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Influences of Linguistic and Non-Linguistic Factors in the Processing of American Sign Language: Evidence from Handshape Monitoring*

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0. Introduction

Signed languages used in Deaf communities are naturally occurring human languages. Despite the differences in language form, signed languages have formal linguistic properties like those found in spoken languages (Stokoe 1960, Klima and Bellugi 1979, Sandler and Lillo-Martin 2006). However, only a few psycholinguistic studies of on-line processing in signed languages exist (for reviews of psycholinguistic studies of ASL see Emmorey 2002, Corina and Knapp 2006), and only a subset of these have directly addressed lexical recognition.

Studies of lexical recognition in signed languages have provided evidence for well-known psycholinguistic properties such as lexicality, usage frequency, and semantic and form-based context effects (Corina and Emmorey 1993, Mayberry and Witcher 2005, Dye and Shih 2006, Carreiras et al. 2008). However, a fuller explication of the processes by which a gestural-manual sign form is mapped to a meaningful lexical representation remains to be determined. A prominent issue is to determine whether the processes involved in sign recognition are driven by factors that are common to human action recognition in general or entail specialized linguistic processing. The present experiment investigates perceptual, motor and linguistic factors of sign recognition in the context of a sub-lexical monitoring task.

0.1. Phoneme Monitoring

Phoneme monitoring experiments are a staple of the spoken-language psycholinguistic literature (for a review see Connine and Titone 1996) and this technique has been useful in helping determine the relative importance of autonomous (bottom-up) versus interactive (top-down) processes in language comprehension. Though results are not always consistent, researchers have generally found faster

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reaction times for phoneme monitoring in the context of words rather than non-words (e.g., Cutler et al. 1987, Eimas, Hornstein, and Payton 1990, Pitt and Samuel 1995), supporting the idea that top-down influences are relevant even in the processing of sub-lexical linguistic elements.

In the present study, subjects were asked to respond when seeing a sign form articulated with a particular handshape. The viewed actions were either real ASL signs or phonologically possible "non-signs." Based on the results from spoken-language studies, one would expect to find faster RTs in the sign context than in the non-sign context and additionally, such an effect would only be expected in subjects able to tell the difference (i.e. signers). Though the paradigm used here has clear parallels with spoken-language phoneme-monitoring tasks, it must be noted that phonemes and sign parameters like handshape are not necessarily same-level units; in fact, the proper analogue of the phoneme in sign language is not a settled question. Spoken-language studies have found that monitoring RTs are slower, respectively, for phonemes, syllables, and words (Foss and Swinney 1973, Savin and Bever 1970, Segui et al. 1981), but the position of sign parameters like handshape in such a hierarchy is as yet unclear.

0.2. Lexicality

In the psycholinguistic literature, investigations of lexicality have examined how the word-form influences a subject's decisions when he or she is asked to recognize or determine a true word as opposed to a "non-word" (a form which by definition was made up by the experimenter and has no lexical entry). The assumption is that our ability to recognize a word is aided by its prior mental representation. A common finding is that the more word-like a non-word stimulus is, the harder it is to determine whether it is a true word or a made-up form. The fact that pseudo-words like "nust" are more difficult to reject than phonotactically impossible word-forms like "ntpw" is thought to be due to sub-lexical components of these stimuli forms engendering partial activations of existing mental representations, ultimately leading to more difficult correct rejections (Forster and Chambers 1973, Forster 1976, Coltheart et al. 1977, Gough and Cosky 1977).

In the present experiment, we created phonotactically possible non-signs by altering one parameter of well-formed existing signs. While several studies have reported lexicality effects in the context of lexical decision experiments for signs, whether such forms would be capable of engendering lexicality effects in the context of a handshape monitoring task is unknown. If such effects are found, it would argue for automatic top-down processing during sign recognition.

