

Mirror drawing in a deafferented patient and normal subjects: Visuoproprioceptive conflict

Article abstract—Results on a mirror drawing task showed that a deafferented patient had no problem completing the pattern, whereas normal subjects needed more than four trials to attain a similar performance. The results suggest the presence of integrated visual and proprioceptive maps. The inversion of visual coordinates requires the need for a recalibration. Without proprioception, the task is more like a simple visual tracking task.

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Y. Lajoie, MSc; J. Paillard, PhD; N. Teasdale, PhD; C. Bard, PhD; M. Fleury, PhD; R Forget, PhD; and Y. Lamarre, MD, PhD

The organization of visuomotor behavior relies on a tight integration of visual and proprioceptive information. When the visual and proprioceptive modalities are available, the whole system uses a feed-forward mode of motor control based on continuous updating of limb position in extrapersonal space. The feed-forward mode relies on proprioceptors and visual detection of errors.¹ When discordant information must be processed, as in visuoproprioceptive conflict induced by prismatic deviation of the visual field, a reorganization of proprioceptive information is necessary.

In a conflictual task of prismatic deviation, the visual modality is dominant,² and proprioception is less important for resolving this conflict. Plasticity or adaptability of sensory modalities presents an inverse function of the attention level given to information coming from these modalities.^{3,4} Therefore, resolving a visuoproprioceptive conflict when vision is altered will be more difficult when the subject relies more on visual information.

The mirror drawing task is another example of discordance information. The mirror drawing of a six-pointed star is characterized by a visuoproprioceptive discordance created by the directional inversion of movement required to draw oblique and vertical lines in the figure plan. This task permits evaluation of how visual and proprioceptive information are integrated and modified through learning processes. In the present experiment, we examined how a deafferented patient and five neurologically normal subjects resolved this conflict.

Method. Subjects. Five young right-handed subjects (mean age, 24 years) and one deafferented patient (41 years) participated in the experiment. The patient suffered a permanent and specific loss of the large sensory myelinated fibers in her four limbs following two episodes of sensory polyneuropathy. Clinical investigations showed a total loss of the senses of touch, vibration, pressure, and kinesthesia, as well as absent tendon reflexes in the four limbs. The patient has been in this situation for 12 years without any improvement or

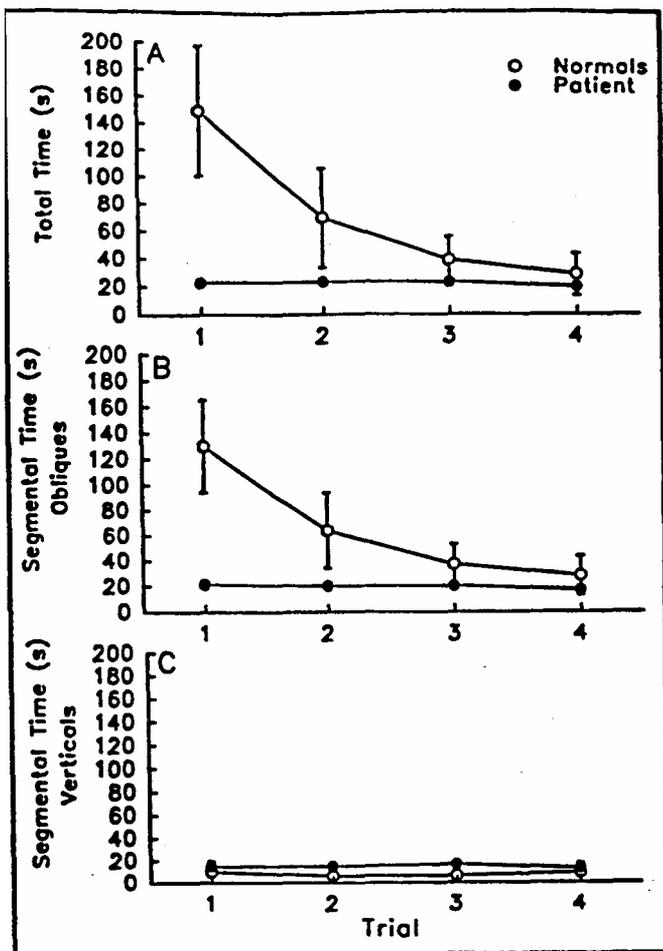


Figure 1. (A) Total time needed to trace the drawings for normal subjects and patient for each trial. (B) Average segmental time for obliques. (C) Average segmental time for verticals.

deterioration. A complete clinical description of the patient can be found elsewhere.⁶

Task. While viewing the image through a mirror, subjects were instructed to trace the six pointed star pattern as fast and as accurately as possible. None of the subjects had seen this particular star pattern before drawing it. Four trials were given, with 5 minutes' rest between trials.

Apparatus and measures. A commercially available mirror drawing apparatus (Lafayette Instruments Co., Lafayette, IN) was used. The total time necessary to complete the star pattern (12 segments: segment width, 1 cm; segment length, 7 cm) was evaluated. Further, the position of the tip of the pointer was digitalized (100 Hz) with a 3-D motion-analysis system (Selspot 11; Selcom, Selective Electronic, Inc., Southfield, MI). The position and the acceleration profiles of the drawings were computed.

