Limb Apraxia: A Clinical Perspective

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When a person with neurological impairment engages in an unusual action such as pouring hot water into a cup with no tea bag and stirring it with a fork, or cutting bread with a knife oriented upside down and sideways, the impairment of limb apraxia should be suspected. Apraxia has been defined as, " a neurological disorder of learned purposive movement skill that is not explained by deficits of elemental motor or sensory systems".[1] While motor problems such as abnormal tone and posture, paresis, ataxia and dysmetria can coexist with limb apraxia,[2,3] this movement problem is one of conceptual understanding of action and / or production of movement.[4] The deficit cannot be explained by intellectual deterioration, lack of cooperation, sensory disturbances, agnosia, disrupted body schema, visuospatial disturbances or aphasia.[3,5] There is evidence that aphasia and apraxia commonly cooccur, as they are predominantly found in right-handed clients with left hemisphere lesions; however, they are often clearly dissociated.[6]

The reported incidence of apraxia in persons with neurological impairment ranges from 28–57% in left hemisphere (LH) damage and 0–34% in right hemisphere (RH) damage.[7,8] While most incidence studies focus on the stroke and acquired brain injury populations, apraxia is also common in Alzheimer disease[9-11] and has been reported in Parkinson's Disease.[12]

Blatant deficits in performance of activities of daily living (ADL) do not always appear in persons with apraxia; however, stroke studies have suggested that this impairment is highly correlated with and / or predictive of ADL status at admission, discharge and / or follow–up.[13,14] Although this ADL-apraxia relationship was recently refuted,[15] sensitivity of the tool used to identify apraxia was weak. Historically, functional impact of apraxia has been underrated. It was once thought that apraxia could only be elicited with testing when the person had to voluntarily generate a movement to command since he / she could often perform these same movements automatically without error in a natural context.[16] This voluntary-automatic discrepancy in praxic performance does exist. However, recent studies of performance of apractic persons in naturalistic environments have indicated that errors of performance such as misuse of tools and problems in sequencing occur in this context.[17-19] Everyday apraxia is often missed because the client frequently manages to accomplish a task, albeit in an awkward fashion and with considerable fluctuation in accuracy.[17-19] Alternatively, the person may avoid or abandon activity that requires complex mechanical problem solving.[20] Problems in ADL may also be masked by an inability to express difficulty due to aphasia, lack of awareness or attribution of problems to challenges such as need to utilize the non-dominant hand.[5] The true nature of the impact of apraxia on ADL performance continues to evolve with increasing sensitivity of the clinical assessments of apraxia and clearer understanding of processing deficits underlying apraxia.

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Limb Apraxias and Related Assessment

Ideational (IA) and ideomotor (IMA) apraxia are the two most commonly described disruptions of praxis. These were first described by Leipmann[21] as disorders caused by disruption to the dominant left hemisphere praxis system in right-handers. Both of these forms of apraxia are bilateral. In contrast, callosal apraxia affects only the left hand and is thought to be due to lesions of the callosum, which disconnects praxis information in the dominant LH from the right motor areas.[22] Limb kinetic apraxia is a less common unimanual apraxia, believed to affect fine movement control of either hand. It is believed by some to be a more elemental motor disturbance rather than a true apraxia.[23]

Testing for apraxia involves requests for single or sequential movements through pantomime, imitation and tool / object use. In pantomime, the person is asked to perform a movement in response to verbal command, visual stimuli, tactile presentation of an object or passive kinesthetic manipulation of a limb prior to response. Utilization of different sensory modalities to test praxis dissociates modality specific apraxias[24-26] and provides clinically useful information regarding how to elicit movement. Imitation testing requires replication of a model's movement either concurrently (concurrent imitation) or after it is complete (delayed imitation). Concurrent imitation assesses the person's ability to visually analyze the movement while delayed imitation involves both visual analysis and encoding information in working memory.[27] Imitation testing also reduces the impact of aphasia on gesture performance. Performance with the actual tool reflects the ability of the person to use the sensory and contextual cues of the tool to evoke movement. Pantomime and imitation assessment often include the following types of gestures: representational, either transitive (tool and/or object related gestures such hammering a nail) or intransitive gestures (expressive gestures such as a saluting) and non-representational or meaningless gestures.[28] Little agreement exists regarding the sensitivity of these gesture types in differentiating apraxias;[28] however, it is clinically informative to determine what type of gestures are affected most in apraxia.