0.3. Markedness

The notion of markedness in phonological theory dates from the time of the Prague School, in particular the work of Trubetzkoy (1939/69) and Jakobson (1941/68). The term is generally used to indicate that the values of a phonological feature or parameter are in some sense patterned asymmetrically, in that one value may be realized with more natural, frequent, or simple forms than those of the

other. The properties Jakobson (1941/1968) associated with unmarked elements included cross-linguistic frequency, ease of production and acquisition, and resistance to loss in aphasia. Within a specific language, "markedness" is often considered a synchronic property of the grammar; however, extra-linguistic factors such as those just mentioned point to interplay between performance factors and grammaticization. We know of no studies that have examined processing efficiency as a function of markedness. Indeed, a priori it is difficult to predict the direction of the effects of markedness.

Within the literature on sign language phonology, some researchers have sought to distinguish marked and unmarked handshapes, based either on general notions of markedness like those mentioned above, or on others specific to sign language, such as the behavior of the non-dominant hand. Battison (1978) argues for a limited set of unmarked handshapes (B, A, S, C, O, 1 and 5), based on properties such as distinctiveness, frequency in ASL and other sign languages, and weaker restrictions on their occurrence, relative to other handshapes.

0.4. Type

In addition to the linguistically-based factor of lexicality and handshape markedness, stimuli could also be classified according to the perceptual factor of Type, where a sign or non-sign is either Type 1 (involving the dominant hand only), Type 2 (two-handed signs with symmetry in handshape and movement between the hands), or Type 3 (two-handed asymmetrically formed signs).[1] Notice that while Markedness is a factor defined with respect to a particular linguistic system, the Type of a sign or non-sign is defined in terms which are purely visual. Therefore, one might expect both deaf and hearing subjects to show effects related to Type but only deaf subjects to be sensitive to Markedness.

0.5. Motor Involvement During Perception

Researchers have found that visual images of hands may facilitate grasping or finger actions when there is congruency between the image and the final hand or finger posture (Craighero et al. 1999, 2002, Brass et al. 2000, Vogt, Taylor and Hopkins 2003). Contrariwise, Miall et al. (2006) reported faster discrimination times for visual target discrimination of hands in the context of congruent hand actions (cf. Schütz-Bosbach and Prinz 2007). Whether such effects might be found in manual language perception is as yet unknown. The handshape-monitoring paradigm used in the present study enabled us to investigate this issue.

In this experiment, subjects were asked to monitor for non-changing ASL handshapes under two conditions: 1) while overtly shaping their dominant hand in the shape of the target (the "congruent" condition), and 2) while shaping their dominant hand in a different shape from the target. If congruency between motor action and perception has an influence here similar to what has been seen in the

[1] Our use of Type as a perceptual factor should be distinguished from Battison's use of Type in his study of sign language phonotactics.

aforementioned studies, it would be expected to manifest itself as faster RTs in the congruent condition. Since the task is not strictly language-dependent, such effects might be expected in both the deaf and hearing subjects. A very interesting question is whether the knowledge of the language and/or the linguistic status of the stimuli might influence such motor-perceptual interactions.

1. Methodology

1.1. Subjects

A total of 45 participants took part, of whom 25 were deaf (17 female) and 20 were hearing (12 female). Four subjects (all deaf) were left-handed. Of the deaf subjects, 10 were native signers, having learned ASL from infancy, and 15 were late learners, having acquired ASL in elementary school or later. All of the deaf subjects were students at Gallaudet University, while the majority of the hearing subjects were undergraduate students at UC Davis. Subjects were given either course credit or a small fee for participating; all gave informed consent.

1.2. Stimuli

Each subject viewed a sequence of short video clips showing a person performing an action, which could either be an ASL sign or a "non-sign" formed by changing the handshape of an actual sign. The action shown in each clip was performed by one of two deaf performers, one of whom was male and the other female. Clips were normalized to a length of 1034 ms. The distance from subject eye to the computer screen on which the stimuli were presented was 24 inches. A total of 180 manual actions (90 signs and 90 non-signs) appeared in these clips, of which a third were the main object of study in this experiment ("target" clips) and the rest fillers. Overall, the set of clips was designed to be balanced in terms of sign frequency (see below for additional discussion). Each video clip was shown once.

