Linguistic Permeability of Unilateral Neglect: Evidence from American Sign Language

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Abstract

Unilateral visual neglect is considered primarily an attentional deficit in which a patient fails to report or orient to novel or meaningful stimuli presented contralateral to a hemispheric lesion (Heilman et al. 1985). A recent resurgence of interest in attentional disorders has led to more thorough investigations of patients exhibiting neglect and associated disorders. These studies have begun to illuminate specific components which underlie attentional deficits, and further serve to explicate interactions between attentional mechanisms and other cognitive processes such as lexical and semantic knowledge. The present paper adds to this growing literature and presents a case study of a deaf user of American Sign Language who evidences severe unilateral left neglect following a right cerebral infarct. Surprisingly, his ability to identify visually presented linguistic signs is unaffected by the left neglect, even when the signs fall in his contralesional visual field. In contrast the identification of non-linguistic objects presented to the contralesional visual field is greatly impaired. This novel and important finding has implications for our understanding of the domain specificity of attentional disorders and adds new insights into the interactions and penetrability of neglect in the face of linguistic knowledge. These results are discussed in relation to the computation model of neglect proposed by Mozer and Behrmann (1990).

American Sign Language

American Sign Language (ASL), is a manual gestural system passed down from one generation of deaf people to the next. It has evolved into an autonomous language with its own internal linguistic mechanisms for relating visual form with meaning. These linguistic mechanisms are not derived from English or any spoken language, but rather are deeply rooted in the visual modality. One of the most significant and distinguishing aspects of sign language structure is the unique role of space. Spatial contrasts and spatial manipulations figure structurally at all linguistic levels; phonological, morphological and syntactic. For example, in the syntactic domain nominals introduced into the discourse are assigned arbitrary reference points in a horizontal plane of signing space; signs with pronominal function are directed toward these points and verb signs obligatorily move between such points in specifying grammatical relations. Thus a grammatical function served in many spoken languages by case marking or by linear ordering of words is fulfilled in ASL by spatial mechanisms (Klima and Bellugi, 1979). The existence of a language in which linguistic forms are developed and communicated through visual spatial devices provides a unique opportunity to examine interactions between the neural systems underlying language and spatial cognition.

Visual Spatial Neglect

Unilateral neglect manifests as a disorder in which patients appear unaware of, or fail to respond to stimulation occurring contralateral to the damaged hemisphere. Behaviorally these patients may not orient to tactile or visual stimulation in the contralesional visual field. In constructional tasks, they may only draw one half of a figure, or write only on one side of a page (Heilman et al. 1985). Another common characteristic of neglect, especially in its later stages, is extinction. A patient who can detect a single contralesional stimulus may fail to report that stimulus when a second stimulus appears simultaneously in the ipsilesional space. Extinction may manifest in tactile, auditory and visual modalities. Left neglect associated with right hemisphere damage tends to be more common that right neglect associated with left hemisphere damage.

A priori neglect could disrupt ASL production at two levels. In a patient with neglect for left space, there might be omission of the left half of signs, or failure to use the left part of articulatory space. Similarly, neglect could impair the ability to comprehend ASL, either because of failure to process part of individual signs or failure to attend to signs communicated in the neglected space. Below we report the case study of a deaf signer, patient J.H., who following right hemisphere damage exhibits severe visual spatial neglect. We systematically explore the extent to which J.H.'s hemi-neglect interferes with sign language and visual object processing.

Background & Medical Report

J.H. is a 61 year old right handed congenitally deaf male who suffered a right hemisphere CVA 9/78. The large right hemisphere stroke involved central portions of the frontal, parietal and temporal lobes as well as associated deep white matter and basal ganglia structures. Born to normally hearing parents, J.H. attended a residential school for the deaf when he was 5. He is a fluent signer and was an active member of the Deaf community prior to his CVA. We tested J.H. several times, beginning in 1988 and the most recently in 1991. Thus our data reflect a stable rather than transient condition.

