatively as errors. Two groups of errors were coded: repetitions and intrusions. Intrusions were defined as items from a different category; in our data, these were most frequently drinks coming into the "food" category. For the category "animals", for example, MONSTER was counted as an intrusion as it is mythical, but DINOSAUR was counted as correct, as it is a real animal, albeit extinct. Self-corrections or "whisperings to self" (e.g. as a reminder that a particular sign had just been produced) were glossed but not included in scoring[5].

All responses, whether correct or incorrect, were assigned to semantic subcategories (in line with previous studies, e,g. Troyer, 2000). These were done on the basis of the categories that emerged from the data (as *per* Kosmidis, Vlahou, Panagiotaki & Kiosseoglou, 2004; Marshall et al., 2013). For "animals", both thematic (e.g. "zoo animals", "farm animals",

[5] Whisperings are harder to code in BSL than in spoken languages, where volume is often used to distinguish self-talk from actual responses. In BSL, signers might reduce the size of their signs, but more frequently in our data they used facial expression and emphasis to show novel responses or to indicate uncertainty as to whether a response was repeated or did indeed fit into the target category.

“pets”, “water animals”, “British wild animals”) and taxonomic categories (e.g. “birds”, “reptiles”, “invertebrates”) emerged, as has been reported for spoken languages. An item could therefore be assigned to one subcategory on one occasion, but to a different subcategory on another, depending on the items it was produced with. For example, TORTOISE produced with DOG, CAT, HAMSTER and FISH was categorised as a “pet”, but TORTOISE produced with SNAKE and LIZARD was categorised as “reptile”. Similarly, both thematic (“breakfast foods”, “Italian foods”, “takeaway meals”) and taxonomic (“meat”, “fruit”, “vegetables”, “dairy products”) categories emerged for “food”. Clusters were defined as two or more adjacent responses from the same subcategory (as *per* Koren et al, 2005). Once clusters of semantically-related items had been identified, we calculated switches between clusters and/or unclustered adjacent items.

We then coded all responses for potential membership of a phonological cluster. For spoken languages such as English, phonological clusters are defined differently by different researchers, but might include successively generated words that begin with the same two letters, differ only by a vowel sound, rhyme, or are homonyms (e.g., Troyer, 2000). The phonology of BSL is, of course, very different, and we coded for clusters by looking for adjacent items that shared handshape, movement, and/or location, or that were full homonyms (i.e. that shared all three manual parameters but had a different meaning, as indicated by different mouthings).

Phonological categories

Responses were scored as correct if they were real signs that showed membership of the specified phonological category, i.e. contained the target handshape, movement or location, depending on category instructions. Repetitions (repetition of responses or items used in the instructions) and intrusions (real signs that did not belong to the specified category) were scored as incorrect. There was an error type which did not occur for semantic categories, namely “non-signs”. For example one signer produced the sign ANGRY using the “I” handshape instead of the “Claw 5” handshape for the category “I”, thus changing the phonology of the sign in order to fit it into the category. On other occasions signers created signs that fitted the category but did not seem to bear a relationship to an existing sign, and these were also classified as non-signs. Finally, errors that could not be fitted into any of these three categories were classed as “other” errors. These included pointing signs for the “G” handshape, gestures, and signs from other sign languages.

All responses were coded for potential membership of a phonological cluster, either because they shared phonological properties (i.e. handshape, movement, and/or location) with an adjacent sign, or were full homonyms. Again, incorrect as well as correct signs were considered.

The first and second authors worked together to code all the data. The third author then independently coded the data from three participants, and there were high levels of agreement throughout: 97.5% for coding into the different categories of: correct, repetition, intrusion, non-sign, other; 98.6% for semantic clusters; 93.4% for handshape clusters; 94.4% for location clusters; 97.5% for movement clusters. For the statistical analyses we use the first and second authors’ joint codings.

RESULTS

We report on fluency (i.e. the number of responses to each category), the number of responses per quadrant of the minute, the clustering of responses, and (for the semantic categories only) the most frequent responses.

Fluency

The number of responses produced for each category are illustrated in Figure 4, and further details can be found in the Appendix. With respect to the semantic categories, paired t-tests revealed no significant differences between food and animals for total and correct responses, $t(29) = 1.968$, $p = 0.059$ and $t(29) = 1.894$, $p = 0.068$, respectively.

INSERT FIGURE 4 ABOUT HERE

As can be seen in Figure 4, fluency for the phonological categories was numerically lower than for semantic categories, and phonological categories attracted more errors. However, fluency varied significantly across the 6 phonological categories, $F(5,70) = 24.47$, $p < 0.001$, partial $\eta^2 = 0.636$ for total responses, and $F(5,70) = 21.08$, $p < 0.001$, partial $\eta^2 = 0.601$ for correct responses.

Fingerspelled items were rare, representing just 1.60% of responses to “food” and 2.12% of responses to “animals”, and 1.43% across the phonological categories. As expected, the majority of these items are either lexicalised (e.g. SEED, HAM) or low frequency (e.g. GECKO, MANDRILL). Some, however, were not expected, as they are higher frequency items for which established signs are available (e.g. ZEBRA, TIGER). Nevertheless, their occurrence was marginal.

Fingerspelling and single manual letter signs for the phonological categories only occurred where the phonological category in question was one that could be involved in fingerspelling. For example, location on the “palm of the dominant hand” elicited items such as h-h for HARD OF HEARING, m-m for MOTHER, t-v for TELEVISION and t-h for

THURSDAY. Seven participants gave the letter “s” for the “I” handshape, which is the only letter in the BSL manual alphabet that uses this handshape.

Number of responses per quadrant

To calculate whether the number of responses declined over the course of the minute, we averaged across the two semantic categories, and across the six phonological categories. These data are shown in Figure 5, where it can be seen that for both types of category the response rate declines during the course of the minute, with the greatest number of responses in the first quadrant and the fewest in the fourth quadrant. Please refer to the Appendix for full details of the number of responses per quadrant for each category.