Handshapes classified by Battison (1978) as unmarked that were used in this study were "S," "5" and "A," while the set of marked handshapes consisted of "F," "I" and "V." During congruent trials, subjects held their dominant hand in the same configuration as the intended target. For incongruent trials, subjects held an alternative non-target handshape that nonetheless shared some formational similarity with the target. In each case the non-congruent handshapes utilized finger specifications that were present in the target form. For example, while monitoring for the "V" handshape, in which the index and middle finger are outstretched, the incongruent handshape was an "R" handshape, which also involves the index and middle finger, but with a crossed configuration.

1.3. Task

The task consisted of 12 blocks of 15 clips each, with random ordering within blocks. The duration of the task for each subject was approximately 8 minutes. The subject was told that she would be watching a series of short video clips and that her task was to decide as quickly as possible whether or not the gesture shown in the clip was formed using a particular handshape, and if it was, to

respond by pressing a button on a response device using her non-dominant hand. At the same time, the subject had to hold a particular handshape on her dominant hand. Instructions telling the subject which handshape to hold and which handshape to respond to were given at the start of each block. The handshapes being monitored for and held by the subject were the same (congruent) in half of the trial blocks. Hearing non-signers were explicitly shown each handshape at the start of each trial block. The ISI was approximately 350 ms.

2. Results

2.1. Perceptual and Motor Factors

Overall, deaf signers were faster (mean RTs for deaf = 665 ms and for hearing = 764 ms; $t(41.4)=5.03$, $p<0.001$) than hearing subjects. While this is not particularly surprising, it indicates that these data do not exhibit a speed-accuracy tradeoff, as hearing subjects were both slower and less accurate than deaf subjects.

2.1.1. Effects of Type

Significant effects of Type were found for both hearing and deaf groups. For both groups, the pattern was similar, with Types 1 and 2 associated with similar RTs and Type 3 RTs significantly slower (Type 1 vs. Type 2: $t(44)=0.23$, ns; Type 2 vs. Type 3: $t(44)=6.64$, $p<0.001$; Type 1 vs. Type 3: $t(44)=7.62$, $p<0.001$).

For hearing subjects compared to deaf subjects, RTs to Type 3 stimuli were substantially slower. This indicates that while Type 3 stimuli were the most difficult of the three action types for both groups, the hearing subjects found it more challenging to separate out the useful information (the target handshape, seen only on the dominant hand for Type 3 actions) from the distracting information (the non-dominant hand's handshape). Indeed, when asked about their responses to Type 3 stimuli, most deaf subjects said that they had ignored the non-dominant hand altogether, even though that hand is formed in some particular handshape in any two-handed sign. If this were shown to hold for signers more generally, it might support the suggestion that has been made (e.g. Sandler and Lillo-Martin 2006) that the non-dominant hand serves as a place of articulation in such signs rather than as an articulator in its own right.

One might have expected that Type 2 sign-forms (in which both the dominant and non-dominant hands are formed into the target handshape) might be responded to faster than Type 1 forms, in which only one target handshape is evident. While the hearing subject means for Type 2 versus Type 1 stimuli were numerically in the expected direction, the magnitude of this effect was not statistically significant. This may indicate that subjects were attuned to the dominant hand of the sign models. However, the data from Type 3 actions indicate that a non-dominant hand with a non-target handshape did influence RT. This was especially true for the non-signers. Taken together, these data indicate that perceptual factors (the sheer differences in the amount of handshape information to monitor) drive these effects to a substantial degree, but the interaction with

Group suggests that language-specific knowledge also modulates the magnitude of these frank perceptual differences.