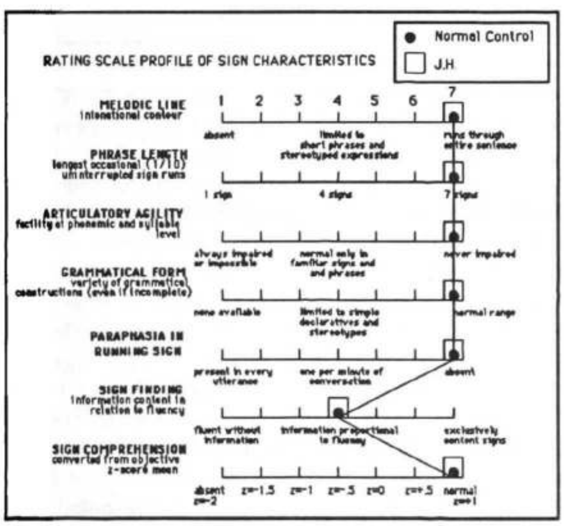

Figure 1

Spared Linguistic Capacity. We administered several standard aphasia tests including the Salk Institute adaptation of the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1972) . The test results indicate that J.H. was not at all aphasic for sign language. Figure 1 illustrates the language profile for the Salk Institute adaptation of the BDAE. The profile for J.H. is compared to a non-brain damaged elderly control. As is evident from the figure, J.H. shows no evidence of core language impairment in either production or comprehension. In production his language is fluent and grammatically complex. He shows no signs of articulatory difficulty, and no semantic or formational paraphasias.

Non-language Visual Spatial Abilities. In contrast to his well preserved linguistic abilities, J.H.'s performance on a variety of non-language visual spatial tests reveal frank disruptions. J.H. showed profound impairments in line orientation judgments (Benton et al. 1977), form perception (Delis et al. 1986), and visuoconstructive tasks.

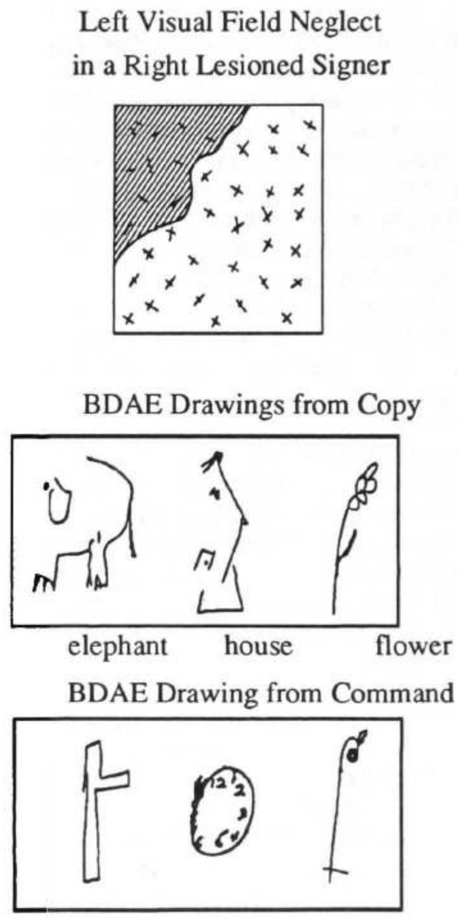

Figure 2

Severe Visual-Spatial Neglect. One persistent finding in our testing of J.H.'s visual spatial abilities was visual spatial neglect. Figure 2 (top half) illustrates J.H.'s performance on the Albert's (1973) neglect test. In this test the subject is given a page with a random distribution of short lines, and is asked to cross each of these lines. J.H. systematically fails to cross lines appearing in the upper left half of this figure. Figure 2 (middle and bottom half) shows drawing from the parietal lobe battery of the BDAE. All of J.H.'s drawing evidence omissions of left sides of these figures.