INSERT FIGURE 5 ABOUT HERE

The number of responses differed significantly according to quadrant, for semantic categories, $F(3,87) = 83.48$, $p < 0.001$, partial $\eta^2 = 0.742$, and phonological categories, $F(3,42) = 97.22$, $p < 0.001$, partial $\eta^2 = 0.874$ respectively. Paired samples t-tests to compare the number of responses in adjacent quadrants (and with the alpha level reduced to $p = 0.013$ to account for multiple comparisons within each category) showed that for semantic categories there were significantly more responses in the first compared to the second quadrant, $t(29) = 10.802$, $p < 0.001$, and in the second compared to the third, $t(29) = 4.233$, $p < 0.001$, but not for the third compared to the fourth, $t(29) = 2.202$, $p = 0.036$. There was a similar drop off in responses over the course of the minute for the phonological categories. There were significantly more responses for the first quadrant compared to the second, $t(14) = 9.234$, $p < 0.001$, and for the third compared to the fourth, $t(14) = 3.410$, $p = 0.004$, although the difference between the number of responses in the second and third quadrants failed to reach significance, $t(14) = 2.074$, $p = 0.057$.

Clusters

In this section we first analyse the semantic and phonological clustering found within the two semantic categories, and then discuss the clustering found within the phonological categories.

Clustering within semantic categories

The data for semantic (congruent) and phonological (incongruent) clusters are presented in Table 1. Paired samples t-tests revealed that the average number of semantic clusters did not differ significantly between "food" and "animals", $t(29) = 0.278$, $p = 0.783$, and nor did average cluster size, $t(29) = 0.271$, $p = 0.788$. There were, however, significantly more switches for food compared to animals, $t(29) = 2.322$, $p = 0.027$.

INSERT TABLE 1 ABOUT HERE.

Because the phonological clusters sometimes overlapped, we did not calculate switches. Although every participant produced at least one phonological cluster, not every participant produced one of every type of phonological cluster, and we therefore report average cluster size as the mode rather than the mean. As can be seen in Table 1, the most frequent number of items in each phonological cluster, for both "food" and "animals", is two, although the largest cluster had eight items in it. Significantly more phonological clusters were produced for "animals" than for "food", $t(29) = 4.958$, $p < 0.001$.

An ANOVA demonstrated that phonological parameters (averaged across food and animals) clustered to different extents, $F(2,58) = 46.631$, $p < 0.001$, partial $\eta^2 = 0.617$. A series of paired t-tests (with the alpha level set at $p = 0.017$ to compensate for 3 comparisons) revealed no significant difference between the number of handshape and location clusters, $t(29) = -1.292$, $p = 0.206$. However, there were significantly more handshape than movement clusters, $t(29) = 7.691$, $p < 0.001$, and significantly more location than movement clusters, $t(29) = 11.704$, $p < 0.001$. An alternative way of presenting the phonological clustering data is to show the percentage of adjacent signs that share handshape, location, movement, or are full homonyms. These are shown in Figure 6. While handshape and location both play an important role in guiding lexical retrieval, the role of movement appears to be considerably more minor.

INSERT FIGURE 6 AND TABLE 2 ABOUT HERE.

Finally in this section, we investigated how strongly semantic fluency correlates with the size and number of semantic clusters that participants produce, and the number of times they switch to a new cluster or to an unclustered item. All these correlations were significant, as shown in Table 2, indicating that participants who produce most responses do so because they are producing larger and greater numbers of semantic clusters, and switching more frequently. However, mean cluster size itself is not correlated with the number of clusters or number of switches.

Clustering within phonological categories

As was the case for the two semantic categories, we identified four types of phonological (i.e. congruent) clusters, namely handshape, location, movement and homonyms. However, for handshape categories and for the location category “palm of the non-dominant hand” we did not count handshape and location respectively, as this was identical for all signs as per category instructions. For the location category “above the shoulders” we *were* able to calculate location clusters: we subdivided this region up into smaller locations, namely upper head (including forehead), side of head, eyes, nose, cheek, ear, mouth/chin, and neck. Therefore we could calculate location clusters for this category. Similarly, for the movement category “two-handed movement” different types of movement were possible, e.g. opening and closing of the hands, a flutter of the fingers, and a double contact movement, so we calculated movement clusters for this category. The phonological and semantic cluster data for phonological categories are presented in Table 3.

INSERT TABLE 3 HERE

As Table 3 shows, there is rich clustering in these data according to both semantics and phonology. However, the number of clusters differs significantly between categories. An ANOVA with the six categories as the within-subjects factor and the number of semantic clusters as the dependent variable shows a significant effect of category, $F(5,70) = 11.42$, $p < 0.001$, partial $\eta^2 = 0.449$. A similar ANOVA with the number of phonological clusters as the dependent variable also shows a significant effect of category, $F(5,70) = 22.69$, $p < 0.001$, partial $\eta^2 = 0.618$. Visual inspection of the data in Table 3 shows that semantic and phonological clustering is particularly rich for the “above the shoulders” location.

As was the case for phonological clusters within the semantic categories “food” and “animals”, the mode number of items in each type of phonological cluster, and across all categories, was two. Once again, there were fewest clusters for movement compared to the other phonological parameters of handshape and location. This is not straightforward to test statistically, because clusters in all three parameters are only countable for two categories – “above the shoulders” location and “two-handed movement”. However, an ANOVA with parameter as the within subjects factor and the average the number of clusters for “above the shoulders” and “two-handed movement” as the dependent variable revealed a significant effect of parameter, $F(2,28) = 48.28$, $p < 0.001$, partial $\eta^2 = 0.775$. Paired samples t-tests revealed that there are more handshape compared to movement clusters, $t(14) = 7.160$, $p < 0.001$, and more location compared to movement clusters, $t(14) = 12.616$, $p < 0.001$. In contrast, the number of handshape and location clusters is not significantly different, $t(14) = 0.557$, $p = 0.587$. As was the case for the semantic categories, it appears that movement has a much less important role in guiding lexical retrieval compared to handshape and location.

