Analysis of Apraxia in Alzheimer's Disease

by

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ABSTRACT

The studies in this text were designed so as to explore some aspect of the presence of apraxia, in Alzheimer's Disease, as measured by the Waterloo Apraxia Battery (WatAB) (Roy, 1996). In the first four studies, we confirmed Benke's (1993) suggestion that two forms of apraxia were present and dissociable in AD. The majority of participants were apraxic in both imitation and pantomime conditions and a few were impaired on only one. In all of this work impairment was greater when tasks require analysis of visual gestural information than when a gesture must be generated from memory. The pattern of no difference in performance in Imitation as in Pantomime continued throughout the work herein.

Ochipa et al. (1992) suggest that apraxia in AD is conceptual in nature such findings as reported above are unexpected and contradictory. Of all the patterns predicted by Roy's (1996) model the most prevalent found was that where AD participants were impaired on Concurrent Imitation, Delayed Imitation, Pantomime and gesture- tool-object recognition (Conceptual) tests. According to Roy such a pattern suggests an impaired knowledge of action and tool/object function along with impairment in response organization and control (sensory-perceptual, conceptual and production systems). This pattern suggests that in AD, participants cannot make use of cues to assist their motoric performance as they cannot recognize a gesture, provide it when asked or when asked to copy someone else.

Another purpose of this work was to review the relationship between cognition and praxis via the DRS and the WatAB. First a correlation matrix indicated that many of the tests used, both motoric and conceptual, were highly correlated with the DRS. Many of the WatAB sub tests were also highly correlated with each other. Our findings are perhaps best considered an

indication that the WatAB will be a useful tool for future research and ultimately for clinical use.

The fifth study in this series was designed to test for apraxia under more naturalistic conditions. The Tool Selection Task (TST) was used, allowing an opportunity to manipulate the conditions under which the Concurrent Imitation tasks of the WatAB have been presented. The latter was in response to our consistent findings that the AD group performed praxis tasks with more error when using Transitive (Tool Use) gestures. We had hypothesized that presenting the tasks while sitting directly across from participant was too demanding and leading to difficulties with left and right. The use of a mirror for presenting the task did not eliminate error. We then used a broad measurement of visuo-spatial skills. The results do not determine whether Transitive gestures are particularly sensitive to changes in visuo-spatial changes during AD. We recommend including such a broad measure in future research.

In the WatAB TST the items such as eating are specific and the presentation of each task provides more cues as to the action required. We hypothesized that the presence of more cues would increase performance (reduce error). We report that as the number of cues increase the amount of error decreases in AD. Additionally, the TST is a measure of creativity as each task is presented twice (correct tool present or a reasonable alternative as one of the four choices). We report that using a method of measuring creativity can determine group differences and that the AD group spent more time selecting the correct tool in the alternate condition.

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INTRODUCTION

Purpose:

The purpose of the five studies in this body of research was to explore whether the use of a specialized battery of apraxia tests, developed for stroke research, could identify difficulties in persons with Alzheimer's Disease (AD), and if so, what types of problems they may be experiencing. These studies hope to bring some consistency and clarity to the study of Apraxia in AD which is currently missing from the literature. The objectives and questions unfolded as the results of the first studies led to the subsequent exploration of other questions.

This thesis reports on three broad objectives of this research.

Objective 1: To investigate the aspects of Apraxia in Alzheimer's Disease. Within this objective, we explored AD performance under different performance conditions (eg. Imitation - "Copy me hammering", and Pantomime - "Show me how you would hammer a nail") and under various gesture types (eg. Transitive - using an actual hammer; vs Intransitive - relies on communicating a specific meaning e.g.:wave goodbye) as presented by the Waterloo Apraxia Battery (WatAB). This objective was the focus of Studies 1 and 4 and eventually lead to the focus on changes in visual perceptual skills in AD in Study #5.

