CHAPTER

13

The Limb Apraxia Test: An Imitative Measure of Upper Limb Apraxia

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Clinical and theoretical concepts of apraxia of speech have had a history marked by numerous opinions and controversies over definition, diagnosis, and management. In contrast, approaches to limb apraxia have been relatively free of controversy.

Limb apraxia has been recognized as a behavioral sign of brain injury since the 1800s, and Liepman's conceptual model for the disorder has been accepted and used since the early 1900s (Denny-Brown, 1958; Nielsen, 1946). This apparent stability is surprising in light of Poeck's (1986, p. 130) recent observation that "... no standardized battery of tasks is available for *the clinical examination of motor apraxia.* The diagnosis is made mainly on the basis of personal experience and intuition." The picture is not actually quite so bleak because scoring systems and items for assessment have been described (DeRenzi, Motti, and Nichelli, 1980; DeRenzi, Pieczuro, Vignolo, 1968; Heilman, 1979; Kertesz and Hooper, 1982). However, most tasks either have not been well standardized or have failed to account for the potential influence of aphasia on performance.

All of this could be ignored by speech-language pathologists if the limbs were not part of the communication tree. The relevance of limb movements to communication has been highlighted in recent years by attention to alternative modes of communication for the aphasic individual. In fact, limb apraxia is among the most frequent explanations given for nonverbal propositional communication deficits in aphasia (Baratz, 1986; Goodglass and Kaplan, 1963; Kaplan and Goodglass, 1981). Unfortunately, however, attempts to understand limb apraxia have been complicated by at least three problems: (1) highly variable and subjective approaches to assessment; (2) general acceptance of typologies for limb apraxia (e.g., ideational, ideokinetic, limb kinetic) with little verification through valid and reliable standardized measures; and (3) failure to recognize the role of aphasia in symbolic limb movements, or difficulty in distinguishing the effects of aphasia from those of limb apraxia on such movements.

The goal of the present study was to develop a measure that would quantitatively and qualitatively identify and describe limb apraxia in those with unilateral brain injury. The test, which we call the Limb Apraxia Test (LAT), has been used in studies of pantomime expression in aphasia (Duffy and Duffy, 1981; Watt and Duffy, 1978), but its validity as a measure of limb apraxia and its capacity to identify and quantify the problem have not been described.

Specifically, the purposes of this chapter are to (1) describe the structure of the LAT; (2) present the results of comparisons among groups of normal, right-hemisphere-damaged (RHD) and left-hemisphere-damaged (LHD) groups on the LAT: (3) establish the replicability of findings regarding the presence, severity, and prevalence of limb apraxia in groups of patients with LHD; and (4) discuss the test's potential contribution to our understanding of limb apraxia and nonverbal communication deficits in aphasia.

METHOD

THE LIMB APRAXIA TEST — RATIONALE AND STRUCTURE

The rationale that determined the LATs general nature, subtest structure, and item selection is important to the test's validity. Basically, we believed it important to select items that would cover a variety of unilateral upper limb movements and avoid apparent heavy demands on intelligence, education, and physical prowess.

Like many approaches to assessing limb apraxia, the test is imitative. There are three reasons for this: (1) it allows response parameters to be precisely defined, (2) it avoids verbal stimuli and hence eliminates the influence of verbal comprehension deficits, and (3) it eliminates or reduces the symbolic or representational "intent" of limb movements. This last reason admittedly departs from approaches to assessment that ask the subject to show how or to pretend to do certain things. We did this to avoid confounding assessment of movement programming and control with the representational or communicative intent of the movement, something that may be more strongly related to aphasia than to limb apraxia (Duffy and Duffy, 1981).

With this basic structure in mind, eight subtests, each containing 10 items, were devised. The subtests can be characterized under three binary contrasts that represent features often reported in the literature to be associated with varieties of limb apraxia.