Finally in this section, Figure 7 shows an alternative way of presenting the semantic and phonological clustering, according to which percentage of adjacent signs share semantics, handshape, location or movement, or are full homonyms. This further illustrates the richness of semantic and phonological clustering across the phonological categories.

INSERT FIGURE 7 HERE

DISCUSSION

Despite the widespread use of semantic and phonological fluency tasks for investigating lexical organisation in spoken languages, this is the first study to employ both these tasks in a signed language. As we predicted, there are differences and similarities between Deaf adult signers' performance on the tasks and the performance of speakers as reported in the literature. Thus both modality-dependent and modality-independent factors play a role in the organisation of the mental lexicon. Specifically, we found the following similarities to spoken language: a greater number of responses for semantic than for phonological categories, a decline in response rate over time and semantic and phonological clusters for both semantic and phonological categories. We discovered the following differences: some (although marginal) fingerspelling of responses, a high degree of semantic clustering in response to phonological categories, and clusters of sign homonyms. With respect to phonological clustering in response to both semantic and phonological categories, we found significantly more clustering around the parameters of handshape and location than around movement. We discuss these findings in detail now, starting with a comparison between overall fluency in BSL compared to reports in the literature for a variety of spoken languages.

Direct cross-linguistic comparisons of overall fluency are difficult to make because different studies select participants according to different age criteria, and use different categories. However, comparing the number of correct responses made by signers to "animals" with results from adults of a similar age range in four spoken languages reveals that users of BSL produce a comparable number of responses: a mean of 22.97 compared to 21.50 for English (Harrison, Buxton, Husain & Wise, 2000; Tombaugh, Kozak & Rees, 1999), 22.80 for Hebrew (Kavé, 2005) 25.50 for Spanish (Buriel et al, 2004), and 18.50 for Greek (Kosmidis et al, 2004). It is of course possible that differences are hidden because our group is not matched to the participants of the afore-mentioned studies for age, IQ, or years of education, and so this point requires further study. Nevertheless, it appears on the basis of these first results that semantic fluency in signers and speakers is comparable.

One modality difference between spoken languages and signed languages that could potentially have influenced task performance is the existence of fingerspelling in signed languages. Fingerspelling is used in BSL for items that have no conventional signs because of their low frequency of use, or alternatively for highly frequent items, where fingerspelling has become lexicalised. However, although many signers are, at least to some degree, bilingual in BSL and written English, they did not fingerspell lists of English words in this task, but instead accessed the BSL lexicon as per the task instructions. The vast majority of responses in our data (over 98%) were BSL signs, not fingerspellings. For semantic categories, fingerspellings were predominantly lexicalised spellings that function in BSL as signs (e.g. h-a-m, HAM) or low frequency items that do not have a conventionalised sign and would be fingerspelled in a BSL conversation (e.g., ENCHILADA, OCELOT) For phonological categories, fingerspelling was only used when its phonology was appropriate for that category, e.g. letters on the "palm of the non-dominant hand", or letters using the "I" and "G" handshapes.

Comparing our phonological fluency results to those of spoken languages is complex, because for spoken languages respondents are often instructed to produce as many words as they can beginning with a certain letter of the alphabet (e.g. "s"), making it an orthographic rather than a strictly sound-based task, which arguably means that the task is misnamed as being wholly 'phonological'. For BSL, our phonological categories were by necessity different and more consistently phonological in nature – there is no orthography in BSL, and the phonological categories do not map on to sound categories of English or other spoken languages. Despite these differences comparison to spoken languages is a useful guide to the relative difficulty of phonological categories for signers. Spoken language phonological fluency is in the region of 10-15 words (12.56-13.42 for Spanish (Buriel et al, 2004); 10-13 for Greek (Kosmidis et al, 2004); 13 for Hebrew (Kavé, 2005); 15.3 for English, (Harrison et al, 2000)). Thus it appears that in BSL, the "above the shoulders" location (M=19.53) is particularly productive compared to typical spoken language phonological categories, whereas other categories, e.g. the "I" handshape and "palm of the non-dominant hand" (M=7.40 and 8.13 respectively), are considerably less productive.

Phonological fluency in signed languages may therefore be very dependent upon the particular category chosen. We speculate that this is due, perhaps not surprisingly, to the number of items available within each category. After all, in spoken languages, the variability in productivity across phonological categories has been shown to be correlated with frequency (Borkowski, Benton & Spreen, 1967). As explained previously, there are no frequency counts yet available for the categories that we used in this study, but the BSL dictionary (Brien, 1992) is organised by handshape and presents 167 signs for the “G” handshape, 78 for “claw 5” and 29 for “I”. The fact that signers provide so few responses for “I” (M correct = 7.40) is therefore not surprising, but one might expect on the basis of the number of dictionary entries for there to be more responses for “G” (M correct = 10.93) than for “claw 5” (M correct = 11.20), which was not the case. The low number of “G” responses could be due to signers being asked to suppress pointing, and therefore not being able to respond with items such as pronouns and body parts. As well as reducing the number of signs available for production, inhibition might well have a cognitive cost, thereby reducing fluency further. Although the BSL dictionary is not organised according to location, it is our intuition that the “above the shoulders” location has a large number of signs, and the “palm of the non-dominant hand” fewer, which is reflected in the higher mean number of correct responses for the former (M correct =19.53), compared to the latter (M correct = 8.13).

