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Posture recognition in Alzheimer's disease ☆

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Abstract

Background. Apraxia is neurologically induced deficit in the ability perform purposeful skilled movements. One of the most common forms is ideomotor apraxia (IMA) where spatial and temporal production errors are most prevalent. IMA can be associated Alzheimer's disease (AD), even early in its course, but is often not identified possibly because the evaluation of IMA by inexperienced judges using performance tests is unreliable. The purpose of this study, therefore, is to learn if the Postural Knowledge Test (PKT), a praxis discrimination test that assesses knowledge of transitive (PKT-T subtest) and intransitive (PKT-I subtest) postures and does not require extensive training, is as sensitive and specific as the praxis performance tests. *Methods.* We studied 15 subjects with probable AD as well as 18 age-matched controls by having them perform transitive and intransitive gestures to command and imitation, as well as having them discriminate between correct and incorrect transitive and intransitive postures. *Results.* Overall on all tests, the control subjects performed better than those with AD. In addition all subjects had more trouble with transitive than intransitive gestures. Using a stepwise discriminative analysis, 81.8% of the subjects could be classified according to Group (94.4% of Controls, 66.7% of AD subjects). In this analysis, the PKT-T (transitive posture subtest) was the only measure that contributed to the discrimination of subjects. *Conclusion.* We found that having subjects select the correct transitive hand postures in this "booklet test" was more sensitive than grading their praxis performances even when using judges with extensive training. This suggests that this discrimination test might be an excellent means for diagnosing and screening patients for AD. The reason why recognition of transitive postures is relatively more difficult for our AD subjects is not known. Two possibilities are that the representations for intransitive movements are stronger than those for transitive movements, and hence, more resistant to degradation, or that intransitive acts are stored in parts of the brain not affected by AD.
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1. Introduction

Limb apraxia is the inability to correctly perform purposeful skilled movements with the forelimbs, when this disability cannot be explained by elemental sensori-motor deficits as well as cognitive deficits such as impaired comprehension (Geschwind, 1965; Liepmann, 1920). Based on the skills required by the task and the type of errors made by the patient many forms of limb apraxia have been described (see Heilman & Rothi, 2003, for a review) . However, ideomotor

apraxia (IMA) is the forms of apraxia that has been reported to be most commonly associated Alzheimer's disease (Foundas et al., 1999; Kato et al., 2001) even early in its course (Travniczek-Marterer, Danielczyk, Simanyi, & Fischer, 1993), and thus this paper will focus on IMA.

Patients who have IMA make spatial (postural-configuration, spatial movement, and spatial orientation) and temporal errors (Poizner, Mack, Verfaellie, Rothi, & Heilman, 1990; Rothi, Mack, Verfaellie, Brown, & Heilman, 1988). There are several methods of testing for IMA, including: producing intransitive gestures or transitive pantomimes to command or in response to seeing tools (e.g., hammer) or objects (e.g., nail), upon which the tool works, imitation of meaningless or meaningful (transitive or intransitive) gestures and using actual tools and implements. Errors can be scored by trained observers (Rothi et al., 1988) or by kinematic analyzes (Poizner et al., 1990).

It has been posited that the spatial parameters of movement and postural representations (praxicons) are stored in the dominant parietal lobe (Heilman, Gonzalez-Rothi, & Valenstein, 1982; Rothi, Heilman, & Watson, 1985). The premotor cortex (i.e., Brodmann's area 6) translates these representations into a motor code, and this code activates the motor system. Support for this model comes from the observation that, patients with posterior (i.e., parietal) lesions (infarctions) are impaired at both pantomime performance and correct versus incorrect discriminations, and apraxic patients with anterior lesions can correctly discriminate (Heilman et al., 1982; Rothi et al., 1985). Most often in patients who have AD the first place to degenerate are the structures in the medial temporal lobe, inducing memory loss, but the second area is often the inferior parietal lobe (Braak, Braak, & Bohl, 1993; Terry et al., 1991). Thus, we would expect that these patients might be impaired in both performance and recognition tests that assess the quality of information stored in these networks and would not only demonstrate apraxia when asked to gesture or pantomime, but also would have a deficit in their ability to discriminate between correctly and incorrectly performed movements and postures.

The diagnosis of probable AD (McKhann et al., 1984) requires that the patient have deficits in two or more cognitive domains. Many AD patients with involvement of both the medial temporal and parietal lobes might appear to only have a disorder of declarative memory and thus are diagnosed as mild cognitive impairment (MCI) (Petersen et al., 1999). Although the presence of IMA together with a declarative memory deficit might be important in the diagnosis of AD, the correct determination of the presence of apraxia, unlike many other cognitive tests, often requires extensive examiner training and in the absence of this training clinicians might have difficulty diagnosing this disorder based on the patient's ability to perform skilled movements (Hollingsworth et al., 2003). Therefore, we developed a Postural Knowledge Test (PKT) (Mozaz, Rothi, Anderson, Crucian, & Heilman, 2002) that is designed to assess the recognition of postures associated with both transitive and

intransitive movements, and we wanted to learn if this test, which does not require extensive training, when administered to patients with AD, is as sensitive as having trained and experienced raters assess subjects' ability to pantomime to command.