Summary. The test reported above are consistent with a profile of left neglect following right hemisphere lesion. What is most surprising however, is that despite this severe and persistent neglect, our preliminary findings found no evidence for comprehension or productive sign language deficits. We chose to extend these preliminary findings and explore in a systematic fashion the effects of left neglect on visual sign and object processing using a visual half field procedure.

Sign Neglect Test.

The structure of ASL provides a unique opportunitiy to investigate visual-linguistic processing in patients with neglect. Several sign pairs can be identified that are minimal pairs (or near minimal pairs) which are distinguished solely on the presence or absence of a single hand. For example the one handed sign FATHER in many contexts is signed with a handshape in which all fingers are upright and spread (an "open-5" handshape) with the palm facing away from the signer, the thumb touching the forehead. A common form of the sign DEER is identical except both the dominant and non-dominant hand simultaneously touch the forehead. In face to face signing, under normal viewing conditions, the receiver focuses attention about the lower half of the signers' face. Thus while observing the sign DEER, one hand will fall into the right visual field while the other hand will fall into the viewer's left visual field. Given this scenario one could well imagine how neglect of one half of visual space could severely disrupt comprehension of signing. In particular under some conditions, neglect may render the sign DEER (a two handed sign) to be misinterpreted as FATHER (a one handed sign). Another example is the pair COMPARE vs. MIRROR Illustrated in figure 3.

A second way that sign language can be used to investigate issues of neglect capitalizes upon a discourse convention in which the signer chooses to articulate each half of a semantic pair with the opposite hand. For example in signing the ASL equivalent of "apples and peaches are my favorite fruits", one may choose to sign APPLE with the dominant hand and PEACH with the non-dominant hand. Thus for the viewer one of the signs will fall into the right visual field and the other will fall into the left visual field. A signers with visual neglect may interpret the sentence APPLE PEACH MY-FAVORITE (apples and peaches are my favorite fruit) as the semantically plausible "apples are my favorite fruit", neglecting the sign PEACH which falls into the contralesional visual field.