Even taking these differences in item frequency across different phonological categories into account, we found that the phonological fluency task was challenging for some signers. This was immediately evident to us during our long piloting phase for the phonological categories. Whereas the semantic categories adapted straightforwardly into BSL, devising instructions and a set of phonological categories that would successfully elicit responses took some not inconsiderable effort. Even then, some signers appeared to struggle with the task, as revealed by their repeating the examples given in the instructions and creating non-signs to fit the categories (we can find no reports of the latter error in the spoken language literature). Phonological fluency might be difficult for several reasons. Firstly, there are fewer opportunities for signers than speakers to engage in metaphonological activities.

Anecdotally, although sign language play is directed at young Deaf children in Deaf families, this does not tend to focus on phonology, and BSL poetry is not routinely used at home and is largely limited to poetry performance events. We are not arguing that signers have *no* explicit awareness of the structure of their language's phonology (see Riche et al., 1993, for evidence that even 5 year-olds are able to match signs according to shared handshape in American Sign Language), just that they have less experience in the explicit manipulation of phonological elements in signs, in contrast to the nursery rhymes, "I-spy" games, spoonerisms and other sound play that speakers experience from a young age.

Additionally, and perhaps more strikingly, there is no writing system for BSL or for any other signed language, and so the metaphonological awareness than develops as a result of becoming literate in a particular spoken language (e.g., Morais, Bertelson, Cary, & Alegria, 1986) is not available for sign. In support of this interpretation, Loureiro and colleagues found that illiterate speakers of Brazilian Portuguese produced significantly fewer responses on a phonological fluency task compared to semiliterate speakers of that language (Loureiro, Braga, Souza, Filho, Queiroz, & Dellatolas, 2004). Similarly, Ratcliff and colleagues dropped phonological fluency from a proposed battery of neuropsychological tasks for use in a rural district of northern India because many participants with low levels of literacy could barely complete the task, despite having no difficulty with the semantic fluency categories (Ratcliff, Ganguli, Chandra, Sharma, Belle, Seaberg, & Pandav, 1998). Also relevant is work revealing that adult speakers who are dyslexic (i.e. who have reading difficulties) show significantly poorer phonological fluency than non-dyslexic controls (Snowling, Nation, Moxham, Gallagher, & Frith, 1997). A direct test of this metaphonological hypothesis could involve, in future work, giving signers both a signed phonological fluency and a signed phonological awareness task.

A second reason that phonological fluency might be more difficult for signers relates to differences in the formational properties of signs. Although there are many similarities in the segmentation of words and signs from the speech stream and sign stream respectively (Orfanidou, Adam, Morgan & McQueen, 2010), segmentation within a sign is different. There is no equivalent to the spoken onset in signs – the greater simultaneity of signs compared to spoken words means that the parameters of handshape, location and movement are not initial or final, but spread over the entire sign (Sandler & Lillo-Martin, 2006). Even in signs where there is some sequentiality, only a very small number of phonological features – generally only one – change during the sign (Sandler & Lillo-Martin, 2006). This has implications for sign recognition: signers are able to recognise signs on presentation of just the first 35% of a single sign due to the simultaneity of handshape, orientation and location (Emmorey & Corina, 1990), and this contrasts with the temporal unfolding of speech, which requires around 80% of the word to be presented before it can be identified (Grosjean, 1980). The signed phonological fluency task is therefore unlike the spoken version, where participants are required to retrieve words with a particular sound or orthographic onset, and where the experience of language games and literacy (e.g. the listing of words in a dictionary by alphabetical order) presumably supports efficient search strategies. We argue that the more simultaneous and composite nature of handshape, location and movement makes them more difficult to explicitly extract from the sign in comparison to the onset of spoken words. Ultimately, direct comparison of phonological fluency between sign and speech is problematic because we are not comparing like with like.

When we consider the clustering of responses we again find differences and similarities in comparison to spoken languages. Signers produce both task-congruent clusters (i.e. semantic clusters within semantic categories and phonological clusters within phonological categories) and task-incongruent clusters (i.e. phonological clusters within semantic categories and semantic clusters within phonological categories), as is the case for spoken languages. Yet we predicted that because of the close links between semantics and phonology in BSL – certain handshapes and location can bear meaning – clustering would be particularly rich in this language, and that there would be frequent semantic clusters for handshape and location categories. This certainly seems to be the case in our data, where, for example, in response to the "I" handshape category 14 of the 15 participants produced clusters of signs with a negative meaning. For the "above the shoulders location" participants produced clusters located at, for example, the forehead (e.g. UNDERSTAND, THINK, KNOW and CLEVER), the top of the head (e.g. CAP, HAT and HOOD), the ear (e.g. HEARING, DEAF) and the eyes (e.g. BINOCULARS, WATCH, SEE), where in each case the particular location is iconic. In fact, it is possible that the particularly rich opportunities for iconically-motivated semantic clusters in this category are partly responsible for the high number of responses that it elicited. The production of homonym clusters, i.e. two or more items with identical manual phonology and, for the most part, high semantic relatedness, also contributed to the rich clustering in the data for all categories, across both semantic and phonological tasks.

Again, it is difficult to directly compare the clustering in our signers' data with the spoken language fluency literature because of differences in participant selection, and the data are not always reported in a way that facilitates detailed comparison. In the few studies of spoken language fluency that have calculated both task-congruent and task-incongruent clusters, the latter are less common (Abwender et al, 2001; Raskin, Sliwinski, & Borod, 1992). For example, Abwender and colleagues report that for their study of English letter fluency, phonological clusters based on shared phonemes ("phonemic clusters") were about three times more common than semantic clusters, while for animal fluency, semantic clusters were about fourteen times more common (Abwender et al, 2001). Our data show a different picture. For animals, our signers actually produced *more* phonological than semantic clusters. Although for our phonological categories there were always more phonological than semantic clusters, the ratio of phonological to semantic ranged from 1.16:1 (for “palm of non-dominant hand) to 2.26:1 (for 2-handed movement; see Table 4), and was never as high as 3:1 as reported by Abwender et al (2001). The high level of task-incongruent clustering in BSL reflects, we believe, the close links between semantics and phonology in the morphological structure of signs and the BSL lexicon more generally.

