

WE present the case of a patient with a lesion of the thalamus who was completely anaesthetized on his right side. He was unable to detect and describe a tactile stimulus applied to his affected right arm, but could direct his normal left hand toward the specific right hand site where the stimulus had been applied when so instructed ('blind touch'). Strikingly, this pointing ability disappeared when the patient had to indicate on a picture of an arm where the stimulus was applied, and when he had to name the stimulus location during his pointing. Similar results were also obtained for localizing the unfelt fingertip ('blind proprioception'). Neuropsychological case studies have demonstrated that brain lesions can produce reciprocal dissociations between object identification (what is the object) and object-oriented action (how to direct a movement to the object). Along these lines, it is suggested that our patient exhibited a dissociation between a 'where' system and a 'how' system for tactile and proprioceptive stimuli.

Key words: Touch; Proprioception; Implicit perception; Blind touch; Action; Perception; Representation; Sensorimotor; Consciousness; Neuropsychology

Implicit processing of somaesthetic information: a dissociation between where and how?

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Introduction

Implicit processing of somatic sensation following a lesion of central somatosensory areas has been reported by several authors.^{1–3} Typically, these patients could point to a location stimulated on their 'deafferented' forearm while unable to report any tactile experience: this phenomenon has been considered as a tactile equivalent of blindsight. These 'blind touch' observations have raised several questions. First, it has been stressed that a significant influence of stimulus location on pointing responses occurs despite the lack of conscious report about the stimulus applied. It can be argued however that the pointing performance obtained in such patients might be observed with other kinds of forced-choice responses, e.g. verbal. Indeed, it has been shown in normal subjects that verbal response about localization can be more accurate than verbal report about detection of the same stimulus.⁴ In a case reported by Brochier *et al.*,⁵ significant performance was observed in a verbal forced choice task, but no pointing task was presented to the same patient. Comparison of verbal and motor forced choice responses in the same patient would therefore be of great interest. Second, if one wishes to interpret this phenomenon in terms of a dissociation between different streams of information processing such as 'what' and 'where',^{2,5} one needs to demonstrate a dissociation not only between different modes of response, but also between similar responses when sustained by different process-

ing, e.g. pointing movements sustained either by a where or by a how processing. Several anatomical interpretations of so-called blind touch have been proposed. In the case reported by Paillard *et al.*,² with a parietal lesion, spared frontal somatosensory evoked potentials (SEPs) implied a possible involvement of precentral areas. The patient described by Brochier *et al.*⁵ had an anterior parietal lesion, frontal SEPs were not reported and the interpretation focused on the potential role of the posterior parietal cortex. Another possible hypothesis is that uncrossed somatosensory projections (revealed by infantile lesions^{6,7}) can provide unconscious information to the healthy limb pointing at the affected limb.

We had the opportunity to study a patient (J.A.) who presented with a complete sensory loss of the right half of the body.⁸ This case allowed us to compare verbal and pointing responses using the same forced choice paradigm, and to compare pointing made in direct response to the stimulus or after a representation of the stimulus location was constructed. In addition, detailed paraclinical investigations (SEPs, PET) allowed discussion of the above-mentioned anatomical hypotheses.

Previous neuropsychological reports have focused on the dissociation between different pathways pertaining to the same modality. However, in the visual system, interconnections have been described between the dorsal and the ventral streams.^{9,10} This anatomical feature could supply a basis for a functional interaction between so-called parallel systems. This assumption was tested for touch and proprioception by asking J.A. to produce two forced choice responses (pointing and verbal) simultaneously.

A preliminary report about this work was presented at the International Congress of Stroke Rehabilitation, Berlin 1993.

Material and Methods

Case report: J.A. was a 64-year-old ambidextrous male who developed a sudden right hemiparesia with a complete sensory loss in the right half of the body following a cerebral haemorrhage within the deep territory of the sylvian artery. Clinical examination showed a Dejerine–Roussy syndrome with right incomplete hemiplegia, complete hemianaesthesia of the right body and ipsilateral choreo-athetotic movements. Four months later, J.A. would not use his right arm spontaneously. He could nevertheless reach and manipulate objects under visual control. Without vision, alterations of the movements were comparable with those of a centrally deafferented patient described by Jeannerod *et al*¹¹ (see also Ref. 2). In contrast with this latter case, the tactile and proprioceptive deficit was complete, even in the right facial territory, sensitivity to temperature, pain, vibration, deep pressure and passive movement being abolished. Identification and detection of all objective somaesthetic stimuli, stereognosis and matching were impossible on the right side. J.A. spontaneously reported an illusory sensation of his right arm moving when he was lying in the dark. He showed no impairment of memory, language, gnosis or praxic abilities and he could name, detect, match loci and objects on his left side normally. No visual field defect or visual extinction was noted.

