Pergamon

S0028-3932(96)00008-5

Neuropsychologia, Vol. 34, No. 7, pp. 737–740, 1996

Printed in Great Britain
0028-3932/96 $15.00+0.00

Note

Hemispheric specialization for sign language

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(*Received* 4 *July* 1995; *accepted* 6 *December* 1995)

Abstract—Most studies on sign lateralization provide inconclusive results about the role of the two hemispheres in sign language processing, whereas the cases reported in the clinical literature show sign language impairment only following left hemisphere damage, suggesting a similar neural organization to spoken languages. By discriminating different levels of processing, a tachistoscopic study found that in deaf subjects matches of sign language handshapes based on equivalence of meaning are processed faster in the right visual field, thus demonstrating a left hemisphere superiority. Copyright © 1996 Elsevier Science Ltd.

Key Words: sign language; hemispheric specialization; phonological matching task.

Introduction

Sign languages, widely used by deaf people, raise the interesting issue of how the right–left functions in the brain are distributed [1]. Indeed, unlike the case of spoken languages, for which abundant evidence exists indicating left hemisphere processing, in sign language the linguistic signal is spatially organized. The processing of visual–spatial relations is widely acknowledged as a right hemisphere function [13]. How, then, and in what hemisphere do congenitally deaf signers better process the spatially organized linguistic stimuli of sign language?

Indeed, available data about sign language lateralization are controversial. On the one hand, the cases reported in clinical literature show aphasia only in patients with left hemisphere damage [7, 14]. On the other hand, experiments on sign lateralization tend to show predominantly right hemisphere involvement [18] or no asymmetries at all [10, 11, 22]. Only one study using the dual task-paradigm found evidence of a left hemisphere advantage [8]. There are many reasons for this apparent contradiction, i.e., the great variation between subjects concerning the age of acquisition of both deafness and sign language, the linguistic competence of the subjects and their use of different strategies according to task requirements. In this study we hypothesize that one of the most confounding factors in signs (and a major source of ambiguity in available data) is their visual complexity. Indeed, experimental findings suggest that the visual complexity of a stimulus can favour the right hemisphere during the first stages of visual processing, even if the subject is performing a linguistic task [2, 17, 20].

In the present study the linguistic/semantic and the visual aspects of sign language have been disentangled, by taking into account the morphophonemic features that characterize the handshapes of sign language, using a matching task based on Posner's paradigm [15, 16].

In this experimental paradigm the subjects have to decide whether two letters have the same name. In order to decide if "AA" are the same letter (PI, physical identity condition), it is sufficient to compare their shape according to a visual representation that Posner and Mitchell called "physical code" [15, 16]. When the two letters have the same name but a different shape (as in "Aa"—NI, name identity condition), they are assumed to be matched according to a phonological representation of the name of the letters, or "name code" [15, 16]. A right visual field advantage for name identity matches, found in several studies, though not universally, supports the idea that phonological matching of letters takes place in the left hemisphere. No clear visual field/hemisphere advantage has emerged for physical matching [19, 20; but also see Refs. 3, 4, 5 for a more dubitative position]. Handshapes that happen to be visually different but share the same meaning can indeed be found in sign language [6, 9, 21]. It is thus possible, using such material, to reproduce the physical/name identity contrast exploited in Posner's paradigm.

Methods

Subjects

Sixteen hearing and 16 prelinguistically or congenitally deaf subjects participated in the study. All subjects, aged 15–26

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years, were right-handed. The deaf subjects were also right-handed in signing. All of the deaf subjects had deaf parents, so they acquired Italian Sign Language (LIS) as a first language. All subjects had normal or corrected normal vision.

Procedure and stimuli

The subjects had to decide whether two handshapes presented one above the other in the left or in the right visual field were the same or different according to the LIS phonology. Hearing subjects, unfamiliar with sign language, underwent some training and were instructed to answer "same" where two handshapes had a similar meaning. They were not told the actual meaning that the handshapes have for the deaf subjects, they only learnt to match the stimuli correctly. They were allowed to proceed with the experiment only when their accuracy level became comparable to that of the deaf subjects. The three types of matches are shown in Fig. 1:

1. Physical identity (PI) matches: handshapes with both identical shape and meaning;
2. Semantic identity (SI) matches: handshapes with identical meaning but different shapes;
3. Different (DIFF) matches: handshapes with both different shapes and meanings.