The first binary contrast is called Object/No-Object. Object subtests contain items in which real objects are used or manipulated. No-Object subtests do not involve object use. For example, one of the Object items involves turning over a cup and then placing a block on top of it. One of the No-Object items involves extending the arm with the fist clenched, then flexing the arm while opening the fist, and then returning to the initial postion.

The second contrast is Simple/Comlex. Simple subtests are operationally defined as containing elements with one to three movement components. Complex subtests contain items with four to six movement components. For example, one of the Simple items involves placing the hand to the contralateral cheek with the palm facing out. One of the Complex items involves pretending to spoon sugar, move it to a cup, dump it in, and stir.

The third binary contrast is Segmented/Sequenced. Segmented subtests contain items that are performed one component at a time. Sequenced subtests are performed only after the entire item is completed by the examiner. For example, one of the Segmented items involves turning over a cup, followed by patient imitation, followed by the examiner grasping a block, followed by patient imitation, followed by the examiner placing the block on the cup, followed by patient imitation. The Sequenced item counterpart involves presentation of the entire sequence followed by patient imitation of the entire sequence.

In summary, the LAT contains eight subtests, each with 10 items, each item containing from one to six movement components, for a total of 252 components on the test. Each subtest is characterized by one of the contrasts in each of the three binary features just discussed. The test's subtest structure is summarized in Table 13-1.

SCORING

The test is scored with a 21-point interval scoring scale. Similar to the scale used in the Porch Index of Communication (PICA) (Porch, 1967), it is based on performance in the dimensions of accuracy, completeness, promptness, responsiveness, and efficiency. The use of 21 scoring categories, as opposed to the PICA's 16 categories, was intended to include additional information about response completeness, responsiveness, and efficiency.

Judgment of *accuracy* is generally based on the angle of a movement or a target posture. Movements or target postures more than 90 degrees dif-

TABLE 13-1. SUMMARY OF LIMB APRAXIA TEST SUBTEST STRUCTURE (10 ITEMS PER SUBTEST)

			Features		
Subtest	*Item components*	*Total components*	*Sequenced*	*Complex*	*Object*
I	1–3	17	+	–	–
II	1–3	17	+	–	+
III	4–6	46	+	+	–
IV	4–6	46	+	+	+
V	1–3	17	–	–	–
VI	1–3	17	–	–	+
VII	4–6	46	–	+	–
VIII	4–6	46	–	+	+

ferent from the stimulus target are scored as inaccurate. *Completeness* also deals primarily with movement angle and targets; accurate movements or postures that are 45 degrees off the target are scored as incomplete. *Promptness* refers to immediacy or delays in initiation or completion of a movement. *Responsiveness* refers to whether stimuli are repeated, and *efficiency* to the smoothness versus awkwardness of movement.

Interval values for each of the scoring categories were developed through a pair comparison scaling experiment (Duffy, 1974). To determine if a simpler-to-use ordinal scale could be adopted in place of the interval scale, the LAT scores obtained using both the interval and ordinal scale values were correlated for the normal, right-hemisphere-damaged, and three left-hemisphere-damaged groups that will be described shortly. Because all correlations exceeded 0.99, the ordinal values were adopted for all subsequent scoring and analyses. The scoring categories and interval and ordinal scale values are summarized in Table 13-2.

Each component of each item in the test is scored. An item score is the average of the component scores in the item. A subtest score is the average of item scores in the subtest. The overall LAT score is the average of the eight subtest scores.