MRI inspection showed a lesion of the left ventrolateral and ventroposterolateral nuclei of the thalamus (Fig. 1). Recording of somatosensory evoked potentials showed a complete absence of the parietal (post-central) response (N20–P27–P45 components) and the frontal (precentral) response (P22–N30) following electrical stimulation of the second and third digits of the right hand. An attempt to record ipsilateral responses failed to show any significant signal. A PET study (Ref. 9, FDG) showed hypometabolism in the lesioned subcortical area and in the whole left parietal and frontal cortex, consistent with a thalamocortical diaschisis (see Ref. 12). Vibratory stimulation of the right hand elicited no activation of the left thalamus nor the left somatosensory areas. These data support a severe left hemisphere deafferentation following an ipsilateral thalamic stroke.

Procedure: To test the patient's tactile ability, stimuli were delivered to his right forearm and hand with the tip of a pencil, left in place until the patient initiated his response. The investigator randomly stimulated locations that had been demonstrated on the left normal arm prior to the session. Since the patient did not feel the stimuli applied, he had to be instructed when to produce his response. No information was provided to the patient about his performance during the experiment. However, given the lack of explicit localization information, the patient required considerable encour-

agement. The first experiment investigated J.A.'s ability to locate tactile stimuli applied to his right hand. The patient was blindfolded and motor and verbal performances were compared. Motor responses involved pointing movements using the left index finger. No constraint was imposed on movement speed, but the patient was encouraged not to delay his response, since preliminary experiments have shown that long latencies decrease performance. Pointing movements were recorded by a video camera. Verbal responses were obtained by a forced-choice paradigm among the six possible stimulus locations demonstrated previously. In order to test whether the somatic sensation was processed only for motor interaction with the stimulus or whether it had also a value for proper location perception, we used another pointing response which was not directed to the stimulus. In this second experiment, a drawing of an arm (scale 1) was placed on the table 20 cm left of his hidden, stimulated right arm. J.A. was then asked to point on the drawing to the point matching the location of the stimulus applied to the arm. In the third experiment, the possible interference between the systems responsible for the pointing and the verbal responses was investigated. J.A. was required to produce simultaneously the pointing movement and the verbal response to a single tactile stimulus.

When testing proprioceptive information processing, J.A. was blindfolded. A tablet was used above which the patient's right fingertip was positioned. The right, affected arm was manipulated by the investigator in such a way so as to place the right fingertip on one of two locations, 30 cm in front from the patient's trunk and 10 cm respectively to the left and right of his sagittal axis. In order to avoid interference between tactile and proprioceptive information processing, the arm was provided with as little tactile information as possible and was manipulated by touching areas as close to fingertip as possible. Since no conscious processing of arm proprioception was available to J.A., two guessing responses were evaluated. In one session, he was asked to point underneath the tablet to the point corresponding to the location of his right index fingertip. In another session, J.A. was asked to guess verbally whether his fingertip was on the right or on the left location. In the final session, J.A. was asked to produce simultaneously the verbal and pointing responses for each trial.

Performance: Performance was evaluated by two means. First, analysis of verbal responses and comparison between verbal and pointing responses used a dichotomous measurement (correct *vs* incorrect). We assigned the value of one or zero to each trial, respectively for correct and incorrect responses, i.e. inside *vs* outside the stimulated territory (e.g. the whole finger in the case of fingertip stimulation). Second, for comparison between pointing conditions we also used a quantitative measurement of the distance between