On testing, the person with IMA may or may not recognize what action or gesture is required when given a verbal command. Heilman and colleagues[29] demonstrated two forms of IMA: LH posterior IMA, in which a person fails to recognize gesture (i.e. cannot identify which of three videotaped actions match a verbal command) and cannot pantomime; and LH anterior IMA, in which pantomime to verbal command but not gesture recognition is affected. In IMA, the person's production of accurate and efficient movements is affected by spatial, temporal and sequencing errors.[30,31] IMA errors are thought to occur in all testing conditions although performance in tool use should be better due to the presence of contextual information. There are, however, several reported cases of clients who are impaired in tool use alone.[32-34] Typical errors that distinguish IMA and IA are presented in Table 1, although a recent review[28] suggests that these might not be clearly delineated. Clinically, error analysis is useful in informing intervention.[35]

The person with IA appears to lack the concept or idea of the movement on testing. He/She is unable to perform a correct movement in pantomime or tool/object use testing. When imitating a model, performance may improve because imitation does not require access to motor memory. Disrupted sequencing of action is felt by some[36] to be the main feature of IA. This suggests that it would be wise to incorporate more naturalistic action sequences into assessment; for instance, those in the multiple objects

Table 1

Errors in Ideomotor and Ideational Apraxia

Ideational	Ideomotor
Tool/Object Related Errors – Inappropriate tool selection – Performance of a related but incorrect action to the target object* – Performance of an unrelated action to the target object* – Use of hand to perform action rather than imagining target tool*	**Spatial Errors** – Spatial orientation of hands incorrect to imagined tool (internal configuration)* – Finger, arm and hand in inappropriate position with respect to imagined tool and object (external configuration)* – Movement in the wrong plane + – Use of wrong muscle groups (movement)* – Body part as tool * + **Note:** Tools are the instruments performing the action. Objects are the recipients of the action.
Sequencing Errors – Perseveration of part of the series of the action+* – Problems in terminating movements + – Sequence of action out of order + – Blending of two actions + – Omission of action part + – Repetitions + – Substitution of movements unrelated to the movement + – Sequencing of individual movements in an action +	**Temporal Errors** – Timing of movement is irregular* – Occurrence or increase in repetitions required for the action* – Unsustained action – Clumsiness – Sequencing of pantomime *
Other – No response – Perplexity +	**Other** – Perseveration of sub-part of the action+ – No response – Amorphous movements – Gestural or verbal augmentation when performing movement

*From Rothi, Raymer, Heilman (1997) +From Roy (1998) Unmarked Other items From Tate and MacDonald (1995) tests requiring performance of acts such as hanging a picture.[36,37] Others feel that the disturbance is one of failing to recall the action associated with tools / objects for both singular and / or sequences of movements.[38] It has been suggested that sequencing disorders be termed IA and separated from conceptual disorders termed as conceptual apraxia.[31] The latter is reflected in apraxia models proposed by Heilman[39] and Roy[2,4,27] and their colleagues.

Roy's model[2,4,27,40-43] considers praxis to be based on three systems: sensory / perceptual, conceptual and production systems. The sensory / perceptual system enables one to analyze input information. The conceptual system represents a knowledge base for action and includes knowledge of objects and tools and their uses, knowledge of actions and knowledge of action sequences. Errors in the conceptual system may result in content errors such as incorrect choices of action for the tool or in problems understanding the sequence of events. To assess the conceptual system, measures of tool and action knowledge are suggested. Knowledge of action sequencing might also be tested using action card ordering.[36] The production system involves processes associated with execution of action such as generating the image for the movement, selecting the appropriate response, encoding in working memory and in response generation.

According to this model, a specific pattern of performance on a praxis test(s) and conceptual praxis tests may help to determine the nature of the impairment and distinguish among various forms of limb apraxia. Such forms include conduction apraxia, in which motor production through visual analysis in imitation is more impaired than pantomime to verbal command,[44] and frontal apraxia, an executive disturbance affecting the sequencing of action[45] (Table 2).

A full assessment of apraxia such as that in Table 2 and that presented by Rothi and colleagues[46] would be most clinically informative but currently exists only for research purposes.[28]

Table 2

Full apraxia assessment based on Roy's Model of Apraxia

System	Process/Structure	Cognitive Assessment	Praxis Assessment	Type of Apraxia
Sensory Perceptual	Visual-gestural Analysis	Gesture Matching	Imitation—concurrent	
Conceptual	Knowledge of tool function	Tool naming/ identification Tool naming/ identification by function	Pantomime—transitive	Conceptual/ Ideational
	Knowledge of action	Gesture recognition	Pantomime—transitive or intransitive	Conceptual/ Ideational
	Knowledge of tool-action	Tool-action association Tool selection	Pantomime—transitive	Conceptual
	Knowledge of serial order of action	Action card ordering	Action sequencing	Ideational
Production	Response selection		Pantomime—transitive or intransitive	Ideational
	Image generation		Pantomime—transitive or intransitive	
	Working memory		Imitation-delayed and pantomime	
	Encoding visual gestural information into working memory		Imitation—delayed	
	Translation of visual gestural information into movement		Imitation—concurrent	Conduction
	Movement organization and control—single gesture		Pantomime and imitation tasks	Ideomotor
	Movement organization and control—sequence of gesture		Action sequencing task E.g. Multiple Objects Test	Ideational
Executive Control	Attentional coordination of actions	Executive functioning assessment	Action sequencing task Naturalistic observation	Frontal Apraxia