SUBJECTS

The LAT has been administered to five groups of subjects, including:

1. *Controls* (N = 30). This group consisted of hospitalized adults without neurological deficits or significant visual impairment. The group mean age was 62.4 years (SD = 12.1). The mean educational level was 9.3 years (SD = 2.4).
2. *Right hemisphere damaged* (RHD) (N = 44). This group consisted of hospitalized adults with single unilateral right-hemisphere lesions without significant visual acuity deficits. The group mean age was 63.4 years (SD = 9.6). The mean educational level was 10.8 years (SD = 3.0).
3. *Left hemisphere damaged* (LHD) (N = 77). This large group was made up of three smaller subgroups of adults with single unilateral left-hemisphere lesions without significant visual acuity deficits; each subgroup was tested at a different point in time. The total group mean age was 61.5 years (SD = 12.5). The mean educational level was 11.1 years (SD = 3.2).
   a. The first subgroup (OHD1) contained 20 adults on whom the LAT was initially developed (Duffy, 1974).
   b. The second subgroup (LHD2) contained 36 adults who were tested as part of a larger investigation of pantomime abilities in aphasia (Duffy and Duffy, 1981).

TABLE 13-2. INTERVAL AND ORDINAL SCALE VALUES FOR THE 21-POINT LAT SCORING SCALE

Category	*Interval value*	*Ordinal value*
Complete	21.00	21
Distorted (Dist)	19.00	20
Delay (Del)	17.84	19
Incomplete (Inc)	17.32	18
Del-Dist	14.90	17
Inc-Dist	14.86	16
Corrected (Corr)	14.16	15
Inc-Del	13.37	14
Repeated (Rep)	12.90	13
Corr-Dist	11.53	12
Inc-Del-Dist	10.90	11
Rep-Dist	9.95	10
Corr-Inc	9.74	9
Rep-Inc	7.95	8
Corr-Inc-Dist	7.84	7
Rep-Inc-Dist	5.68	6
Related	5.58	5
Error	3.46	4
Perseveration	1.74	3
Unintelligible	1.53	2
No response	1.00	1

c. The third subgroup (LHD3) contained 21 adults who were tested as part of an investigation to establish a short form of the LAT (Duffy, Duffy, and Uryase, 1988).

There were no statistically significant differences among the control, RHD, and LHD groups in age or educational level ($p > .05$). The RHD and LHD groups did not differ in time post-onset, which ranged from 2 weeks to 26 years ($p > .05$).

TEST ADMINISTRATION

Half of the control subjects performed with their right hand, half with their left. Most brain-damaged subjects were hemiplegic or hemiparetic.

All subjects used the limb ipsilateral to the side of lesion. Standard nonverbal conditioning procedures were employed for each subtest, and no subtest was started until subjects demonstrated that they understood the nature of the task.

RESULTS

RIGHT VERSUS LEFT LIMB PERFORMANCE

It was first necessary to ask if the use of the right or left limb had any significant effect on LAT performance. This was addressed by examining the performance of the control subjects who used their left versus right hand. A two-factor analysis of variance (ANOVA) (hand by subtest) did not identify statistically significant differences between right and left hand performance on any subtest ($F = 0.1371$; $df = 18,1$; $p > .05$) and suggested that comparisons among the control, RHD, and LHD groups would not be significantly influenced by the exclusive use of the left or right limb in the brain-damaged groups. Control subjects tested with their right or left hand were combined for subsequent group comparisons.

COMPARISON OF THE THREE LHD GROUPS

The replicability of findings generated by a test is important to its reliability and usefulness. Before comparing the LHD to the control and RHD groups, therefore, it was appropriate to ask if similar results were obtained across the three left-hemisphere subgroups. ANOVA of the overall LAT scores among the three LHD subgroups was not statistically significant ($F = 0.197$; $df = 74,2$; $p > .05$). Thus, group performance appears replicable across independent samples of LHD patients. Because the three LHD subgroups did not differ from one another, they were combined for comparisons with the control and RHD groups.