Objective 2: To investigate the relationship between cognition and apraxia. Studies # 2 and 3 explored relationships among a standard accepted measure of cognitive status in AD and the conceptual and gesture based tests of the WatAB.

Objective 3: To investigate whether the addition of context can influence AD performance in the Pantomime condition of the WatAB; and whether the addition of a measure of creativity relates to AD performance on the Tool Selection Task (TST) of the WatAB. Study #5 specifically addresses this objective.

Alzheimer's Disease:

Alzheimer's Disease (AD) is defined as a degenerative neurological disease characterized by a progressive decline in cognition and functional competence (Molloy & Caldwell, 1998). Traditionally, AD is confirmed on autopsy by the presence of plaques and neurofibrillary tangles (NFT). More recently, several authors have argued that new neuroimaging techniques can aid in confirming a diagnosis (e.g.: Black, 1996; Wahlund, 1996). Lezak (1995) and also Black (1996) reported that techniques which measured regional cerebral blood flow were especially effective and consistently suggested reduced activity in both anterior and posterior association areas and especially in the posterior temporal and contiguous parietal and occipital areas. Such neuroimaging, when used along with a set of established clinical criteria, can lead to an accuracy of AD diagnosis (when confirmed by autopsy) as high as 86% (Tierney et al., 1988). However, most researchers and clinicians rely on the set of diagnostic criteria set by the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association (NINCDS/ADRDA) working group (McKhann et al.., 1984). Lezak (1995) suggested that the most distinguishing cognitive features of AD were: severe verbal memory disorder, defective speech comprehension and production, deficits in attention, orientation, reasoning and psychomotor speed.

The most common diagnostic definition used for AD is that from the NINCDS / ADRDA criteria (see Appendix A1). Wallin and Blennow (1996) reviewed these criteria and suggested that they are still too broad in scope and exclusive as to details, and that such criteria could be describing several different diseases. They felt that the latest imaging techniques had not been included nor had any biochemical markers (e.g., analysis of blood and cerebral spinal fluid). They suggested that a more appropriate label would be Alzheimer's Syndrome due to the heterogeneity of symptoms, patterns of progression and even presence of diagnostic markers. Such a change in label was echoed by Wahlund (1996) when he offered that AD was a multi factorial disorder with multiple etiologies (p 90). However, more commonly AD is believed to break down into two types: Familial and Common. The Familial type can be found in those with at least one first degree relative (sibling or parent) who has or has had the disease and most importantly this type of AD is only found in those with an early onset (i.e., before age 60). The Common type and the type on which this research is found in persons with no hereditary links to AD and always begins after the age of 60 or 65 (Wallin & Blennow, 1996; Almkvist, 1996).

Lezak (1995), agreed with the authors above and indicated that AD has two well established findings. One was that, while AD affects every area of behaviour, the cognitive changes are the most striking and have attracted the greatest amount of research attention. Secondly, the variability between patients was very striking and, while the disease presented in many patterns, the overall downhill path of AD ended in all skills lost.

Almkvist (1996) cautions that while AD disrupts function over a vast spectrum of abilities, the earliest stages of AD are often a time where symptoms are overlooked and often not easily measured by the common neuro-psychological methods. For example, changes in attention may be subtle and are often easily excused and explained by those around the person with AD. Also changes in episodic memory (memory for the events of one's own life) at this stage are often just slightly worse than what is considered normal for ageing and again is easily explained or ignored. However, the hallmark of a diagnosis of AD is that such problems gradually worsen and that more and more areas of functioning are affected. By the time a clinical diagnosis is possible many areas are involved, including: verbal and spatial episodic memory, spatial defects as measured by constructional tasks (drawing and copying tasks), verbal fluency and naming are disrupted as is attention. Together, deficits in these areas affect the ability to complete some simple tasks and many complex tasks. As noted above, deficits in these areas progress with the disease and are joined by deficits in sensory function (as measured by visual, auditory, olfactory and tactile assessments) and executive functions (planning and organization, initiation, self-monitoring) all of which leave a person quite unable to live independently.