The task required a "same" response for PI and SI matches and a "different" response for DIFF matches. There were 140 trials, 70 consisting of "same" responses (35 PI and 35 SI matches) and 70 "different" responses. For each trial the sequence of events was as follows: the central fixation point appeared at the centre of the screen; after 500 msec the handshapes were presented in one of the two visual fields and masked after 200 msec. The stimuli were presented one above the other to eliminate horizontal scanning effects. The handshapes had the same dimensions and were placed in 5 cm side squares. The handshapes extended from approximately 5.4° to 2.5° of visual angle from the central fixation point. The separation between the fixation point and the centre point of stimuli was approximately 4.26°. The mean width of the stimuli was 3° and the mean height was 4.09°. The handshapes were presented as mirror images in the two visual fields so that the crucial features appeared at the same distance from fixation in each visual field.

The subjects made their decision by pressing two buttons with their index and middle fingers. To balance the test one half of the subjects used their right hand and the other half their left hand. Half of the subjects used their index finger for "same" responses and the middle finger for "different" responses and the other half used the opposite arrangement.

The visual stimuli were also balanced. Each handshape made the same number of appearances on the screen. Moreover, each handshape appeared the same number of times both in the upper and lower position, and in the right and left visual fields.

Subjects were instructed both to fixate on the central point and to answer as rapidly and accurately as possible. Feedback regarding speed and accuracy were given after each trial.

Results

The mean overall reaction times (RT) for correct responses are shown in Table 1.

Accuracy was similar in the two groups (75.6% in deaf sub-

Table 1. The mean overall RTs for deaf and hearing subjects in the left visual field (LVF) and in the right visual field (RVF)

	Deaf		Hearing		
Match	LVF	RVF	LVF	RVF	Mean
PI	834.55	823.32	806.61	814.72	819.92
SI	952.62	865.85	816.43	875.18	877.52
DIFF	856.74	802.02	782.66	776.59	804.50
Mean	881.30	830.56	801.90	822.16	

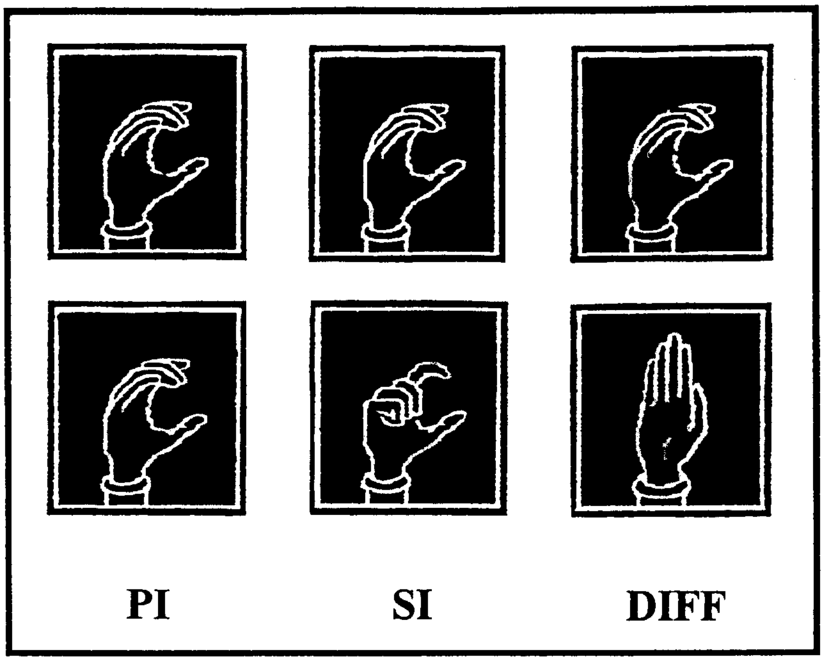

Fig. 1. The three types of matches for the handshapes phonological matching task. The subjects had to answer "same" for PI (handshapes with both identical shape and meaning) and SI matches (handshapes with different shapes but sharing the same morphophonetic features according to Italian Sign Language phonology) and "different" for DIFF matches.

jects and 79.1% in hearing subjects). No significant differences in accuracy were found between the two visual fields for any type of match, so that the results cannot be explained as a speed–accuracy trade-off.