Results. Total time. Figure 1A shows the total time needed to complete the star pattern for normal subjects and the patient. An ANOVA on normal subjects' data with trial as a factor showed that the first trial was significantly slower than the three others ($p < 0.05$). Student's *t* tests performed on the patient's results

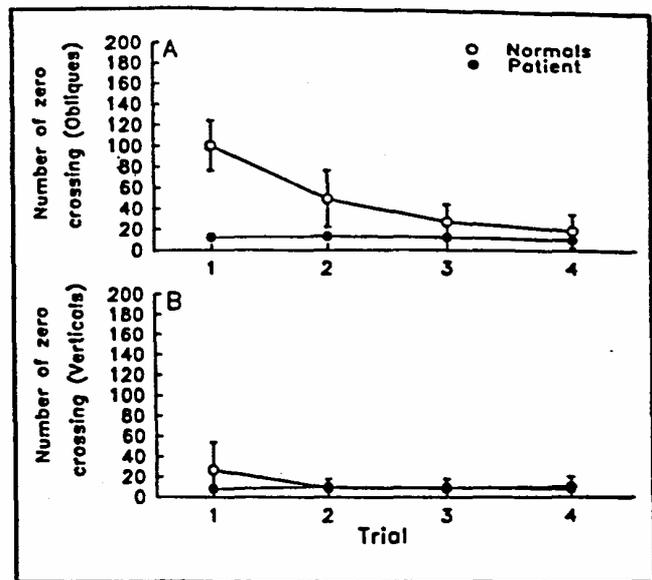


Figure 2. (A) Number of zero crossings for obliques. (B) Number of zero crossings for verticals. This measure gives information on the number of movements executed to trace the segments.

showed no significant difference between trials, suggesting a constant performance. Furthermore, *t* tests (comparison of a single observation with the mean of a sample⁶) were performed for each trial to compare the total time of normal subjects with the total time of the patient. Normal subjects were significantly slower than the patient for the first trial only ($t_4 = 2.83$, $p < 0.05$).

Segmental time. In figure 1, B and C, the two types of segments (obliques and verticals, respectively) that compose the drawings were separated. In mirror drawing, obliques are more difficult to draw than vertical lines because the conflict is not a simple binary choice (ie, up versus down) but rather a multiple choice (combination of up, down, left, and right). For normal subjects, a two-way ANOVA (trial x type of segments) showed a significant interaction of trial x type of segments ($p < 0.01$). The decomposition of the interaction showed a significant linear trend ($p < 0.01$), suggesting a learning effect for the obliques but not for the verticals. On the other hand, the patient behaved similarly for obliques and verticals ($p > 0.05$). The main difference with normal subjects was observed for obliques only.

Number of zero crossings. A submovement is composed of an acceleration phase and a deceleration phase. The transition from acceleration to deceleration is characterized by a zero crossing (ie, a moment at which acceleration is equal to zero). In order to determine the smoothness for drawing each segment and economy of movement,⁷ the number of zero crossings was calculated. A more optimal and smoother drawing should be characterized by a smaller number of zero crossings, which would indicate a smaller number of submovements to draw a segment. For normal subjects, the decomposition of the significant interaction of trial x type

of segments showed a significant linear trend ($p < 0.01$), suggesting a smoother drawing performance for the verticals than for the obliques. Figure 2 shows that, for all trials and types of segments, the patient exhibited a smoother performance. Furthermore, as for total time, the main difference with normal subjects was observed for obliques only.

Discussion. As observed in previous experiments,⁸ normal subjects had difficulties when changing direction and when drawing oblique lines during mirror drawing. The patient had no problem doing so. For normal subjects, the problem in performing the mirror task involves the comparison of the reversed visual information coded within a visual map and the proprioceptive information coded within a normal proprioceptive internal map. These conflictual sources of information cause difficulties in choosing the right movement orientation. With practice, normal subjects learned how to use the reversed visual information by recalibrating the proprioceptive map to resume its discordance with visual information. This recalibration allowed them to achieve a level of performance similar to that of the patient. Since the deafferented patient had no sensory conflict, the execution of the task required no more than a simple visual tracking, and there was constant performance across trials. These results suggest the existence of a tight coupling between visual and proprioceptive reafferent information in the execution of visuomotor tasks and emphasize the role of proprioception in the pretuning of motor commands driven by visual cues. Absence of such proprioceptive pretuning in the deafferented patient left the visual cues free to drive her movements in a servocontrolled mode from the beginning of her mirror drawing, without the intrusion of the discordant proprioceptive information. The discordant information hindered the performance of normal subjects until recalibration by the learning process.

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From the Laboratoire de Performance Motrice Humaine (Y. Lajoie and Drs. Teasdale, Bard, and Fleury), Université Laval, Québec; the Laboratoire de Neurosciences Fonctionnelles (Dr. Paillard), Centre National de la Recherche Scientifique, Marseille; the Université de Montréal (Drs. Forget and Lamarre), Centre de Recherche en Sciences Neurologiques and Hôpital Dieu de Montréal (Dr. Forget), Montréal, PQ, Canada.

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Address correspondence and reprint requests to M. Yves Lajoie, Laboratoire de Performance Motrice Humaine, Université Laval, PEPS, Ste-Foy, PQ, Canada G1K 7P4.

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