PERFORMANCE OF CONTROL, RHD, AND LHD GROUPS

Table 13-3 summarizes the distribution of overall LAT scores for the three groups. The control and RHD scores distributed similarly, although 27 percent of the RHD subjects performed more poorly than the poorest control subject. Thirty-two percent of LHD subjects performed within the distribution of control scores, but many (68%) performed more poorly than did the poorest control. ANOVA of these overall LAT scores among

TABLE 13-3. DISTRIBUTION AND SUMMARY OF SUBJECT SCORES FOR CONTROL, RHD, AND LHD GROUPS ON THE OVERALL LAT

Score	*Control*	*RHD*	*LHD*
20.0–2100	21 (70%)	15 (34%)	7 (9%)
19.0–19.99	9 (30%)	17 (39%)	18 (23%)
18.0–18.99		3 (7%)	13 (17%)
17.0–17.99		8 (18%)	11 (14%)
16.0–16.99		1 (2%)	11 (14%)
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11.0–15.99			15 (19%)
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1.0–10.99			2 (3%)
N	30	44	77
$\bar{X}$	20.17	19.40	17.36
SD	0.45	1.10	2.63
Range	19.32–20.85	16.60–20.83	7.73–20.89

the three groups was statistically significant (F = 18.29; df = 2,114; $p < .0001$). Post hoc Scheffé comparisons indicated that the differences between the control and RHD groups were not statistically significant ($p > .05$), but that the LHD group was inferior to both the control and RHD groups ($p < .05$).

Results of group comparisons across the eight LAT subtests were similar. A multivariate ANOVA conducted primarily to examine differences among the three groups across the subtests revealed significant group and subtest effects as well as a significant group by subtest interaction (all $p < .001$). Subsequent ANOVAs and post hoc tests to examine differences among the groups for each subtest indicated that the control and RHD groups did not differ on any of the subtests (all $p > .05$) but that the LHD group was inferior to both the control and RHD groups on all subtests (all $p < .001$).

What was the incidence of limb apraxia in the LHD group? Using the poorest control as the cutoff point for normal, 68 percent of the LHD subjects can be said to have performed abnormally. The incidence of abnormal performance was high for each of the three LHD groups: 65 percent, 89 percent, and 71 percent for LHD1, LHD2, and LHD3, respectively.

RELATIONSHIPS AMONG LAT SUBTESTS AND SUBTEST CHARACTERISTICS INFLUENCING LHD GROUP PEFORMANCE

For all three groups, correlations between LAT subtests and the overall LAT score were statistically significant ($p < .001$) and most were moderately high to high (Table 13-4). For the LHD group, all r equalled or exceeded .80. These high correlations attest to the LATs internal consistency. The intersubtest correlations for the LHD group were similarly high, and to the extent that the different LAT subtests may measure different types of limb apraxia, this suggests that the presence and extent of one type generally predicts the presence and extent of others.

To determine which of the test's characteristics influenced performance of the LHD subjects ($N = 64$), the binary contrast features (Object/No-Object, Segmented/Sequenced, Simple/Complex) were compared by averaging the subtests characterized by each feature as an index of performance for that feature. Results of t-test comparisons indicate that Sequenced tasks were more difficult than Segmented tasks and that No-Object tasks were more difficult than Object tasks ($p < .01$). The difference between Sequenced and Segmented tasks was greater than the difference between Object and No-Object tasks ($p < .01$), suggesting that Sequenced tasks have a greater influence on reducing performance than movements without objects. There were no differences between Simple and Complex tasks ($p > .05$).

DISCUSSION

This study demonstrates that the LAT has face validity, internal consistency, and replicability as a measure of limb apraxia. It appears capable of identifying limb apraxia in patients with lesions presumed to cause the disorder (i.e., left hemisphere) and does not identify (in terms of group

TABLE 13-4. CORRELATIONS* BETWEEN LAT SUBTESTS AND OVERALL LAT SCORES FOR EACH GROUP

Group	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
LHD	.85	.84	.92	.91	.89	.80	.92	.86
RHD	.64	.82	.84	.71	.67	.84	.83	.80
Normal	.67	.71	.74	.74	.56	.32	.59	.62

* Corrected for spurious overlap.
Note: All r significant ($p < .001$).

effect) patients with lesions generally presumed not to have the problem (i.e., right hemisphere). (The finding that 27% of RHD patients scored below normal on the LAT is in general agreement with DeRenzi, Notti, and Nichelli [1980], who classified 20% of their RHD patients as apraxic on an imitative measure of ideomotor apraxia.) Furthermore, the ability of the LAT to separate patients with LHD from control and RHD patients appears consistent and replicable, insofar as similar deficient performance was obtained in three separate samples of LHD patients.