Table 3

Summary of Studies in Rehabilitation of Apraxia

Study & Design	Subjects	Training Used	Results
Rehabilitation of Non-Communicative Gestures			
Maher, Rothi and Greenwald[47]	55-year-old man with a 22 m. history of IMA with preserved gesture recognition	**Goal:** Successful gesture to visual presentation of tool **Intervention:** Multiple cue provision (tool, object, visual model, feedback) with gradual fading **Feedback:** Knowledge of results and error correction through modeling and physical limb manipulation **Frequency:** 1hr/day for 2 wks	Post-treatment—improved verbal pantomime error performance on both trained and untrained gestures but no improvement on a probe measure of 10 meaningless gesture sequences. Two weeks post-treatment—both treated and untreated gestures performance diminished with the former having some retained gains.
Ochipa, Maher and Rothi[37]	Two participants with 3 and 4 yr. history of IMA with preserved gesture recognition and aphasia	**Goal:** Decrease errors in movement **Intervention:** Treatment geared toward their specific IMA error profile **Frequency:** 44 sessions 1/day, 4/wk (Subject 1) and 24 sessions 2/day, 2/wk (Subject 2)	Errors did not decrease until targeted in treatment. At post-treatment and two-week follow-up both subjects demonstrated treatment gains on treated but not untreated gestures, as measured by verbal pantomime error scoring and Florida Apraxia Screening Test (FAST).
Pilgrim and Humphreys[49]	Head injured participant with left-sided IMA 23 m. post-injury	**Goal:** Appropriate gestures during object use **Intervention:** Modified conductive education coupled with diminishing amounts of physical assistance **Frequency:** 1/day for 3 wks + 15 min/day practice with spouse	Differences between pre- and post-tests measuring ability to gesture to verbal, visual, and visual and tactile command demonstrated changes in trained but not untrained gestures. Strategy was not carried out spontaneously post-treatment.
Smania, Girardi, Domenicali, Lora and Aglioti[50]	13 left CVA participants with apraxia lasting greater than 2 m. Random assignment to apraxia treatment or conventional treatment group	**Goal:** Improve gesture production on wide range of tests **Intervention:** Training occurred in 3 parts for transitive, intransitive-symbolic and intransitive non-symbolic gestures. Training in each segment graded from multiple to minimal contextual cueing conditions and assistance was provided verbally, visually or manually. **Frequency:** 35 sessions maximum (50 min, 3/wk)	Treatment group showed significant improvement in post-tests of IMA and IA, significant error reduction in IMA and IA tests, and a trend toward improved gesture comprehension following treatment.
Training of Communicative Gestures			
Code and Gaunt[51]	71-yr-old man with severe Broca's aphasia limb apraxia & disrupted communicative hand signs following CVA. 20 m post-onset	**Goal:** Teach client to use signs paired with words **Intervention:** Six stage hierarchical program involving imitation, fading and reinforcement focused on pairing the word and sign in response to various commands **Frequency:** 45 min. 1/wk for 8 m	Improved production of gesture to word, word to gesture and gesture and word to word on post-tests. Improved performance on Psychosocial Adjustment Scale. No changes in aphasia or apraxia pre-/post-tests

Table 3 cont.