Despite the difficulty that some signers had in explicitly searching for signs within phonological categories, the rich phonological clustering that we found throughout our data indicate that the phonological parameters are *implicitly* available to signers and *are* intimately involved in lexical organisation. The significantly greater number of clusters for handshape and location compared to movement, however, suggests either that signs are more closely grouped according to handshape and location compared to movement, or that signs sharing movement are, for some other reason, less readily retrieved during lexical access. We highlighted in the introduction the mixed findings with respect to lexical access tasks in the sign language literature, and in particular in the case of priming studies, with different studies finding priming (or lack of priming) for different parameters. However, the findings from our study do have commonalities with two lexical access studies that used different methodologies, namely those by Emmorey and Corina (gating; 1990) and Thompson et al (tip of the fingers; 2005). Both sets of authors found that location and handshape patterned together. These two studies and ours therefore converge, suggesting that movement has a more marginal role in lexical access compared to handshape and location.

Why should movement have a more marginal role in lexical access? In the case of gating, handshape and location are available at the very start of the sign and can be recognised almost immediately, whereas movement unfolds over time (Emmorey & Corina, 1990). Likewise, Thompson et al (2005) consider that this property could explain their tip of the finger data. Signers in those tasks were, of course, being asked to do different things to what was asked of signers in our study. Emmorey and Corina's gating study was a sign identification task, whereby increasing longer portions of a sign were displayed until the signer identified it correctly. In Thompson et al's task, signers were given low frequency English words and the names of cities and countries to translate into (American) sign language. In both of these tasks, then, there was only one correct target.

Fluency responses, on the other hand, are not constrained in this way – the only constraints are that responses belong to the given category. One way of generating responses is for participants to search for lexical items which share features with the sign they have just produced. Participants have only a limited time in which to complete the task, and are told to produce as many items as they can. If handshape and location are more readily available at the start of the sign, participants might (consciously or unconsciously) choose a sign that shares one those parameters with a previous sign. Hence the explanation for the greater clustering around handshape and location could be similar to that for the data from the gating and tip of the finger studies.

An alternative explanation is that movement is under-represented in the lexicon. The inventory of movements in the core lexicon of signed languages is limited (Sandler & Lillo-Martin, 2006). Path movements in particular are often redundant, being, in many signs, nothing more than straight paths between locations that can be generated automatically as the sign is phonetically implemented. It has therefore been claimed that movement is not present in the lexical representation. (Although this position is disputed; see discussion in Sandler & Lillo-Martin, 2006, and van der Kooij & Crasborn, 2008). If this explanation is correct for at least some types of movements in some signs, then it might offer a plausible explanation for why handshape and location are more readily available when signers are generating signs in a fluency task.

In conclusion, there are both modality-independent and modality-dependent factors at play in the organisation of the signed language lexicon, as revealed by semantic and phonological fluency tasks. Modality-independent factors are evidenced by the many similarities on performance in the signed and spoken language versions of this task, namely greater productivity for semantic compared to phonological categories, a decline in the rate of item production over the course of the minute, and the clustering of responses. We argue that the specific, or modality-dependent, characteristics of signed languages are responsible for aspects of performance that differ from spoken languages, namely the difficulty of the phonological fluency task overall for some signers, and the particularly rich clustering of items according to both semantics and phonology. We suggest that this is explained by the unique interrelatedness of semantics and phonology occurring in signed languages.

As probes of language, semantic memory and executive function, fluency tasks are widely used to assess individuals with neurological conditions, such as those with frontal lobe disorders, aphasia, dementia, and focal brain injury. The similarity of cognitive signatures in BSL and spoken languages suggests that semantic fluency tasks are suitable for use with Deaf clinical populations too (with the proviso that the task is normed for the particular sign language in question). However, the difficulty that many healthy adults of working age showed on phonological categories, as well as individual differences in metaphonological awareness, mean that greater caution and further research are needed before recommending signed phonological fluency tasks for clinical use.

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Table captions

Appendix 1: Semantic and phonological fluency: responses to semantic and phonological categories

Table 1. Semantic fluency: semantic and phonological clustering

Table 2. Semantic fluency: correlation matrix showing relationships between the total number of responses, correct number of responses, number of clusters, cluster size and number of switches (averaged across “food” and “animals”)

Table 3. Phonological fluency: semantic and phonological clustering

Appendix 1: Semantic and phonological fluency: responses to semantic and phonological categories