The mean RTs for correct responses were subjected to a three-way analysis of variance (ANOVA) with hearing status as the between-subjects variable and with type of match and visual field as within-subjects variables. The subjects were faster with PI and DIFF than with SI matches [$F(2,30) = 8.685$; $P = 0.0005$]. The interaction between hearing status and visual field was significant [$F(1,30) = 12.196$; $P < 0.002$] but only the deaf group showed a significant visual field effect as they were faster with stimuli presented to the right visual field [$F(1,15) = 9.414$; $P < 0.01$]. The interaction between hearing status, type of match and visual field did not reach full significance but a clear trend was evident ($P < 0.06$). Also, the mean comparisons revealed significant differences between the visual fields only for SI matches. The deaf subjects were faster in the right visual field [$F(1,15) = 8.784$; $P < 0.006$], whereas the hearing subjects were faster in the left visual field [$F(1,15) = 5.029$; $P < 0.03$].

This result was confirmed by a two-way ANOVA carried out only for the SI matches. The interaction between hearing status and visual field was found to be significant [$F(1,30) = 11.731$; $P < 0.002$]. Hemifield differences for DIFF matches were not obtained in the experiment. These stimuli could be matched on the basis of a visual code: indeed, the absence of differences in the RTs between PI and DIFF matches confirms this hypothesis.

Discussion

These results show that by discriminating between different codes for sign language stimuli, a clear pattern of lateralization in the left hemisphere for the linguistic code can be obtained. This clearly confirms clinical findings.

The statistically non-significant difference between the two visual fields in the PI and DIFF matches rules out that the left hemisphere advantage displayed by the deaf subjects is due to the use of linguistic stimuli *per se*. The lateralization depends on the kind of processing to which the stimulus is subjected. It is not absurd to assume that these processes are different in each of the two groups considered here. The deaf subjects based their matching on the phonological features of handshapes, whereas the lateralization in the right hemisphere of hearing subjects can be interpreted as revealing a preference for spatial coding of the stimuli which are, for them, linguistically meaningless. The non-significant difference in RTs between PI and DIFF matches could hardly have been explained by the Boles' visual generation model [4, 5]. Boles, indeed, has argued that two letters of different case may activate a representation of their opposite cases. Name matching may involve a kind of visual matching between the presented letters and the generated representations of the same case (for example, a pair like "Qg" might produce "q" and "G", and matching takes place between "QG" and "qg"). However, we believe that this argument is appropriate only for alphabetic stimuli and hardly applies to the material used for this study.

Another hypothesis could be advanced to explain these data: because sign language is spatially organized, the visuospatial functions, normally performed by the right hemisphere, shift to the left hemisphere. Indeed, some recent findings show that the auditory cortical areas are reorganized in deaf people. Neville [12] has shown that both peripheral visual perception and more complex cognitive processes, such as attention to space and perception of motion, are performed better by the left hemisphere in deaf subjects. These differences were found not only with behavioural measures (accuracy and reaction times), but even with electrophysiological parameters (ERP recordings). Therefore, both auditory deprivation and early experience with a visuospatial language do have an impact on the organization of the brain, both for non-linguistic processing and linguistic processing.

Acknowledgements—This study was supported by a CNR grant to Carlo Semenza. We are grateful to Prof. Carlo Umiltá, Dr Jana Iverson and Dr Gerardo Papalia for their valuable suggestions. We thank the staff and the students of Istituto Magarotto, Padova, and all the subjects who participated in the study.

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