# Apraxia in a Patient with Atypical Cerebral Dominance

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Liepmann postulated that the left hemisphere of right-handed persons contains the "movement formulas" that control purposeful skilled movements of the limbs on both sides of the body. Accordingly, in right-handers apraxia should follow damage to the left hemisphere, whereas right hemisphere damage should not lead to apraxia. Although this is generally true, we recently examined a righthanded man who after a right hemispheric stroke became aphasic and apraxic with his nonparalyzed right hand. Our observations suggest that the right hemisphere of this right-handed man made a critical contribution to the planning and execution of skilled movements. This case provides evidence that right-handers should not be considered a homogeneous group in terms of cerebral motor dominance and that contrary to Liepmann's postulate, hemispheric dominance for the control of skilled movements does not entirely determine handedness. © 1987 Academic Press, Inc.

### INTRODUCTION

Apraxia is a disorder of skilled movement not caused by weakness, akinesia, deafferentation, abnormal tone or posture, movement disorders, intellectual deterioration, poor comprehension, or uncooperativeness (Heilman & Gonzalez Rothi, 1985). According to Liepmann, abnormalities of skilled movement in apraxic patients are caused by a destruction of motor engrams or by a disconnection of these engrams from the motor areas that control movements of the extremities. Since in right-handers the left hemisphere contains these engrams, apraxia should follow damage to the left hemisphere, whereas right hemisphere damage should not lead to any appreciable impairment in performing gestures. Liepmann's own study provides support for this theory. He tested 41 patients with right

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hemiparesis and 42 patients with left hemiparesis and found 20 patients in the former group who were apraxic, whereas no patient in the latter group showed this deficit (Liepmann, 1905). Liepmann's hypothesis of left hemisphere dominance for motor skills in right-handers received almost unanimous support from subsequent investigators as well (Ajuriaguerra, Hécaen, & Angelergues, 1960; Geschwind, 1965; Goodglass & Kaplan, 1963).

In the present study we describe a right-handed patient who became severely impaired in his ability to perform skilled movements with his dominant hand after a right hemispheric stroke. Detailed study of his gestural abilities allowed us to define better the nature of his disorder and to examine the relationship between motor dominance and handedness.

## Case Report

A 61-year-old man was originally admitted to his local hospital for elective surgical repair of a hydrocele. The operation was uneventful, but the day after surgery he suddenly became mute and left-sided weakness developed.

He was transferred to the Gainesville Veterans Administration Medical Center the same day. The patient had had three myocardial infarctions in the past and has a documented ventricular aneurysm. He has also had coronary bypass surgery and has a mitral valve prosthesis. He has had three previous episodes of left-sided weakness, each of which occurred in association with the heart attacks, and the neurological deficits cleared within 24 to 48 hr. None of these episodes was associated with language disturbance. He sustained head injury while in the Navy in 1951 and a post-traumatic seizure disorder developed. The seizures were described as tonic-clonic convulsions without any obvious focality. The patient had had normal electroencephalographic findings several times in the past and has been maintained on phenytoin and phenobarbital with reasonably good seizure control. He has no history of birth trauma or early brain damage.

On admission, the patient was awake and alert, but was mute and could follow only simple midline commands. He could not follow written commands, but could write. Writing posture of the right hand was normal, and he produced well-formed letters. His writing, however, was linguistically incorrect, with only a few recognizable closed-class words. Perseverations were also evident. He wrote obliquely and tended to leave a wide margin on the left side of the page. His writing could be characterized as "jargonagraphia" with features of spatial agraphia as well.

He had a right gaze preference and oriented to visual and auditory stimuli better when presented on the right than on the left. Extinction on bilateral simultaneous stimulation was present in the visual and auditory modalities. The patient had a dense left hemiparesis with a flaccid plegic left arm and only minimal movements of the left leg. Left central facial weakness was pronounced. Muscle tone was diminished on the left, and all deep tendon reflexes were brisker on that side as well. Sensation was diminished to all modalities on the left. Strength, tone, and sensation were all normal on the right side.

The admission diagnosis was infarction in the distribution of the right middle cerebral artery probably due to embolization from the heart. This was confirmed by computerized tomogram (CT) that showed a large right frontotemporoparietal infarct with slight shift of the midline structures and compression of the lateral ventricle on the right. Contrast CT showed luxury perfusion and gyral enhancement in the same regions (Fig. 1). No lesions in the left hemisphere were seen.

The CT measurements of the width and length of the left occipital and right frontal regions showed the pattern of asymmetry typical for right-handed males (Naeser, 1984).