		Food	Animals	"I" handshape	"G" handshape	"Claw 5" handshape	"Above the shoulders" location	"Palm of non-dominant hand" location	2-handed movement
Total number of items	M	25.07	23.57	9.80	15.33	14.27	22.93	11.20	15.07
	(SD)	(5.55)	(5.29)	(3.28)	(4.51)	(3.97)	(6.56)	(3.14)	(5.50)
	Range	15-39	16-37	4-16	8-23	7-23	13-37	5-17	7-24
Correct items	M	24.33	22.97	7.40	10.93	11.20	19.53	8.13	12.13
	(SD)	(5.37)	(5.35)	(2.53)	(4.50)	(4.44)	(6.78)	(3.27)	(6.19)
	Range	15-36	16-37	4-14	3-19	4-22	11-34	3-13	2-24
Repeated items	M	0.37	0.57	1.60	1.73	2.20	1.33	1.13	1.47
	(SD)	(0.81)	(0.82)	(1.06)	(1.03)	(1.47)	(0.98)	(1.06)	(0.92)
	Range	0-4	0-2	0-3	0-3	0-5	0-3	0-3	0-3
Intrusions	M	0.40	0.03	0.33	0.73	0.20	0.20	1.40	1.07
	(SD)	(0.67)	(0.18)	(1.29)	(1.10)	(0.56)	(0.56)	(2.16)	(1.39)
	Range	0-2	0-1	0-5	0-3	0-2	0-2	0-7	0-4
Non-signs	M	0	0	0.33	0.93	0.27	0.87	0.27	0
	(SD)			(0.62)	(1.22)	(0.46)	(2.33)	(0.59)	
	Range			0-2	0-3	0-1	0-9	0-2	
Other errors	M	0	0	0.13	1.73	0.40	1.13	0.27	0.40
	(SD)			(0.35)	(1.98)	(1.55)	(1.64)	(1.03)	(0.91)
	Range			0-1	0-6	0-6	0-5	0-4	0-3
1st quadrant (1-15s)	M	8.73	9.30	5.00	6.00	5.40	8.87	5.27	5.60
	(SD)	(1.91)	(2.12)	(1.13)	(2.17)	(2.03)	(3.02)	(1.71)	(1.59)
	Range	5-12	6-14	3-7	3-10	2-9	5-14	3-8	3-8
2nd quadrant (16-30s)	M	6.43	5.80	1.73	3.93	3.67	4.73	2.53	3.33
	(SD)	(2.30)	(1.86)	(1.29)	(1.83)	(1.23)	(1.53)	(1.19)	(1.40)
	Range	2-10	2-10	0-4	1-7	1-5	2-8	0-5	2-6
3rd quadrant (31-45s)	M	5.20	4.57	1.73	3.67	2.73	4.73	1.53	3.33
	(SD)	(1.86)	(2.01)	(1.39)	(1.91)	(1.39)	(1.79)	(1.88)	(1.68)
	Range	2-10	1-8	0-4	0-7	1-5	1-7	0-3	0-6
4th quadrant (46-60s)	M	4.60	3.90	1.33	1.73	2.47	4.73	1.87	2.87
	(SD)	(2.25)	(1.99)	(1.29)	(1.16)	(1.46)	(2.74)	(1.41)	(2.13)
	Range	2-12	1-10	0-4	0-4	0-4	2-11	0-4	0-7

Table 1. Semantic fluency: semantic and phonological clustering

			Food		Animals	
Semantic clusters	Clusters, mean (SD)		6.03	(1.97)	5.93	(1.20)
	Items in each cluster, mean (SD)		3.83	(1.06)	3.76	(0.87)
	Switches, mean (SD)		7.77	(2.21)	6.53	(2.11)
Phonological clusters	Phonological (total)	Clusters, mean (SD)	3.67	(1.86)	7.17	(3.81)
		Items in each cluster, mean (SD)	2.47	(1.86)	2.33	(0.35)
	Homonym	Clusters, mean (SD)	0.50	(0.73)	1.23	(1.07)
		Items in each cluster, mode (range)	2	(2-4)	2	(2-3)
	Handshape	Clusters, mean (SD)	1.27	(1.01)	2.93	(1.84)
		Items in each cluster, mode (range)	2	(2-7)	2	(2-6)
	Location	Clusters, mean (SD)	1.70	(0.79)	2.97	(1.47)
		Items in each cluster, mode (range)	2	(2-6)	2	(2-8)
	Movement	Clusters, mean (SD)	0.70	(0.75)	1.27	(0.94)
		Items in each cluster, mode (range)	2	(2-6)	2	(2-6)

Table 2. Semantic fluency: correlation matrix showing relationships between the total number of responses, correct number of responses, number of clusters, cluster size and number of switches (averaged across "food" and "animals")

		Number of clusters	Cluster size	Number of switches
Total number of responses	Pearson Correlation	0.691	0.538	0.504
	Sig. (2-tailed)	<0.001	0.002	0.005
Number of correct responses	Pearson Correlation	0.664	0.548	0.471
	Sig. (2-tailed)	<0.001	0.002	0.009
Number of clusters	Pearson Correlation		-0.159	0.655
	Sig. (2-tailed)		0.400	<0.001
Cluster size	Pearson Correlation			-0.316
	Sig. (2-tailed)			0.088

Table 3. Phonological fluency: semantic and phonological clustering

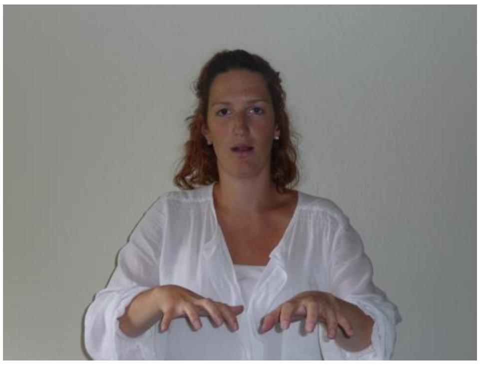
			"I" handshape	"G" handshape	"Claw 5" handshape	"Above the shoulders" location	"Palm of non-dominant hand" location	2-handed movement
Semantic clusters	Clusters, mean (SD)		1.80 (0.94)	2.27 (1.44)	3.27 (1.10)	5.20 (2.21)	2.07 (1.22)	2.53 (1.88)
	Items in each cluster, mean (SD)		3.05 (0.83)	2.39 (0.81)	2.42 (0.39)	3.22 (1.34)	2.44 (0.83)	2.54 (0.64)
Phonological clusters	Phonological (total)	Clusters, mean (SD)	2.13 (1.30)	3.47 (1.92)	4.80 (2.14)	9.33 (4.17)	2.40 (1.12)	5.73 (2.84)
		Items in each cluster, mean (SD)	2.68 (0.80)	2.97 (1.14)	2.45 (0.39)	2.83 (0.84)	2.77 (0.81)	2.91 (0.70)
	Homonym	Clusters, mean (SD)	0.33 (0.62)	0.47 (0.64)	0.80 (0.56)	0.73 (0.88)	0.27 (0.46)	0.40 (0.91)
		Items in each cluster, mode (range)	2 (2-4)	2 (2-2)	2 (2-2)	2 (2-3)	2 (2-2)	2 (2-2)
	Handshape	Clusters, mean (SD)	n/a	n/a	n/a	3.73 (1.79)	1.67 (0.82)	2.77 (1.29)
		Items in each cluster, mode (range)	n/a	n/a	n/a	2 (2-4)	2 (2-6)	2 (2-7)
	Location	Clusters, mean (SD)	1.93 (1.10)	2.80 (0.67)	3.07 (1.22)	4.53 (1.85)	n/a	2.20 (1.37)
		Items in each cluster, mode (range)	2 (2-4)	2 (2-6)	2 (2-10)	2 (2-11)	n/a	2 (2-13)
	Movement	Clusters, mean (SD)	0.20 (0.42)	0.67 (0.82)	1.73 (1.53)	1.07 (1.03)	0.73 (0.80)	0.87 (1.24)
		Items in each cluster, mode (range)	2 (2-4)	2 (2-3)	2 (2-3)	2 (2-3)	2 (2-2)	2 (2-3)