2.1.2. Motor-Concurrent Effects

In this task, while subjects were monitoring for target handshapes, they were instructed to configure their *own* dominant hand in a congruent or incongruent handshape (i.e., the same as or different from the monitored-for handshape, respectively). During this procedure, subjects rested their elbow on the table while they held the required handshape. In principle, subjects could benefit from a myriad of factors, including motor, somatosensory, visual, as well as memory effects during the target detection task. Unexpectedly, we observed no effects of motor congruency in these data.

While a growing number of studies have reported such effects, it is difficult to directly compare many of them, as procedures and assumptions vary widely (see Schütz-Bosbach and Prinz 2007 for a recent discussion). One clear difference is the fact that in our task, subjects were not asked to re-articulate the handshape for every target; that is, once they assumed an instructed handshape posture, they maintained this during an entire block of trials. In a study of working memory for signed language by Wilson and Emmorey (1997), the researchers reported a phonological suppression effect during a sign language working-memory task in which the subject had to continually re-articulate handshape posture. In a study by Miall et al. (2006) in which congruency effects were obtained in the context of an oddball detection task, subjects alternated between two hand configurations approximately every 4 seconds, while performing the handshape-oddball detection task (specifically, detecting a handshape that was not congruent with the articulated handshape). To the extent that the re-articulation of the articulatory configuration is a critical variable, it would suggest that the interplay between perceptual and action representation does indeed find a common code within the motor domain rather than a representation deduced from a somatosensory-postural code.

2.2. Linguistic Effects

2.2.1. Lexicality

Subjects were collectively faster at detecting handshapes in signs compared to non-signs (for signs, mean RT = 697 ms; for non-signs, mean RT = 717 ms). This reaction time difference was significant only for deaf subjects [654 vs. 677 ms, $t(24)=2.23$, $p<0.05$; for hearing subjects [755 vs. 772 ms; $t(19)=2.04$, ns]. These data indicate that handshape monitoring in a sign language evokes linguistic representations of lexical forms. As with spoken languages, these lexicality effects indicate a top-down influence of the lexical content during the detection of handshape information in signs in persons familiar with signed languages.

2.2.2. Effects of Markedness

Deaf subjects were consistently *faster* at detecting marked handshapes than unmarked handshapes [656 vs. 674 ms, $t(24)=2.71$, $p<0.05$], while hearing subjects showed no significant difference [768 vs. 759 ms, $t(19)=0.76$, ns]. Examination of errors shows that deaf subjects maintained highly accurate responses to both marked and unmarked handshapes (for marked and unmarked HSs, mean accuracy = 98.5 and 98.4% [$t(24)=0.19$, $p=0.85$]), while hearing subjects made more errors responding to items with marked handshapes (mean accuracy = 94.8% vs. 88.7% [$t(19)=2.54$, $p<0.05$]). These findings suggest that marked handshapes such as "F," "I" and "V," compared to unmarked forms such as "S," "5" and "A," may provide more distinct targets for individuals who know the formal sign system. Hearing individuals without tacit knowledge of the formal properties of sign inventories do not show such RT benefits and show poorer performance in the detection of these more complex forms.

3. General Discussion

3.1. Overview

Several important findings emerge from these data. Notably these data indicate that the task of handshape monitoring in single-sign targets is sensitive to processes observed in studies of phoneme monitoring in spoken languages. In addition, we have been successful in evaluating perceptual and linguistic factors that influence the sign recognition process.

The fact that deaf subjects were faster overall is unsurprising in light of their greater experience processing this kind of visual information. Similarly, the finding of faster RTs for deaf subjects to signs than to non-signs is consistent with previous work on phoneme-monitoring tasks in spoken language, which has tended to find that responses in the context of lexical items are faster than those for non-lexical items (e.g. Cutler et al. 1987, Eimas et al. 1990). The absence of such a lexically-driven effect in the hearing non-signers is again not surprising, since these subjects should have no way of knowing which stimuli showed lexical items (cf. Cutler et al. 1987, who found that English speakers showed no lexical effects when performing a phoneme monitoring task on French stimuli).