The sensitivity of the LAT to limb apraxia is suggested by its identification of higher incidence rates than that often reported in the literature (DeRenzi, Motti, and Nichelli, 1980; DeRenzi, Pieczuro, and Vignolo, 1968; Hecaen and de Ajuriaguerra, 1964). Finally, the high subtest–overall LAT and high intercorrelations among LAT subtests raise questions about the validity of divisions of limb apraxia into different subtypes, at least as isolated types in substantial numbers of patients.

This study suggests that objective, standardized assessment of limb apraxia may help to improve our understanding of the disorder. It also may provide valuable information to those interested in a more complete understanding of the reasons for nonverbal symbolic communication deficits in aphasia and to their efforts to establish augmentative forms of communication for aphasic individuals. From this standpoint, history may need to repeat itself. That is, one reason for long-standing efforts to improve our ability to identify and describe apraxia of speech is that apraxia of speech must be treated differently than aphasia. Because deficits in symbolic/representational limb movements of aphasic patients may represent a barrier to using limb movements as a means of communication, it seems important to identify the contribution of both aphasia and limb apraxia to such deficits. The ability to assess limb movements objectively seems to be one step essential to that process.

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DISCUSSION

Q = question; A = answer; C = comment.

Q. You report poorer performance on the sequencing tasks than on the nonsequenced tasks. Did you in any way try to determine the short-term memory capabilities of your patients, or would you care to speculate as to the reasons for decreased performance on sequenced tasks? Do you think it's strictly a length and a memory problem, or is there something inherent in trying to organize and put different gestures in strings that might contribute or explain the deficit on sequencing?

A We did not look specifically at the influence of memory on performance. I can say that many patients who performed poorly did not consistently omit components of movements, which might be expected if memory were a major determiner of performance. Also, the sequenced subtests were highly corrrelated with the segmented subtests, and segmented subtests placed almost no load on memory; this would argue against memory as a major factor.

C. But it might be determined by a qualitative analysis of the nature of their responses, as I guess you've just suggested.

A. Right, and those data are probably there, but we haven't examined them.

Q. What, if anything, do we risk by featuring imitation so prominently in both our definition and our testing of limb apraxia?

A. Imitation is featured only in the *operational* definition used in our test. Obviously, what you lose by featuring imitation is information about what happens when movements occur more spontaneously. The problem that we thought was more significant was our inability, based on our current level of knowledge about what this problem is, to separate apraxic movement difficulty from what might be the product of an inability to represent something symbolically. So, "Show me how to comb your hair" might yield poor performance either because of difficulty programming the movements necessary for that act or because of some representational problem in executing that act. Our inability to know how to separate that out led to our choice of imitative tasks.

Q. In looking at your correlations, it looked like the normals' correlations were consistently lower. What does that mean?

A. The reason is probably the reduced range of performance in the control group. They did so well that the range of performance was narrowly distributed and that tends to reduce the magnitude of correlation.

Q. What would you think you would get if you had them sharpen a pencil versus put the block in or on the cup?

A. The complex items, in terms of number of movement components, were actually imitations of natural object use. So, one of the complex items was spooning sugar, moving it to a cup, and dumping it in, and stirring. So, there were some pretend activities, but they were imitative. One interesting result was that the complex "pretended" tasks, which were lengthier in terms of number of movement components, were not more difficult than shorter No Object items that were not symbolic or representational.

Q. That's my question then: learned versus unlearned. Is there a learned versus unlearned element that you could sort out in the data and look at?