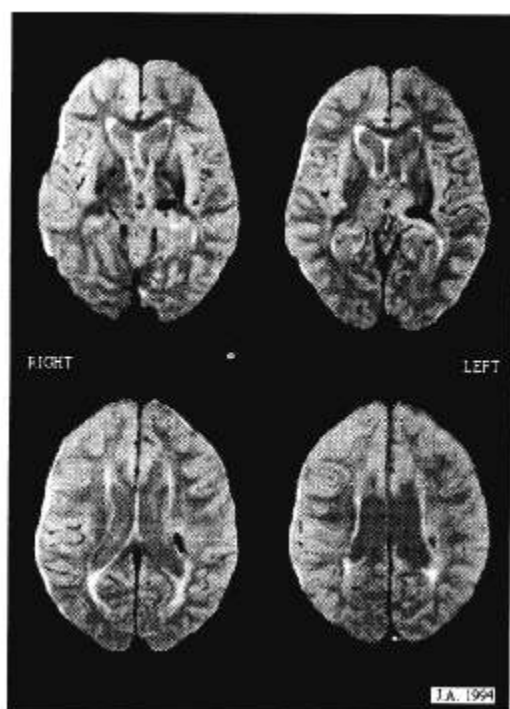


FIG. 1. Axial T1-weighted MRI images show a hypo-intensity limited to the ventrolateral and the ventroposterolateral thalamic nuclei and extending into the posterior part of the thalamoparietal projection of the left hemisphere. The cortical areas and the right hemisphere were intact.

stimulus location and pointing. For this purpose, performance was measured as the distance from stimulus location to the actual point reached on the arm when pointing directly on the arm, and as the distance from the point on the drawing corresponding to the actual stimulus position to the actual hand pointing on the drawing when pointing on the arm drawing. One value was attributed to each trial and the means and s.e.m. over trials were computed for each condition. Similar dichotomous and distance measurements were calculated for the proprioceptive task. Since the two possible fingertip locations were aligned on a frontal axis, the distance between the target fingertip and the pointing location was measured along the same direction.

Statistics: Two statistical methods were used to analyse the performance measures used. Chance performance for the dichotomous guesses was evaluated by testing departure of the observed distribution from the law of Laplace-Gauss⁻¹. Comparison between two pointing conditions was based on the distance measurements. The mean distances obtained in two conditions were compared by one way ANOVA.

Results

Touch: During the pointing sessions, J.A. repeatedly performed above chance level (Fig. 2). In the first experiment using six stimulus locations on the hand,

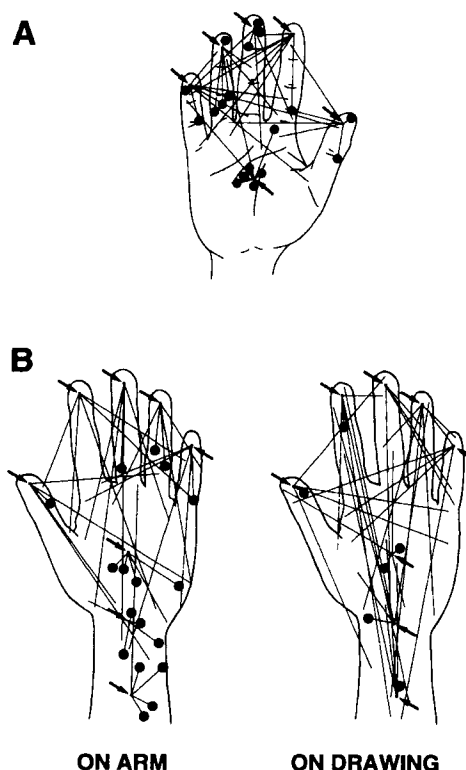


FIG. 2. (A) Points reached when J.A. pointed to tactile stimuli applied to six loci of the right hand (anterior ungual phalanx of the five fingers + the palm centre). Arrows indicate stimulus location, from which a line was drawn to each trial point reached by J.A. Black dots indicate correct reaches. (B) Same conventions as in A. A set of eight stimulus locations was used in the second experiment: the posterior ungual phalanx of the five fingers + the palm centre + the wrist + the middle forearm. Pointing with the left index finger was made toward the locus stimulated (1) directly on the right forearm (2) on an arm drawing of the right forearm (scale 1).

J.A. reached the stimulated area in 18 out of 40 trials, which was significantly above the chance level of 5/40 ($p < 0.001$). The errors observed exhibited the same directional bias as in the case reported by Paillard *et al.*¹⁰ i.e. toward the palm. Contrasting with the pointing responses, verbal performance (4/21, $p > 0.10$) was never significantly different from chance.