List of figures

Figure 1. The starting position of BSL sign CAT. The hands move away from sideways and away from the cheeks.

Figure 2. The starting points of the manual homonyms LION and TIGER. Note the identical handshape and location (the movement is also identical). Mouthing disambiguates the signs.

2a LION



2b TIGER

Figure 3. Handshape categories for the phonological fluency task.

3a “I” 3b “G” 3c “claw 5”

Figure 4. Semantic and phonological fluency: correct and error responses for each category

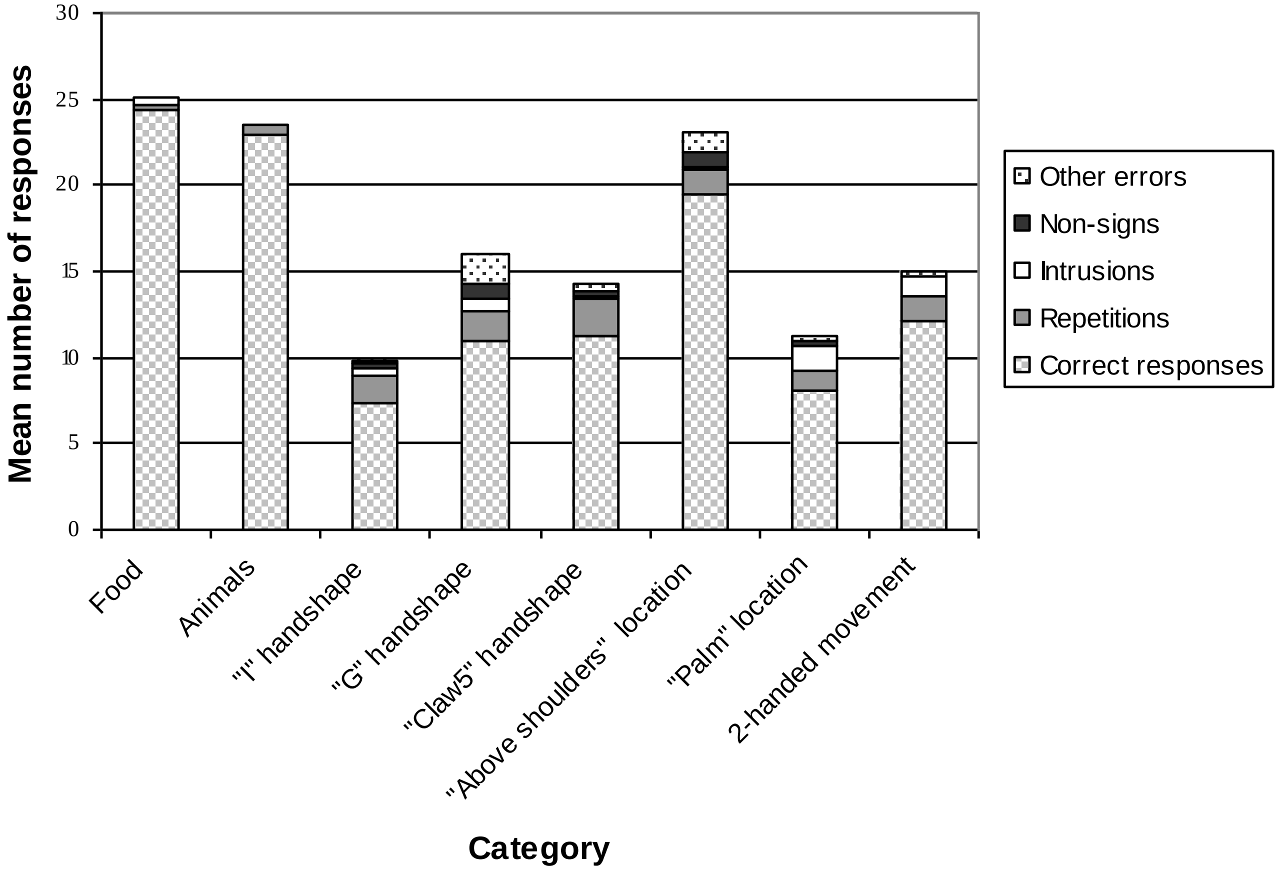


Figure 5. Semantic and phonological fluency: mean number of responses to semantic and phonological categories for each quadrant of the minute. Bars show standard deviations.