A. I think the more familiar movements, spooning sugar for example, probably were relatively easier because of meaningfulness or perceived meaningfulness. I think this is not surprising, especially in light of what we know about aphasia and even apraxia of speech; we know that meaningfulness improves performance for aphasic and apraxic patients, and I think that may be true for limb movements as well.

C. I think I can give a point of information about the question of whether an apraxia test tells you anything about what the patient is going to communicate nonvocally in his environment. We have a paper in press in *Brain and Language* where we correlated performance on our apraxia test, which, by the way, has no nonsymbolic movements; they're all symbolic to both imitation and to command, with rating scales that were done by various professionals, family members, and so forth, with patients' ability to communicate nonvocally on various levels going from everything like a pointing response for something they want to elaborate pantomime. We found a very high correlation, and certainly it's easier to give an apraxia test than to run about watching this patient in a variety of settings. So, I congratulate you for getting your test shaped up, and I think that it is not just reasonable but important to test limb apraxia as a part of our workup because it does tell us something about what the patient will do out there in the real world.

Q. This is just a follow-up question of qualitative differences. Do you have any idea how different aphasic types, either behavioral types or localization types, differ in amount of type of error?

A. No, we have not looked at that factor for LAT peformance.

C. I'm curious about those patients who didn't have apraxic errors and what, if anything, that tells us about the symbolic nature of aphasia and whether or not we can make some assumptions about gestural errors per se telling us something about the nature of aphasia.

A. My bias is probably reflected in the development of the tests and the choice of imitative tasks. When you look at the pantomime expression of aphasic patients, it may well be deficient not necessarily because of limb apraxia but because of their aphasia; this would suggest that aphasia is more than a verbal deficit, and our studies of pantomime comprehension and expression support that conclusion. In the patients we've tested on a pantomime expression test, there has been a higher correlation between pantomime performance and overall PICA scores than there has been between pantomime expression and their performance on the LAT, although that relationship is also significant. But, when you factor things out, the aphasia appears to be the stronger influence on pantomime performance. Both problems are there (limb apraxia and aphasia), and the apraxia makes a significant contribution to the variance in pantomime expression ability, but the aphasia has the stronger influence.

Q. What's the incidence/prevalence of limb apraxia in right hemisphere lesions as compared to left? I think you implied that it's much higher in left than in right.

A. It was 68 percent in the left-hemisphere group. About a quarter of our right-hemisphere patients were poorer than the poorest control subject.

Q. I guess I'm worried about validity. I seem to be the only one who is. I always worry about whether poor performance on a measure is indicative of what the measure is supposedly designed to measure. Does poorer performance on this measure indicate the presence of limb apraxia? Do you have any kind of independent confirmation that poor performance says, aha, that means limb apraxia?

A. No. We certainly need to look at validity by comparing the results obtained with a measure like this with other common approaches to assessing limb apraxia. I think the point about the right-hemisphere patients is a good one, though. When you see their deficient performance I'm not sure what you should conclude. Are those right-hemisphere patients apraxic, or does the test measure some general effect of brain injury on performance so that only when it reaches a certain level of deficiency should you say the disorder is present? I can say that some of the right-hemisphere patients who performed more poorly than the poorest control had profiles across the subtests that looked just like the left-hemisphere patients' profile. It actually made us wonder about bilateral damage in those folks, but we have no evidence that that is the case.

C. I was wondering whether if in your right-hemisphere and your three left-hemisphere samples, you got independent judges, three out of four doctors, to agree that the guys who performed below a certain score were in fact limb apraxic.

A. No.

Q. Do you think that's important? A measure can be fine if it shows you that they can't do something. Call it limb apraxia or they just can't do this.

A. I think the real challenge would be finding judges that have the same common appreciation of how the disorder should be defined. Many physicians, many neurologists, define limb apraxia very differently than I would, or than the literature does, or than other neurologists would.