In an experiment using eight possible stimulus locations on the right forearm, J.A. provided 17 correct responses out of 40 trials ($p < 0.001$). With the same stimulus set, but when pointing on the arm drawing, J.A. provided only six correct responses (NS). In addition, the mean distance (\pm s.e.m.) between the stimulus and the response increased from 8.7 ± 0.96 cm to 12.3 ± 1.20 cm. This difference attained statistical significance ($F(1,79) = 5.57$; $p < 0.025$). This suggests that J.A.'s ability to produce a significant performance is restricted to movements directly aimed at the stimulus itself but does not apply to similar movements matching stimulus location on a picture.

When J.A. was required to produce the two responses at the same time, there was a coincidence between the pointing and the verbal responses. However,

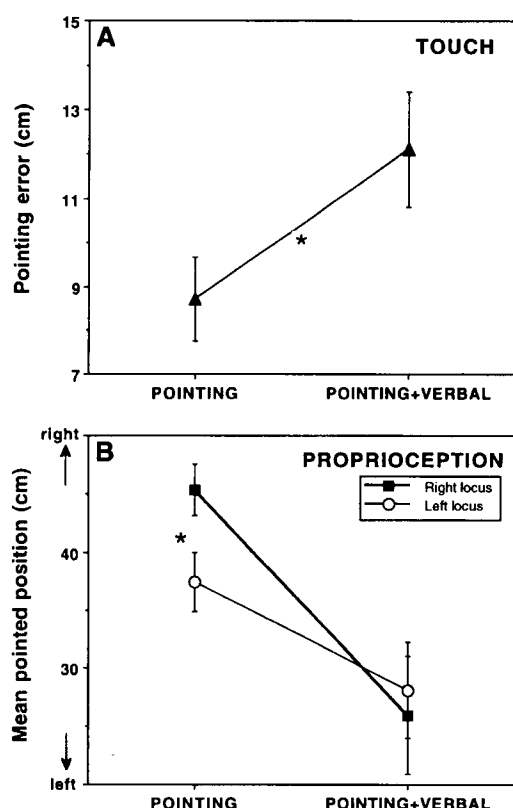


FIG. 3. (A) Pointing error (mean distance \pm s.e.) between the stimulus and the point reached by J.A. in the pure condition ('pointing') and when J.A. had to identify verbally the locus stimulated (e.g. index or palm) during his pointing movement (pointing + verbal). The pointing error was significantly larger in the pointing + verbal condition than in the pointing condition, and not significantly different from that of the pointing on drawing conditions. (B) Mean frontal positions reached by left index finger when pointing under the table toward the right index finger (target finger) positioned either on a left or a right locus. In the pointing + verbal condition, J.A. was asked to verbalize the side of the target finger (right vs left) during the course of the reaching movement, and the discrimination was no longer observed.

J.A.'s responses were not significantly influenced by stimulus location (correct trials: 6/40). In addition, the distance between the stimulus and the response (12.1 ± 1.3 cm) increased to values similar to those obtained when pointing on the arm drawing (Fig. 3).

Proprioception: When asked to locate his index finger by pointing with the left hand, J.A. was significantly influenced by the right finger locus (Fig. 3B). The mean position reached while the right fingertip was positioned on the right location was 15.3 ± 9.9 cm to the right of sagittal axis, but it was only 7.4 ± 11.3 cm to the right when the fingertip was positioned on the left location. Although there was a great variability in the pointing responses, this difference reached statistical significance ($F(1,39) = 5.55$, $p < 0.025$). The dichotomous analysis also showed a significant performance (29/40, $p < 0.05$). By contrast, the distribution of verbal forced-choice responses were not significantly different from a random distribution (24/40, $p > 0.10$). When the verbal and the pointing responses were pro-

duced simultaneously, they always were congruent, but the pointing performance was reduced to random (17/40, $p > 0.10$). This was confirmed by the mean locations reached for the two locations explored, the mean pointing toward the left location being located right of the mean pointing to the right location (1.9 ± 18.6 cm to the left vs 4 ± 22.7 cm to the left; $F(1,39) = 0.10$; NS; see Fig. 3B). As for touch, activation of a semantic representation of where the target finger was (required for the verbal response) disrupted J.A.'s ability to point to this finger. No facilitation of the verbal response by the simultaneous pointing movement was observed.