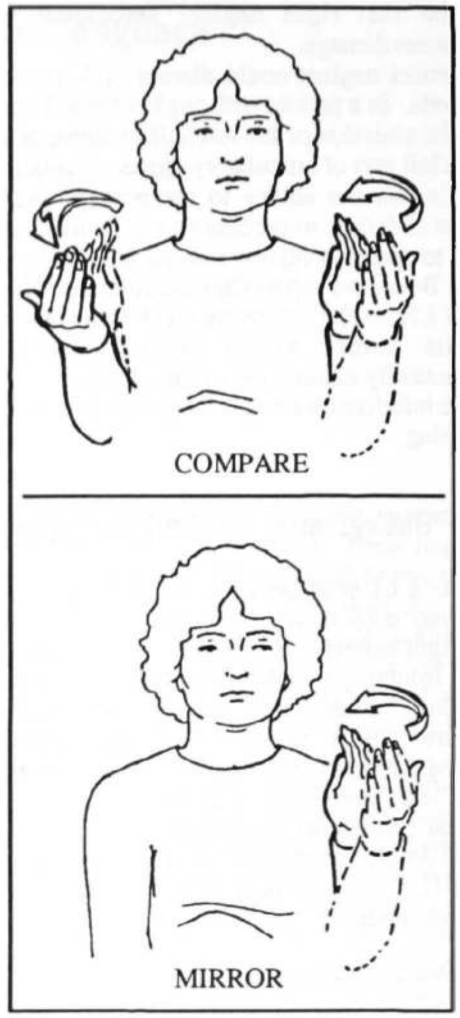

Figure 3

The Corina Sign Neglect Test (CSNT) (Corina, 1991) capitalizes upon the structural properties of ASL to investigate the effects of visual neglect on sign language processing. The first half of the test uses a modified free viewing hemifield procedure to examine the processing of isolated signs and objects. The test stimuli include 35 sign trials composed of 15 minimal pairs (disambiguated by the presence or absence of handshape information falling into the contralesional visual field) and 5 filler items. The signs are articulated at a normal signing speed with an average duration of 1.25 seconds. In addition to the sign processing condition the test includes a non-linguistic control condition. A variety of common objects (e.g. a camera, hair brush, telephone etc.) are presented to the left and right visual field for identification. To make the presentations of objects comparable to the sign condition, the objects are moved into place by a "signer" in locations comparable to the articulatory space used for signing. The object test includes 20 bilateral trials and 10 single object trials. Duration of object trials averaged 2 seconds. All stimuli trials were videotaped for presentation. The second half of the CSNT investigates comprehension of signs in simple sentences which utilize the alternating dominant/non-dominant hand discourse convention. This test includes 18 sentences, half of the sentences are alternating hand format (e.g. APPLES[dominant hand], PEACHES[non-dominant hand] MY-FAVORITE FRUIT) in the remaining nine sentences only one noun is mentioned (e.g. SNAKE DANGEROUS CAN) (snakes can be dangerous). Following each sentences a comprehension question was asked, "What's my favorite fruit?". In this way we can probe to see if the subject had processed the entire sentence or alternatively only attended to "half" of the message.

Methodology. The patient was seated 190.5 cm from a screen where the test videotape was projected. A 63.5 cm. X 63.5 cm. video image was projected onto a screen through the use of a Sharp XG-1100 video projector with back projection capabilities. The image of the signer was slightly larger than life size, all testing was done in a darkened room. Visual angle for object and sign presentations ranged from 3.1^{o} to 5.1^{o} of visual angle during testing. During the first condition, J.H. was told that he would see some signs and some objects, and he was to simply report (i.e. name) what he had seen. During testing the subject's eyes were videotaped for later eye-gaze analysis. In the second condition, the subject was told that he would see some sentences followed by a question, and he was to answer each question as best possible.

Note that the signer who was videotaped on the test tape was right handed. Thus in face to face signing a right handed signer's dominant hand falls largely into the right visual field. However, the patient tested evidences left visual field neglect. To make the right handed signer appear to be left handed, we used the back projection feature of the Sharp XG-1100 video projector, which in essences "flips" the projected image. Thus for the signing experiments disambiguating handshape information falls in to subject left visual field. In fact ,for completeness, the hemifield portion of the test was administered in both "left hand and right hand dominant" orientations, permitting important comparisons which are detailed below.

Results. We first report data from the most demanding left hand dominant condition, whereby the disambiguating hand (i.e. the non-dominant hand) falls in J.H.'s neglected visual field. On the sign identification trials out of a possible 35 signs, J.H. identified 33 correctly or 94%. In contrast, on the object recognition test out of 30 objects to be identified J.H. identified only 15/30 or 50%. An analysis of the object errors revealed that J.H. consistently failed to report the left visual field object during bilateral trials. The impaired object identification performance stands in marked contrast to the excellent identification of two handed signs.

In the mirror reverse condition, numerically the results were nearly identical. For signs J.H. correctly identified 33/35 signs (94%). On the object trials J.H. was correct only for 17/30 trials (57%) trial. Once again he consistently missed bilateral object trials, failing to report the object presented to the left visual field. What is surprising is that these were the same objects he correctly identified in the first condition. For example in the first condition, a camera was presented in the right visual field, simultaneously a package of cigarettes was shown in the left visual field. In this condition J.H. reports only the camera, and fails to report the cigarettes. In the second orientation condition where the entire video image is mirror reversed, the cigarettes appear in the right visual field, and the camera in the left visual field. Now J.H. reports only the cigarettes. However for sign identification flipping the video image has no effect whatsoever on J.H. ability to report both one and two handed signs.

In the sentential condition of the CSNT, where sign sentences are presented with an alternating hand format, J.H. also showed excellent appreciation of information falling into the otherwise neglected visual field. Out of 18 sentences, he correctly comprehended 15/18 sentences, missing one non-alternating sentence and two alternating hand sentences. Thus for sentences where complete comprehension required processing sign information in both the right and left visual fields, J.H. correctly reported 7/9 sentences.