Overall we observed that the perceptual factor of Type influenced all subjects in a similar fashion, independently of their knowledge of sign language. Specifically, two-handed asymmetrical (Type 3) signs led to slower RTs. This likely reflects the fact that there is a greater amount of distracting information in these forms. The fact that hearing non-signers were significantly slower than deaf signers in this condition does indicate that knowledge of the language may influence this decision process. Note that in the Type 3 asymmetric signs, the target handshape is the dominant and moving hand, while the base hand is static. Some sign linguists have argued that the representational status of base hands in these forms should be treated formally as a "place of articulation," rather as a handshape per se (for discussion, see Sandler and Lillo-Martin 2006). The present data suggest that deaf users of sign language are more quickly able to discount

this static handshape as not relevant for the handshape detection task. It is of further interest that this factor of Type does not interact with the AoA variable. Thus this tacit knowledge of the asymmetrical role of handshapes is acquired by even late learners of signed language.

3.2. Lack of Strong Effects of Congruency

Previous work by Wilson and Emmorey (1997) successfully used repeated changes of handshape to induce phonological suppression in memory tasks of ASL. We believed that by configuring the subject's handshape into particular handshapes, we might induce faster recognition by the subject for congruent target handshapes than to incongruent ones. This would suggest that postural control of one's own body can have processing consequences for visual recognition, consistent with proposals of a motor-visual link (Craighero et al. 2002). Furthermore, since performance of this task is not dependent on knowledge of the linguistic system of ASL, congruency-related effects might have been expected in both the deaf signer and hearing non-signer groups. In fact, no significant effects of Congruency were found overall, in either group of subjects.

One possible explanation for the absence of such effects lies in the frequency with which subjects had to articulate a new handshape. Recall that subjects held one handshape during an entire block of 15 video clips, then changed to a different handshape during the next block of 15 clips, and so on, so that the motor action of making a handshape change was required relatively infrequently during the course of the experiment. This suggests that Congruency-related effects might be seen if subjects assumed a new handshape posture more frequently, so that the visual monitoring and motor action tasks were more fully integrated. To explore this possibility, another version of the experiment was run on nine new subjects, all hearing. In this newer version, blocks were five video clips long instead of 15, with articulation of a new handshape required before each of these shorter blocks (i.e. three times as often as in the original task). Still, no significant effects related to Congruency were found. The experience of Wilson and Emmorey (1997) in their ASL study of phonological suppression may be relevant here. The experimenters found that subjects' performance of a memory task was inhibited if subjects were required to perform sign articulations simultaneously, a result consistent with the spoken-language literature. However, Emmorey (p.c.) reports that such effects were not seen in initial versions of the experiment in which the sign forms were not continually re-articulated. Perhaps more substantial Congruency-related effects might be seen in a paradigm similar to the present one, but with much more frequent handshape re-articulation on the part of study participants.

3.3. Issues Related to Markedness

Some of the most striking and important findings in this study concern the effects of handshape Markedness. The absence of a significant effect of Markedness in the hearing group contrasts notably with the Markedness effect we found in the deaf group. Moreover, the significant markedness effects seen in the deaf signers

are limited to the sign stimuli and are not observed for the non-signs. These outcomes give support to claims that markedness reflects a representational property of the sign lexicon.

It is interesting that the deaf subjects' responses to marked items tended to be faster than to unmarked items. Although a Markedness-driven effect in the signing subjects was not unexpected, it was not clear at the outset in which direction such an effect should be expected to work. On the one hand, marked items might stand out and therefore be easier to recognize; on the other, such items might in some sense be more unusual or difficult to deal with, in which case slower RTs might be the outcome. For the deaf subjects who took part in this study, the former is the tendency which prevailed.