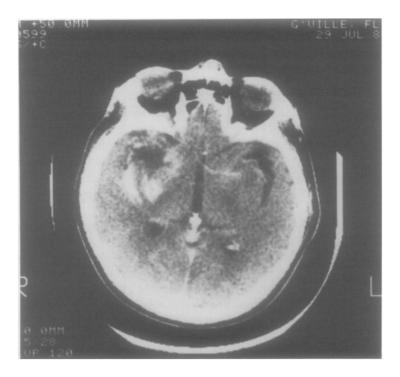


FIG. 1. Contrast-enhanced CT scan showing large right-sided frontotemporoparietal infarction.

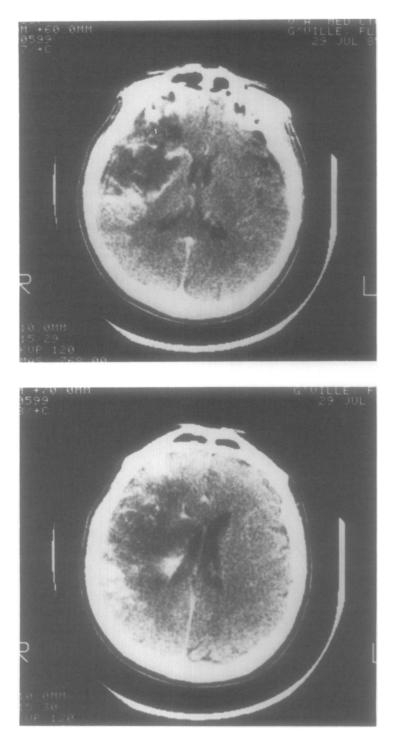


FIG. 1—Continued.

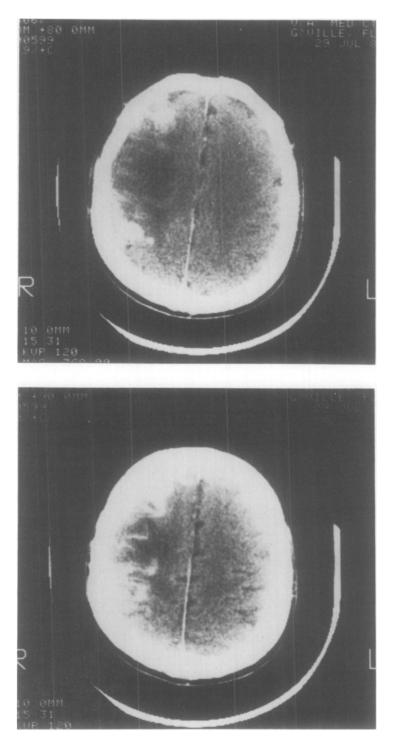


Fig. 1—Continued.

## Neuropsychological Studies

1. Assessment of handedness. Handedness was assessed both by selfreport and by the information obtained from the patient's wife. He always used his right hand for all the activities on a modified version of Annett's (1967) handedness questionnaire. Because the patient grew up in an orphanage and has no living relatives, a family history of handedness is not available to us.

2. Language assessment. Language functions were serially evaluated with the Western Aphasia Battery (Kertesz, 1982).

Although the patient was globally aphasic initially with an aphasia quotient (AQ) of 2, evaluations between the third and sixth weeks of his hospital course documented rapid improvements in language abilities. The AQ increased to 58 when last tested 48 days after the stroke. Figure 2 shows language recovery as measured by AQ over time. Auditory comprehension showed the most improvement, but spontaneous speech remained nonfluent and agrammatical. Writing has remained essentially unchanged. He can match single written words to pictures, and he occasionally follows simple written commands but often fails in reading comprehension at the sentence level.

3. Emotional prosody and processing of emotional information. Our patient's spontaneous emotional prosody was normal, and he could comprehend the emotional prosody of the examiner. He had some difficulty, however, with repeating emotionally intoned but semantically neutral sentences spoken by the examiner. On the repetition task he occasionally reproduced the propositional message without the appropriate emotional intonation and then verbally denoted the affect. For example, instead of sounding sad, he repeated: "The boy went to the store, and he was sad."

He displayed a large variety of spontaneous and appropriate facial expressions. He also gesticulated freely with his right hand. He could produce different emotional facial expressions on command and on imitation. When shown photographs of faces expressing different emotions, he named the affect appropriately. He could also point to the appropriate face when the affect was named by the examiner.

4. Visuospatial and visuoconstructional functions. Spontaneous drawings were oversimplified, lacking spatial perspective and detail. This was more pronounced on the left side of his drawings. His performance improved somewhat on copying, except for the Rey figure that was very poorly done.