Discussion

The CSNT test was used to compare recognition of signs and objects presented in the left and right visual fields in a patient with neglect. J.H.'s performance indicates that he is accurate in identifying signs whose composition require processing of sign information from the left (neglected) visual field. This is particularly striking as the double handed stimuli chosen have a plausible one handed interpretation. In contrast, J.H. showed significant impairment in identifying objects presented in the neglected visual field. This was most evident in bilateral presentation trials, where J.H. consistently reported only the items in the left visual field. This latter finding is compatible with the description of visual extinction, whereby a subject may report single objects in both ipsilesional and contralesional visual fields, but under simultaneous stimulation fails to report or extinguishes visual information presented to the contralesional visual field (Heilman et al. 1985).

The results reported here extends the phenomena of extinction in a new and exciting way. Despite consistent extinction of objects, J.H. shows excellent comprehension of bimanual signs, (signs in which the two hand simultaneously articulate in the right and left visual fields). This finding at first blush suggest that visual linguistic information is treated qualitatively different from visual object information. However recent computational models of neglect suggest a different conception of this problem.

Mozer and Behrmann (1990) discuss a computational model MORSEL which simulates several neglect findings. Crucially MORSEL demonstrates how a single lesion to the connections that help draw attention to an object in the models visual field can result in performance which appears to implicate higher level impairment, for example neglect-dyslexic errors.

Neglect dyslexics may ignore the left side of an open book, the beginning words on a line of text, or the beginning letters of a single word. However Behrmann et al. 1990 have shown that the ability of a neglect dyslexic patient to select the left most of two words is influenced by the relation between the words. When their patient was shown pairs of semantically unrelated three letter words separated by a space e.g. SUN_FLY and asked to read both words the left word was reported on only 12% of the trials; however when the two words could be joined to form a compound word, e.g. COW_BOY the left word was read 28% of trials (Behrmann 1990; Mozer and Behrmann 1990). From this finding Behrmann concluded that operation of attention to select among stimuli interacts with higher order stimulus properties. The most crucial aspect of MORSEL's simulations of neglect dyslexia owes to the presence of the "pullout" network with its semantic-lexical units. The presence of higher order lexical knowledge i.e. the overt representations of items corresponding to "cow", "boy" and "cowboy" permits the lesioned network to recognize the visual input "boy" as "cowboy" some small percentage of the time.

The case of J.H. poses a challenge to the Mozer and Behrmann model as 94% of bilateral trials are reported as correct two handed signs. To the extent that a MORSEL-like model is an approximation of the mechanism underlying neglect, we are forced to consider the crucial stimulus properties which underlie the representations of signs, objects and words. Importantly the representational properties must correctly lead to the quantitative differences in the percentages of whole form retrievals. One property which may go far in explaining these results is the notion of neighborhood competition (Glushko 1979). We note that for bilateral signs, there are few similar phonological forms and thus a sparsely populated neighborhood. Partial activation of a bilateral sign is sufficient to fill out a unique entry. In the case of orthographic compound forms the neighborhoods are more densely populated (consider the possible neighborhood for the partial activation of "cow_boy"; cowboy, cowgirl, cowslip, highboy, batboy, waterboy...). In this case the partial activation of this orthographic form will not uniquely map to a single form. The result is a lower percentage of reliable unique compound response (but statistically higher than for a totally unrelated word pair "sun_fly"). Objects on the other hand typically do not participate in compound membership and thus do not benefit from higher order "compound" representation.

In summary the case of J.H. who demonstrates an unusual ability to process visually presented signs but not objects adds new insights into the interactions and penetrability of neglect in the face of linguistic knowledge. When considered in relation to a current computational model of neglect, we are forced to make explicit representational differences underlying sign, word and object perception. The existence of a language in which linguistic forms are developed and communicated through visual spatial devices provides a unique opportunity to examine interactions between the neural systems underlying language and spatial cognition.

Acknowledgments

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