2. Methods

2.1. Subjects

The experimental subjects were 15 individuals (7 women; 8 men) who met the NINCDS criteria for probable dementia of the Alzheimer's type (McKhann et al., 1984). We also tested 18 (9 women; 9 men) normal, elderly control subjects. All subjects were right-handed, as determined by the hand with which they selected to gesture or pantomime. There were no significance differences between groups in age, $t(30) = 1.64$, n.s., or education, $t(30) = 0.84$, n.s. Potential control subjects with a history of a neurological disease, including dementia or memory loss, alcohol or drug abuse, severe head trauma, substance abuse, psychiatric disease, severe medical disease or developmental learning disabilities were excluded. To assure that control subjects were not suffering with dementia, the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1983), and the Hopkins Verbal Learning Test (HVLT; Brandt, 1991) were administered. These cognitive test data, along with subject demographic information are presented in Table 1. As expected, the MMSE of the control subjects was significantly higher than those with AD, t $(15.86) = 6.72$; $p < .001$. Control subjects also scored significantly higher than AD subjects on the BNT, $t(15.99) = 4.60$, $p < .001$, and HVLT, $t(27) = 5.06$, $p < .001$. The Institutional Review Board approved this research project, and informed consent was obtained.

2.2. Apparatus

The Postural Knowledge Test (PKT) contains 24 cartoons (Mozaz et al., 2002). Four of these cartoons are for training and 20 of for testing. Each of these cartoons depicts a person performing an action. In ten of these test cartoons, the action is transitive (eating, applying lipstick, ironing, writing, painting, cutting hair, firing a gun, hammering a nail, combing the hair, using a key), hereafter referred to as PKT-T. In the remaining ten cartoons, the action is intransitive (victory, salute, be quiet, hitting,

Table 1

Means and (standard deviations) for both our Alzheimer's disease (AD) patients' and control (C) subjects' age, education, as well as scores obtained on Mini-Mental Score Examination (MMSE), Boston Naming Test (BNT) and Hopkins Verbal Learning Test (HVLT)

Group	N	Age	Education	MMSE	BNT	HVLT
C	18	77.41 (3.81)	13.35 (3.35)	29.06 (1.59)	53.94 (4.28)	20.12 (3.84)
AD	15	79.67 (3.98)	14.20 (2.11)	19.00 (5.42)	35.93 (14.65)	11.58 (5.27)

goodbye, snap fingers, okay, pray, applaud, stop), hereafter referred to as PKT-I. The transitive cartoons portray a person acting on an object (e.g., a woman writing), but this person's distal forelimb and tool/implement are not visible (Fig. 1). That is, the hand(s) performing the gesture is erased. The cartoons for the intransitive gesture were similar to those of the transitive pantomimes, only instead of an object upon which a tool works, there is a scene that requires an intransitive gesture. While viewing each transitive and intransitive action cartoon, the subjects are shown a response sheet each containing three pictures. For each trial, one picture demonstrates the arm and hand in the correct posture, and in the two other pictures, the hand and arm are in the incorrect postures (foils) (Fig. 2). The position of the correct posture versus foils on the response page was randomized across trials. The subject was trained to point to the correct hand posture on the response sheet.

The Gesture-Pantomime Production to Verbal Command (VC), the Imitation Test (I) and the Gesture Recognition Test (GR), described below, all have the same 20 test pantomimes and gestures (10 transitive and 10 intransitive) as does the Postural Knowledge Test. All these tests also have four training trials.