He bisected lines slightly to the right of the midline and tended to ignore objects on his left side. Conversely, he crossed out all the lines on the cancellation task.

5. Testing of praxis: Rationale. Patients with apraxia from left hemisphere

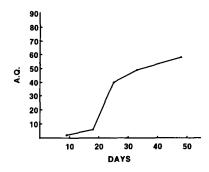


FIG. 2. Language recovery as measured by AQ on the Western Aphasia Battery.

lesions typically make temporospatial errors or use a body part as the object. According to the classical theory of apraxia, these movement errors either result from the destruction of the motor engrams or represent a disconnection of the primary motor areas from these engrams. Without these visuokinesthetic motor engrams, the motor system cannot adopt the appropriate spatial positions of the relevant body parts over time (Heilman & Gonzalez Rothi, 1985). If our patient made predominantly temporospatial and body-part-as-object (BPO) errors, we may invoke a mechanism similar to the one described to account for them.

However, because this patient is apraxic from a right hemispheric lesion, we may find that his errors are qualitatively different from the type of errors made by patients who are apraxic from left hemispheric lesions. Therefore, his apraxia may be related to different neuropsychological mechanisms. A qualitative analysis of errors may also provide clues to the nature of the right hemisphere's contribution to the learning and execution of skilled movements in this unusual case.

Finally, after acute brain injury patients may have severe behavioral disorders that obscure more subtle defects. Observing this patient over a period of time therefore may help uncover behavioral abnormalities not seen immediately after the injury.

### METHODS

The patient's ability to perform transitive limb gestures was evaluated by asking him to demonstrate the use of 15 common household objects. He performed all tasks with his nonparalyzed right upper extremity. He was given this task once a week for the first 6 weeks of his hospital course (Sessions 1-6), and another evaluation was performed at 8 weeks after the stroke (Session 7).

To circumvent our patient's language comprehension deficit, during Testing Sessions 1-5 we first asked him to show how he would use an object that he was allowed to see but not handle (Visual Command). He was then asked to imitate the examiner who was pantomiming the use of an object (Imitation). Finally, he was to demonstrate the use of objects by handling them (Object Use). During the last two testing sessions (6 and 7) he was also asked to perform to commands given in the verbal mode (Verbal Command). By

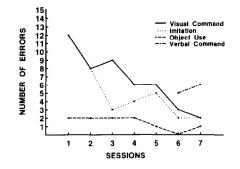


FIG. 3. Number of perseverative errors on Testing Sessions 1-7.

this time the patient adequately comprehended yes-no questions and could follow simple commands. He also had no difficulty pointing to objects named by the examiner and could verbally describe the task he was asked to perform.

Each testing session was videotaped. The tapes were subsequently reviewed by four judges who scored the types of errors committed by the patient. Three of four judges had to reach agreement on the error type before it was used in our final analysis. The operational definitions used to score the movement errors are provided in the appendix.

We also tested buccofacial and intransitive movements on verbal command and imitation, but since the patient's performance on these tasks was similar to his performance with transitive movements, we included only the latter in our analysis.

## RESULTS

The results of our study of transitive movements show that the most common error types were perseverative, spatial, and BPO errors. Temporal errors were so infrequent that we did not include these in our analysis. Spatial and BPO errors are typical in apraxia, so these are considered together and contrasted with perseverative errors.

Figure 3 shows the number of perseverative errors on each testing session, and Fig. 4 illustrates the number of spatial and BPO errors.

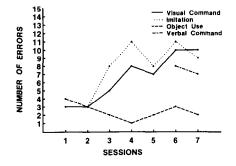


FIG. 4. Number of spatial and BPO errors on Testing Sessions 1-7.

# DISCUSSION

The motor perseveration demonstrated by this patient initially was dramatic. That apraxic patients make some perseverative errors is wellknown. Liepmann (1900) noted perseverations in the patient he described in his first case report; he was careful to point out, however, that these perseverative errors did not dominate the clinical picture. He contrasted his patient's performance with that of another case described by Pick (1892). Pick's patient showed severe motor perseverations, and these seemed to cause all the faulty responses in demonstrating the use of objects. Pick proposed to call this disorder "pseudo-apraxia."

Perseverations on tasks that require cognitive flexibility are characteristic of frontal lobe damage. In fact, qualitatively our patient's motor perseverations were very similar to the "stuck-in-set" type of motor perseveration in patients with massive frontal lobe lesions described by Luria (1977). This is characterized by an inability to switch from one action to another and to control recurrent but no longer appropriate motor responses. To Luria (1965) it meant that "the program of action once initiated becomes inert and the patient having once performed the required task is incapable of switching to the fulfillment of any other task, but continues to perform the first task on which he is stuck." Such patients cannot change their way of responding in accordance with varying environmental signals.