This finding raises the important question of whether the markedness effects observed in the present study might in fact be related to other factors such as lexical frequency or neighborhood density. An investigation of this important question is somewhat limited by the lack of published frequency norms for signed languages. While there are clear limitations, we examined a proxy of sign frequency based upon the English translation of the sign stimuli used. The results of this analysis based upon raw counts and log transforms of scores were not significant (for unmarked items, Kucera and Francis (1967) mean frequency f = 351, log(f) = 4.6; for marked items, mean frequency f = 278, log(f) = 4.24; t-test outcome ps = 0.61 and 0.72 respectively). Thus we do not believe that the markedness effects seen for the current stimuli can be attributed to lexical frequency.

An equally interesting question concerns whether there could be neighborhood effects disguised as markedness effects. This is especially important given the results found in the Carreiras et al. (2008) study, which did observe influences of handshape form on two measures of lexical access. In Experiment 2 of Carreiras et al. (2008), subjects made lexical decisions to LSE signs. The stimuli lists were composed for sign forms that varied as a function of lexical familiarity and handshape form, specifically a factor somewhat akin to "neighborhood density." In this case, a phonological neighborhood was defined as a collection of signs that were phonetically similar to a given stimulus sign by virtue of sharing one parameter, handshape. Specifically, a sign whose phonological specification for handshape is shared by many other signs is said to have a large neighborhood, while a sign with a handshape that is not shared by many other signs has a small neighborhood. As might be expected, large neighborhood handshapes tended to be linguistically unmarked forms (B, l, A, and 5), while small neighborhoods were composed of marked forms (L, bO, F, etc.). The main finding from this experiment was that low familiarity signs with a large "handshape neighborhood" (i.e. those with a preponderance of *unmarked* handshapes) were responded to faster and more accurately than those with small neighborhoods (i.e. those with a preponderance of *marked* handshapes). These effects were most pronounced in non-native signers.

In contrast to the Carreiras et al. (2008) study, in the present experiment we observed that signers were faster at detecting signs with *marked* handshapes in the

context of the handshape monitoring task. Though it is difficult to directly compare these differing methodologies, our results are likely not being driven by *neighborhood* effects (as defined above), as we would have expected the opposite effects given the findings of Carreiras et al. Note however, that like the effects reported in Carreiras et al., markedness effects seen in the present experiment were also pronounced in the non-native signers. One possible explanation for the observed differences in the present study from the results of Carreiras et al. may lie in the sources of the effects. Based on the patterns of facilitation of responses in large density neighborhoods (which typically produce slower RT's and lower accuracy in studies of spoken languages (Goldinger et al. 1992, Monsell and Hirsh 1998, Radeau, Morais and Segui 1995, Slowiaczek and Pisoni 1986, Vitevitch 2002) and the results of handshape lexical decision priming (Carreiras et al. 2008, Experiment 4) which indicated that facilitatory priming effects were limited to non-signs sharing similar handshapes, Carreiras et al. (2008) suggest their result may indicate prelexical activation.

In contrast, for deaf subjects in the present study, markedness effects were limited to lexical sign responses. Following this line of reasoning, we cannot fully rule out that our faster response times to marked handshapes may be related to lexical neighborhood effects (as opposed to pre-lexical effects) whereby, on the balance, the signs with marked handshapes may be drawn from more sparse neighborhoods than those with unmarked handshapes. Further work is required to fully tease apart these effects.

4. Conclusion

This is one of the first psycholinguistic demonstrations of an implicit measure (handshape monitoring) being used successfully to explore lexical access in a sign language; moreover, the design of the study permitted an exploration of the roles played by both linguistic and non-linguistic factors in this process. Some of the study outcomes were in line with expectations: deaf subjects were faster at the task than hearing subjects, and for the deaf group only, RTs to signs were faster than to non-signs. Similarly, perceptual effects related to target handshape Type were seen for both deaf and hearing groups, while the linguistic factor of Markedness was associated with significant effects only in the deaf group. In contrast to these results, the lack of significant overall effects of handshape Congruency was somewhat unexpected, in light of previous work on motor-visual facilitation (e.g. Schütz-Bosbach and Prinz 2007). This may be due to the fact that static handshape postures were used rather than a re-articulation of a handshape for each trial. Further work is needed to expand these initial findings.

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