2.3. Procedures

The subject was seated at a table across from the examiner in a quiet room. With each gesture test, the four training-demonstration trials were administered first, followed by the test trials. In the Gesture-Pantomime Production Test, the subject was asked to pantomime or gesture with their preferred (right) hand in response to a verbal command. While performing these pantomimes, the subject was requested to abstain from using a body part as a tool. In the Imitation Test, the examiner requested that the subject imitate the gesture performed by the examiner, and in the Gesture Recognition Test, the examiner performed these gestures and asked the subject to name each of the gestures performed by the examiner. In the Gesture to Command and Imitation tests, each subject's performance was videotaped and subsequently scored as either correct or incorrect by the consensus of two trained judges. During all these tests, the transitive and intransitive trials were presented in a randomized order, and the order of presentation of these tests across subjects was also randomized. During the training trials, the subject was given feedback regarding the adequacy of his or her performances, but during the test trials, no feedback was given.
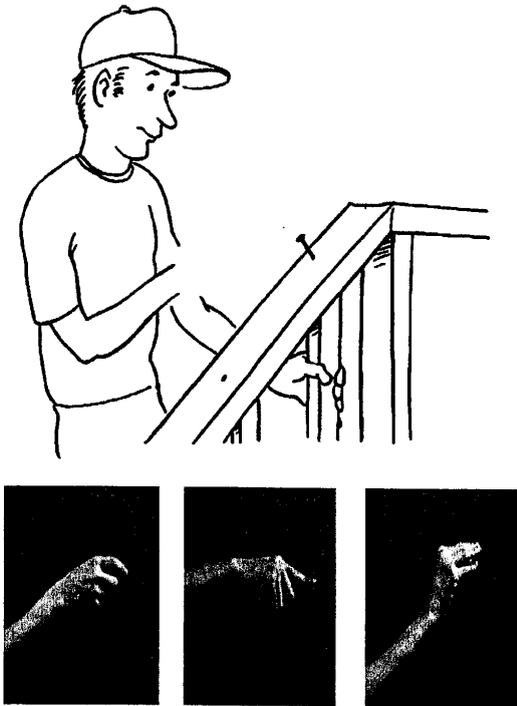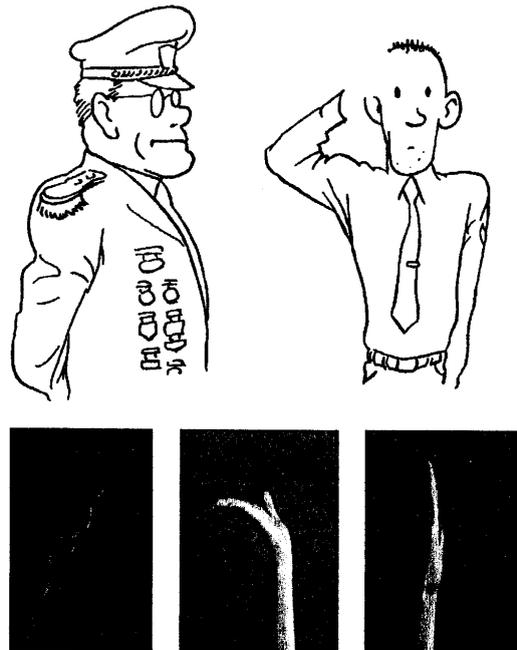

Fig. 1. Transitive gesture example.

Fig. 2. Intransitive gesture example.

3. Results

All subjects completed all the tests except for one control subject who did not complete the Verbal Command task. Using a Multivariate Analysis of Variance to test for differences between men and women in each group, there were no significant differences between the performance of men and women on the four apraxia tests in either the Alzheimer's disease group (Wilks' Lambda $= 0.57$, $F(4, 12) = 2.28$, $p = .12$) or the control (Wilks' Lambda $= 0.67$, $F(4, 10) = 1.23$, $p = .36$). Thus, the scores for men and women were combined in subsequent analyzes.

The means and standard deviations for each of the four praxis tests and for both the control and experimental (AD) group are presented in Table 2. These data were subjected to a repeated measures analysis of variance (ANOVA), with Task (Postural Knowledge, Gesture Recognition, Verbal Command, Imitation) and Gesture (Intransitive, Transitive) as within subject variables, and Group (AD, Control) as between subject variables. This analysis revealed a main effect for Task, $F(3, 28) = 45.61$, $p < .001$. Post-hoc analyzes using Bonferroni correction revealed significant differences between all tasks except Verbal Command and Imitation ($p \leqslant .009$), with the Verbal Command task being the most difficult, and the Gesture Recognition task being the easiest. A main effect for Gesture was also found, $F(1, 30) = 343.75$, $p < .001$, reflecting greater accuracy on intransitive (mean $= 8.77$, $SD = 1.29$) than transitive gestures (mean $= 6.0$, $SD = 1.33$). As hypothesized, a main effect for Group was also found, $F(1, 30) = 14.43$, $p = .001$, indicating that Control subjects were more accurate overall (mean $= 8.21$, $SD = 1.237$) than AD subjects (mean $= 6.55$, $SD = 1.235$).