The inflexibility of the patient with a frontal lobe lesion is most pronounced when the programs to be executed are complex or abstract, while more concrete and automatic sequences can still be performed. This may explain why our patient, whose infarct damaged large areas of the frotal lobe, had more perseverative errors on the more complex tasks of performing to verbal and visual command and imitation, although he could still perform quite well on the more automatic and concrete task of handling objects.

He was also aphasic, and perseverations are commonly seen in aphasics. Perseverative responses can be observed on a variety of verbal and nonverbal tasks and most often in cases of global aphasia (Allison & Hurwitz, 1967; Helmick & Berg, 1976; Mateer, 1978; Yamadori, 1981; Sandson & Albert, 1984). Since globally aphasic patients usually have large lesions that involve the language-dominant frontal lobe, their perseverative behavior may represent examples of the stuck-in-set type of perseveration described by Luria. However, several of Luria's cases were not aphasic, and therefore the presence of aphasia does not appear to be the sine qua non for this syndrome.

We believe that the severe perseverative responses of our patient during the early testing sessions indicate his general inability to develop the cognitive sets necessary to respond adequately to environmental

stimuli. This represents a loss of cognitive flexibility that is probably due to severe frontal lobe damage. The presence of this cognitive disorder precludes classification of his initial performance as ideomotor apraxia.

As recovery took place, these perseverative errors became less and less prominent (Fig. 3). The decrease of perseverative responses was paralleled by the emergence and gradual increase of spatial and BPO errors (Fig. 4). Although conceivably BPO errors in aphasics may be related to an inability to develop the correct cognitive set due to a failure to comprehend the exact nature of the instructions for the pantomime task, the patient's predominant errors were spatial. These errors were especially prominent during the last three testing sessions and were qualitatively similar to the errors of apraxic patients who have left hemispheric lesions. We conclude that our patient's inability to perform skilled movements at this stage was due to apraxia. The emergence of these "classical" apraxic errors suggests that the right hemisphere contributed significantly to the performance of skilled movements and that without this contribution, the left hemisphere could not program these movements on verbal command, visual command, or imitation.

Although decidedly unusual, there have been other reports of defective limb praxis in right-handers after right hemisphere lesions. Assal, Perentes, and Deruaz (1981) reported the case of a 32-year-old right-handed man with no family history of left-handedness who became globally aphasic after a right hemispheric stroke. Limb apraxia was noted both on verbal command and on imitiation. Unfortunately, the authors did not describe the types of errors made by their patient on these tasks. His language functions improved rapidly, perhaps indicative of bilateral language representations. Limb apraxia was no longer present on a repeat evaluation 3 weeks later. This patient subsequently died, and postmortem examination of the brain showed an extensive right hemispheric subcortical infarct. The left hemisphere was intact.

In a recent publication, Basso, Capitani, Laiacona, and Zanobio (1985) described another right-handed patient with no family history of lefthandedness who developed fluent aphasia after a right hemispheric stroke. This patient showed severe ideomotor apraxia when tested on a 24gesture imitation task. Detailed analysis of his movement errors is not provided, but generally they were due to perseverations of previous gestures.

There are also a few reports in the literature of right-handed persons who became apraxic but not aphasic after damage to the right hemisphere. Studies by Italian investigators have shown that when praxis is assessed with a quantitative procedure and apraxia is diagnosed on an objective basis, with reference to the performance of a control group, one can find a few right-handers with right hemisphere lesions who will perform in the apraxic range (Faglioni & Basso, 1985). The incidence of apraxia in

these patients is related to the thoroughness of the testing methods. De Renzi, Pieczuro, and Vignolo (1968) used a 10-gesture imitation test and found apraxia to be present in 2% of 45 patients with right hemisphere damage. Pieczuro and Vignolo (1967) found it in 9% of 35 right-hemispheredamaged patients using a 20-gesture test. With a 24-gesture imitation test 20% of 80 right-hemisphere-damaged patients were found to be apraxic by De Renzi, Motti, and Nichelli (1980). The patients in the last study did not appear impaired on verbal command. Their errors on imitation tasks were not qualitatively different from the errors of the left-hemispheredamaged group, although a detailed analysis of the types of movement errors is not provided by the authors. De Renzi (unpublished data, cited by Faglioni & Basso, 1985) recently confirmed his findings in a sample of 110 right-hemisphere-damaged patients, 12% of whom performed in the apraxic range. Some of these patients also failed when performing on verbal command or on visual presentation of the object, and some made errors even when the objects were handled.