Summary of Studies in Rehabilitation of Apraxia

Cubelli, Trentini and Montagna[52]	64-yr-old woman with global aphasia and limb apraxia following CVA. 6 m post-onset	**Goal:** Production of pantomimes to visually presented objects and actions **Intervention:** Teaching involved drawing attention to distinctive features of objects and perceptual characteristics and presenting possible pantomimes for each picture to be imitated **Frequency:** 90 min., 2/wk for 2 m	Identification of participant's intended pantomime by 3 independent observers improved significantly. Generalization to untrained gestures occurred but no improvements in apraxia pre-/post-assessment were noted. Relatives reported increased self-confidence & spontaneous gesture production. **Conclusion:** Limb apraxia did not affect acquisition of signs/gestures
Rehabilitation of ADL function in Clients with Apraxia			
Pool[53]	5 left CVA clients with apraxia, 5 left CVA clients without apraxia and 5 controls	**Goal:** Learn one-handed sequential skill of tying shoe laces **Intervention:** Demonstration and verbalization of technique	Subjects with apraxia required more trials to learn and recall task after a 5 min. delay period. 4/5 participants with apraxia learned and retained the task.
Goldenberg and Hagmann[20]	15 left CVA participants with apraxia and aphasia Mean time since CVA 6.8 wk. (SD=4.9)	**Goal:** Acquisition of 3 ADL tasks taught separately for 1 wk. periods **Intervention:** ADL, with support given at critical stages through graded hand over hand, simultaneous imitation and delayed imitation and separate sessions highlighting perceptual details and critical features of the task as they related to the actions. **Frequency:** 5 sessions for each ADL task on ward plus 20–40 mins/sessions in OT	Only ADL function training decreased errors that prevented completion of the task (fatal errors). No spontaneous recovery of untrained functions occurred. 10 patients completed all tasks while 3 still committed fatal errors at the end of the intervention. Seven subjects followed up 6–30 months post-treatment only sustained acquired ADL skill when they had the opportunity to practice at home.
Goldenberg, Daumuller & Hagmann[55]	6 left CVA participants with at least a 6 m history of apraxia and aphasia; 6 left CVA participants with no apraxia; and 3 controls	**Goal:** Contrast of exploration training and direct training on acquisition of 4 complex ADL tasks **Intervention:** Exploration training relating structure and function and improving mechanical problem solving through study of critical object features as they relate to functional significance. Direct training approach similar, but assistance was offered only when client requested it. **Frequency:** 6 sessions per pair of ADL tasks with each methodology, 1hr/session	Only direct training reduced error and assistance required in ADL function with no generalization to untrained tasks. Training effects were preserved at a 3 m follow-up period; however, errors increased with use of different tools for the task 1 wk. post intervention. Apraxic paticipants had more difficulty than those with no CVA who were in turn better than controls.
Van Heugten et al.[54]	33 left CVA participants with apraxia Range of time since CVA 1.6–21.4 wk	**Goal:** Improvement of ADL skills **Intervention:** Strategy training. Problems of initiation, execution and control were dealt with by graded methods of instruction, assistance and feedback respectively (presented in study). **Frequency:** 3–5 times/wk for 30 min for 12 wk. Training for new ADL activity every 2 weeks.	Post-treatment ADL scores (Barthel Index, ADL observation and ADL questionnaire) improved significantly while apraxia and motor functioning scores showed less but significant improvement. No control for spontaneous recovery.

Typically, clinical assessment involves screening to detect apraxia which utilizes pantomime to verbal command and may include delayed imitation, real object manipulation and / or error analysis (e.g. Florida Apraxia Screening Test - Revised 46).

Rehabilitation of Clients with Apraxia

Studies of rehabilitation of clients with apraxia have started to appear in the literature in the last 10 years. These have focused on production of gestures[47-52] and teaching ADLs[20,53-55] (see Table 3, page 18, for details). All studies suggest that clients with apraxia are capable of new learning or relearning; however, most studies suggest that this learning does not generalize well.

Three case study designs[47-49] geared at retraining gesture production in clients with IMA utilized individualized programs based on the apraxic presentation of the client. Techniques included cue-fading coupled with knowledge of results feedback and manual or modeling error correction,[47] specific IMA error correction[48] and a modified conductive education technique, which utilized decreasing amounts of physical assistance and goal-directed verbal mediation.[49] In contrast to the specificity of training demonstrated in the above studies, a generalization effect was found for the treatment group in a study by Smania and colleagues.[50] These findings were attributed to the fact that the intervention utilized a comprehensive program of graded cueing contexts and practice with many types of limb gestures, which addressed all error types. This ability to relearn the link between actions and tools or expression is particularly important when one is dependent on gesture as a primary method for communication, as is the case of a person with both aphasia and apraxia. Two single case studies[51,52] have reported successful acquisition of trained communicative gesture production.

Because apraxia often co-occurs with hemiplegia, previously overlearned ADL tasks become novel tasks to be reacquired with one-handed strategies.[20] Pool demonstrated that clients with apraxia are capable of acquisition of such strategies, particularly one handed shoe tying but require more learning trials than non-apraxic persons.[53] Three investigations looking at a broader range of ADL acquisition in clients with apraxia have also demonstrated that clients with apraxia are capable of learning ADL skills but again this learning is task-specific.[20,54,55] All successful treatment methods provided graded methods of instruction, assistance during execution and / or feedback and were largely done in the context of the ADL performance. The only unsuccessful intervention was that which took place outside of the ADL context and was geared towards restoring the person's ability to infer function from structure and to improve mechanical problem solving through the study of critical features of objects as they relate to function.[55] This finding supports the notion that persons are best treated in a naturalistic context.

It is encouraging that persons challenged with the impairment of apraxia seem to be capable of reacquiring gestures and learning functional tasks. As clinicians, we are challenged by the specificity of learning. The development of individually-tailored approaches to intervention will improve with a more complete understanding of apraxia, based on theories of gesture comprehension and production. This will require assessments that go beyond simple detection of apraxia. ◆

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