It should be noted that a significant interaction between Task and Gesture was also found, $F(3, 28) = 51.61$, $p < .001$. Post-hoc paired comparisons using Bonferroni correction ($\alpha = 0.003$) revealed that of the 16 possible comparisons, seven achieved significance. These significant comparisons are listed below:

Postural Knowledge Intransitive > Postural Knowledge Transitive

Table 2
Means and (standard deviations) for scores obtained by the two groups (AD and Controls) on the Intransitive and on Transitive gestures on the following tests of praxis: Postural Knowledge (PK), Gesture Recognition (GR), Production on Verbal Command (VC), Production on Imitation (I)

Group	Test	Intransitive	Transitive	Total
AD	PK	7.20 (2.73)	6.47 (1.77)	13.60 (4.24)
	GR	8.20 (1.74)	7.67 (2.50)	15.87 (3.89)
	VC	8.00 (1.73)	2.80 (1.82)	10.80 (3.12)
	I	8.67 (1.92)	3.40 (2.35)	12.07 (3.81)
Controls	PK	9.56 (0.62)	8.67 (0.77)	18.22 (1.17)
	GR	9.78 (0.43)	9.33 (1.14)	19.11 (1.23)
	VC	9.24 (1.03)	4.71 (2.05)	13.94 (2.54)
	I	9.50 (0.77)	5.17 (1.76)	14.67 (2.09)

Postural Knowledge Transitive > Verbal Command Transitive
Postural Knowledge Transitive > Imitation Transitive
Gesture Recognition Transitive > Verbal Command Transitive
Gesture Recognition Transitive > Imitation Transitive
Verbal Command Intransitive > Verbal Command Transitive
Imitation Intransitive > Imitation Transitive

No other significant main effects or interactions were found.

In order to identify those praxis measures that best discriminate between our AD and control subjects, the various tasks were subjected to a discriminant analysis. Using a stepwise method with the conventional entry α value of 0.05 and removal α value of 0.10, this analysis was significant in correctly classifying 81.8% of the subjects according to Group (94.4% of Controls, 66.7% of AD subjects), Wilks' Lambda $= 0.586$, $\chi^2 = 15.77$, $df = 1$, $p < .001$. In this analysis, the Postural Knowledge—Transitive measure was the only measure that contributed to the discrimination of subjects. Comparing the AD subjects to the control subjects on the Postural Knowledge—Transitive task using the 99% confidence interval of the control subject data (Lower Bound $= 8.14$; Upper Bound $= 9.19$), 13 of the 15 AD subjects fell below the 99% confidence interval, whereas only one of the 18 control subjects fell below the 99% confidence interval.

In an attempt to improve the discrimination between AD and control subject using the praxis measures, we ran a second stepwise discriminant analysis after increasing the entry alpha value to 0.15 and the removal alpha value to 0.20. This analysis increased correct subject classification to 93.9% (100% of Controls, 86.7% of AD subjects), Wilks' Lambda $= 0.469$, $\chi^2 = 21.58$, $df = 3$, $p < .001$. The discriminant function for this analysis included the Postural Knowledge—Transitive task, the Gesture Recognition intransitive task, and the Imitation intransitive task. Calculating the 99% confidence interval for these tasks using control subject data 13 of the 15 AD subjects fell below the 99% confidence interval (9.49–10.07) for the Gesture Recognition intransitive task, compared to four of 18 control subjects, and four of the 15 AD subjects fell below the 99% confidence interval (8.96–10.04) for the Imitation intransitive task, compared to 1 of 18 control subjects.

4. Discussion

The results of this study reveal that patients with AD when compared to matched controls are impaired at recognizing the correct posture that is associated with both transitive and intransitive acts. Although the AD subjects performed more poorly on the performance tasks (pantomiming to command and imitation) than on the posture recognition task, the control subjects performed similarly. Hence, the sensitivity of these performance tests was not

greater than the sensitivity of the posture recognition test, suggesting that in assessing patients for AD the PKT might work better than the traditional performance tests. In addition, judges who had extensive training in the evaluation of apraxic errors evaluated our subjects' praxis performances, and as mentioned earlier, many of the people who will be evaluating and screening people for AD might not have this extensive training. Thus, the use of the PKT in the general population might be both more reliable and more valid than having clinicians assess people for apraxia using performance tasks such as gesture imitation or pantomiming to command.

The reason why recognition of transitive postures is relatively more difficult for our AD subjects is not known. One explanation for this dissociation is that the knowledge about transitive gestures might be stored in more widely distributed networks than are intransitive gestures, and widely distributed networks, such as those that store lexical-semantic representations, might be more susceptible to the widespread neural deterioration associated with diseases such as AD. Another explanation for the dissociation between transitive and intransitive acts, however, may be related to the means by which these representations are learned, used and activated. People use intransitive gestures more often than transitive gestures. For example, people use intransitive gestures when they are verbally communicating or when they want to transmit a non-verbal message. In contrast, people primarily only use transitive postures when actually using tools or objects. In general, people are rarely called upon to pantomime transitive acts in response to a command, and they are very rarely called upon to recognize transitive postures in response seeing the posture in the absence of the tool or object. Representations grow stronger the more they are practiced (Nudo, Milliken, Jenkins, & Merzenich, 1996), and people are less likely to make errors when performing well practiced acts than when performing rarely practiced acts. When representations undergo degradation, such as that seen with AD, the stronger representations are more likely to be spared than the weaker representations.

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