Discussion

A dissociation between pointing and verbal report has already been reported by Paillard *et al.*² in the case of a patient with a parietal lesion involving the somatosensory area. These authors interpreted this finding in terms of the classical distinction between the identification ('what') and localization ('where') systems, i.e. the patient was able to localize the stimulus without being able to identify it. However, they did not investigate verbal report in a forced-choice paradigm, and therefore their results could also be explained as covert information processing that can be observed only when guessing (through verbal or pointing responses). In the present experiment, the absence of significant performance in the verbal forced-choice for stimulus location demonstrates that tactile information is processed not only implicitly but also specifically for motor purpose. Therefore the present result can be interpreted as a dissociation between a pragmatic system responsible for the stimulus driven pointing and a semantic system responsible for verbally depicting the same stimulus location. A similar kind of dissociation has been previously proposed between a 'what' system, responsible for semantic processing, and a 'how' system, responsible for pragmatic processing.¹³⁻¹⁹ By contrast, the dissociation observed in the present case holds for stimulus location (i.e. where vs how) instead of stimulus intrinsic qualities (i.e. what vs how), and can be described for both tactile and proprioceptive stimuli. This dissociation fits with the more general description of sensorimotor and representational modes of spatial information processing that would respectively use a body-centred and an environmental frame of reference (see Ref. 20). Virtually all metric qualities of objects in space could be affected by such a dissociation.

This hypothesis is strengthened by the results obtained when J.A. pointed on the arm drawing. In this case, he had to produce the same pointing movement, but combined with a more elaborate representation of where the stimulus was applied, and consequently his performance was reduced to chance level. The dissociation observed here would therefore not result

from the difference in the response provided (pointing *vs* verbal), but from the difference between the representations underlying the responses (how *vs* where). Following Paillard,²⁰ J.A. appears unable to process the tactile information at levels higher than a direct sensorimotor system, i.e. at more symbolic levels. Indeed, naming the stimulated area requires an underlying representation of the stimulus that is more elaborate than the representation used to point to this stimulus. Therefore, it can be argued that J.A. is able to point to the locus of the stimulus (how) without building a representation (explicitly or implicitly) of where it is located.

When the pointing and the verbal responses were produced simultaneously for either tactile or proprioceptive targets, the pointing performance was reduced to random. These results confirm that attempts to elaborate a semantic representation of the stimulus location can have detrimental effects on the relatively intact sensorimotor processing. It is important to notice, however, that no decrease in accuracy (but rather an improvement) was observed when normal subjects gave two verbal and motor responses to a single coloured stimulus.²¹

Given the qualitative hypoactivation of the left hemisphere observed in J.A.'s activation study, a possible substratum for the residual processing observed here would be the ipsilateral somatic pathways that account for sensitivity in hemispherectomized patients.

Conclusion

This observation provides a new illustration of the relative independence between perception and action processes. Proprioception and touch can thus reveal a similar dissociation to that already observed in patients with optic ataxia or blindsight or after temporal lesions, i.e. when individuals cannot consciously recognize visual objects (what) but remain able to realize object oriented actions (how) (see Refs 14, 15, 17–19, 22 and 23). In the case of J.A., the dissociation

was observed between perceived stimulus location (where) and object oriented action (how). Furthermore, the dissociation between these two systems also showed detrimental effects of verbalization on the pointing performance. This study suggests that the processing of tactile stimuli location may involve different brain pathways, depending upon the level of representation that is activated to produce the response, and that conscious processing (e.g. subserving verbal response) can hierarchically dominate implicit sensorimotor processing (e.g. subserving pointing).

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General Summary

We report here evidence of a striking implicit sensitivity in a patient clinically rendered hemianaesthetic as a result of stroke. This patient was unable to detect any tactile stimulus applied to his right arm (light touch, deep pressure, movement, heat, cold, pinch, pain), but remained able to point with his healthy left arm at the locus stimulated. By contrast, he failed to guess verbally the locus of the stimulus. In addition, he was unable to demonstrate stimulus location on an arm picture by pointing. These results suggest that tactile information about the right arm was available to left hand movement interacting with the stimulus, but could not be accessed by mental representation. Two dissociated systems are proposed account for this phenomenon: a 'how' system, responsible for directing action to the stimulus, and a 'where' system, responsible for representing stimulus location. In search for a possible interaction between these two systems, our patient was required to produce the pointing and the verbal response simultaneously. In this condition, his pointing ability disappeared, which suggests that the representative system dominates the implicit action system.