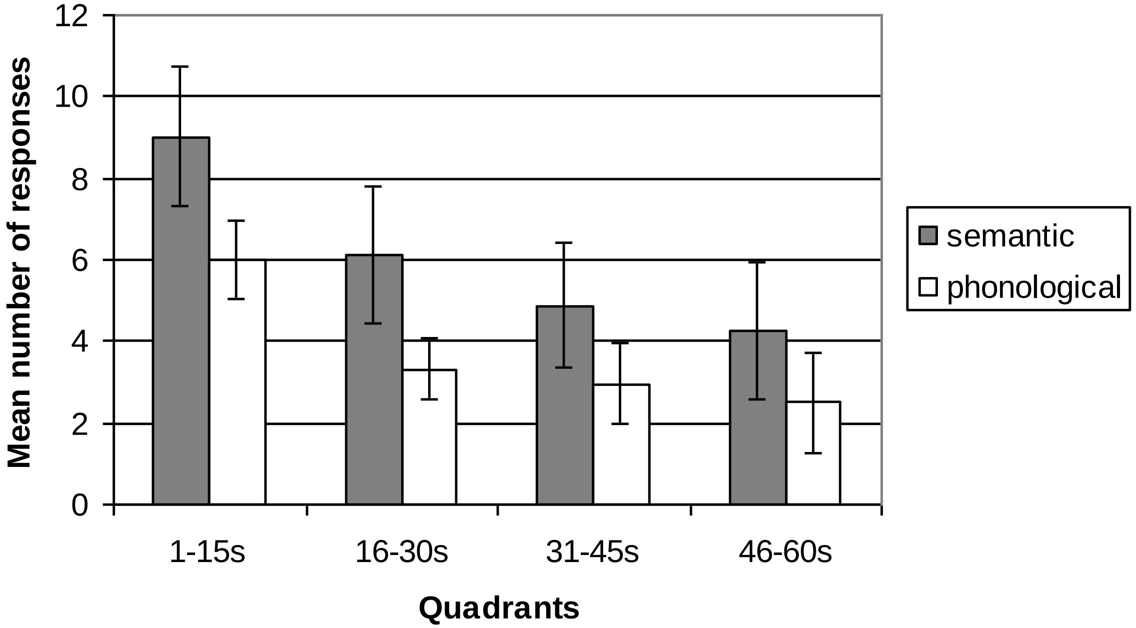


Figure 6. Semantic fluency: proportion of adjacent signs that share handshape, location, or movement, or are full homonyms

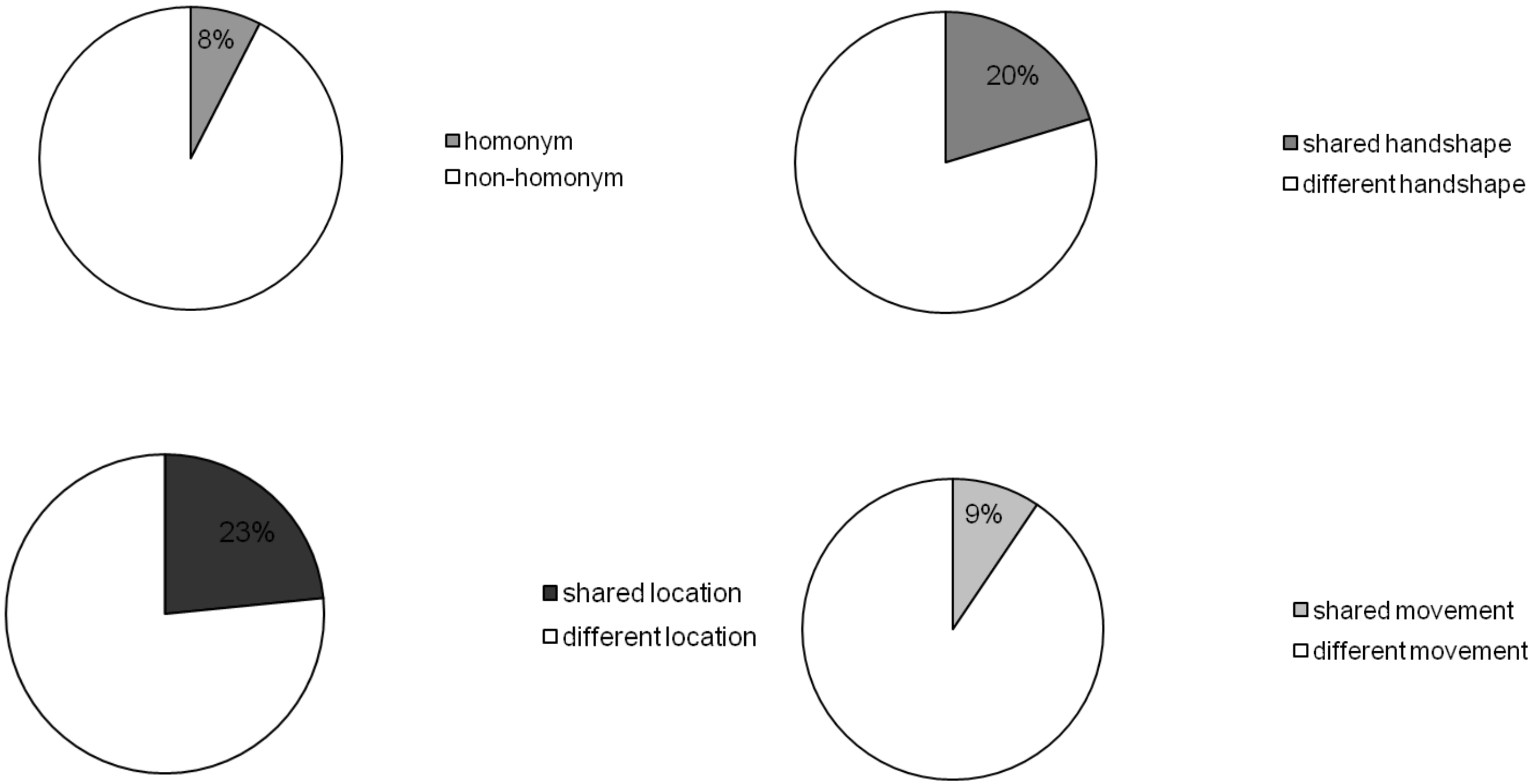


Figure 7. Phonological fluency: proportion of adjacent signs that share semantics, handshape, location, or movement, or are full homonyms