In a smaller sample of patients Haaland and Flaherty (1984) also found right-handed, right-hemisphere-damaged patients who were apraxic. When the errors made by these patients were compared with the errors of apraxic patients who had left hemisphere damage, some qualitative differences were noted. However, unlike Haaland and Flaherty's righthanded patients with right hemisphere damage, our patient made errors qualitatively similar to those made by the left-hemisphere-damaged group in that study, in that the errors reflected a deficit in integrating intrapersonal space with a representation of extrapersonal space.

Our case is unusual and appears to contradict Liepmann's hypothesis that handedness reflects the greater capacity of one cerebral hemisphere to learn the execution of skilled movements (Liepmann, 1908; Geschwind & Galaburda, 1985). According to that theory, the greater skill of the dominant hand reflects the superiority of the hemisphere controlling that hand in learning the "movement formulas" necessary to program these movements. Right-handedness therefore implies that the left hemisphere, which is directly controlling the right hand, is more capable of acquiring programs for motor skills than is the right hemisphere. Because, according to Liepmann, the movement formulas are contained in one hemisphere (e.g., the left hemisphere in right-handers), when called on to carry out skilled movements with the hand ipsilateral to the movement formulas, one must use a transcallosal route. Evidence for this callosal hypothesis has been provided by Liepmann and Maas (1907) and more recently by Watson and Heilman (1983). Because our patient became apraxic after damage to the right hemisphere, we suspect that before the stroke he was using a transcallosal route when performing skilled movements with his right hand.

There is no ideal measure of handedness. However, both by self-report

and a handedness questionnaire, our patient was a right-hander. Since we could not obtain a family history of handedness, "familial sinistrality" cannot be rule out.

Annett (1985) postulates that there is a genetically determined "rightshift" factor, that biases its carriers toward right-handedness. In those persons without this factor, handedness is randomly determined by accidental factors and they may be right-, left-, or mixed-handers. The observation that our right-handed patient became apraxic after a right hemisphere lesion suggests that right-handers should not be considered a homogeneous group in terms of cerebral motor dominance and therefore provides support for Annett's hypothesis. Perhaps those right-handers that have the right-shift factor have left hemispheric motor dominance but those without this factor may be either left or right hemisphere dominant or have bilateral representations.

# APPENDIX: CLASSIFICATION SYSTEM FOR MOVEMENT ERRORS

- 1. *Content*. The pantomime has incorrect content. There are several subtypes of errors:
  - a. *Perseverative*—the subject is pantomiming the content of a prior command.
  - b. *Related content*—Although the content is wrong, it is related to the target (e.g., same category).
  - c. Nonrelated, nonperseverative.
- 2. Temporal.
  - a. Movement sequencing errors.—A correctly performed pantomime may have a sequence of movements. For example, when the subject is asked to use a key to open a door, first there should be adduction of the thumb against the flexed index finger (holding the key), then extension at the elbow (putting the key into the door) followed by rotation at the elbow (turning the key).
  - b. *Movement timing and speed*—Each movement of a pantomime has characteristic timing and speed. For example, in hitting a ball with a bat or tennis racquet, the hitting movement accelerates more rapidly than the preparatory movement. There is also a delay after the bat or racquet is brought back.
  - c. *Movement occurrence*—Single or repetitive movement cycles. For example, scissors and pliers or door knob opening and screwdriver.
- 3. Spatial.
  - a. *Movement amplitude*—Each movement of a pantomime has a characteristic amplitude. For example, while brushing one's teeth, the movement amplitude is small, while when using an ax the movements have a large amplitude.
  - b. Internal configuration (posture)-When pantomiming, the fin-

### RAPCSAK, GONZALEZ ROTHI, AND HEILMAN

gers, hand, and arm must be in specific spatial relationships to one another. Usually there is an (a) initial posture when one begins the act and (b) a final posture when the act is completed. Usually the body parts make an orderly transition from initial to final posture. For example, when flipping a coin all the fingers are flexed at both the MP and IP joints. The index finger is less flexed at the MP joint. The wrist is in a neutral position (neither extended nor flexed) with neither ulnar nor radial deviation. The arm is adducted and the elbow is flexed usually not more than 50° or 60°. The thumb is held by the index finger. In the final posture, the thumb is extended at the IP and MP joints. The elbow may be further flexed. All other parts remain unchanged.

- c. *External configuration*—When pantomiming, the fingers, hand, and arm must be in specific spatial relationship to the object being acted upon in the environment (for example, hammering on the wall vs hammering a nail on the floor.
- 4. Body part as object (BPO)—Instead of pantomiming, the subject uses body parts as objects.

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