It has become evident that even from the early stages of AD some impact on motoric skills may be apparent. Early sensory changes in vision and tactile senses could affect the ability to purposefully select and use a utensil to eat. Changes in visual-perceptual skills could affect the analysis of gestural information and lead to more error when imitating a movement. Auditory changes could influence performance in following the directions to complete a task. As language disturbances seem to follow the reverse order of language development (Reisberg, 1982), one could predict differences in how a person with AD would interpret instructions, with short simple instructions most likely understood further into the disease. Any motoric task based upon some aspect of memory would also be influenced, as the person with AD might not remember how to complete a task. Because of these factors we wished to base our research on the motoric changes in AD as measured by changes in praxis (the ability to complete skilled and purposeful movements) performance.

Apraxia:

Apraxia was first described in 1900 by Liepmann in a patient with left supramarginal gyrus lesions (cited in Travniczek-Marterer, Danielcyk, Simanyi, & Fischer, 1993) and continues to be defined as a disorder of skilled movements not caused by other muscular and/or neurological factors (e.g., weakness, akinesia, aphasia, cognitive decline, or visual problems) (Roy & Square,1994; Roy & Square, 1985; Poeck, 1986). Liepmann further indicated, after studying 83 patients, that apraxia was separate from language dysfunction even though he noted that 20 of his participants presented with both aphasia and apraxia. Discussion as to the relationship between these two dysfunctions continues to the present time (Rothi, Ochipa, Heilman, 1997). However, Liepmann did suggest for the first time that praxis for both hands was mediated by the left hemisphere for right handed persons.

Apraxia has historically been measured by how accurately someone can Imitate a gesture (copy the examiner's movement in response to "Do this") or Pantomime (initiate the correct gesture in response to only a verbal command "Show me how you would ...") a gesture. This has lead to the hypothesis of two forms of dissociable apraxia (Benke, 1993) - Ideomotor apraxia (IM) and Ideational apraxia (IA). Commonly these two forms of apraxia are distinguished by differences in the patterns of performance when pantomiming gestures rather than when imitating gestures (Roy, 1992). IM suggests difficulties in the spatial orientation, selection, and sequencing of movements as performance is impaired in both Imitation and Pantomime conditions (Travniczek-Marterer, et al., 1993). Benke (1993) suggested that this form of apraxia relies on the co-ordination of visual-spatial and sensorimotor information and is most obvious during tests of imitating non-purposeful gestures. The second type of apraxia referred to as ideational or defined by Benke as a conceptual form, is related to object or tool use. This second type further depends upon the understanding and performance of symbolic motor acts such as when asked to pantomime (i.e.: "show me how you would . . ."). The resulting pattern would leave Imitation performance intact but not Pantomime performance. More recent models suggest that apraxia is of a far more complex nature than the above dichotomous models indicated (Roy, 1996; Roy & Square, 1994; Heilman et al., 1996). As will be discussed in more detail later, Roy & Square recently presented a model (see Figure 1) which allows for disruptions in any or all of three component systems - the sensory/perceptual system, the production system and the conceptual system - all of which underlie the comprehension and production of gestures.

There are two main models of apraxia presented in the literature. While both have common components they each arrive at a multi-stage model of apraxia via very different means. Rothi, Ochipa and Heilman (1991, 1997) (hereafter referred to as Heilman's 1997 model) developed a model to understand apraxia based upon their belief that motoric dysfunctions such as those seen in apraxia were similar to the disruptions in speech and language systems seen after specific damage to the brain. That is, that the particular patterns of dysfunction that they were seeing in their apraxic participants could only be accounted for by more than one system being disrupted, and that such patterns were seen as being conceptually similar to the specific speech patterns of disrupted performance in their patients with language dysfunction. However, it must be noted that Heilman's model is based on the clinical observations of: sometimes groups of patients with similar performance patterns and sometimes only one patient presenting with one pattern.

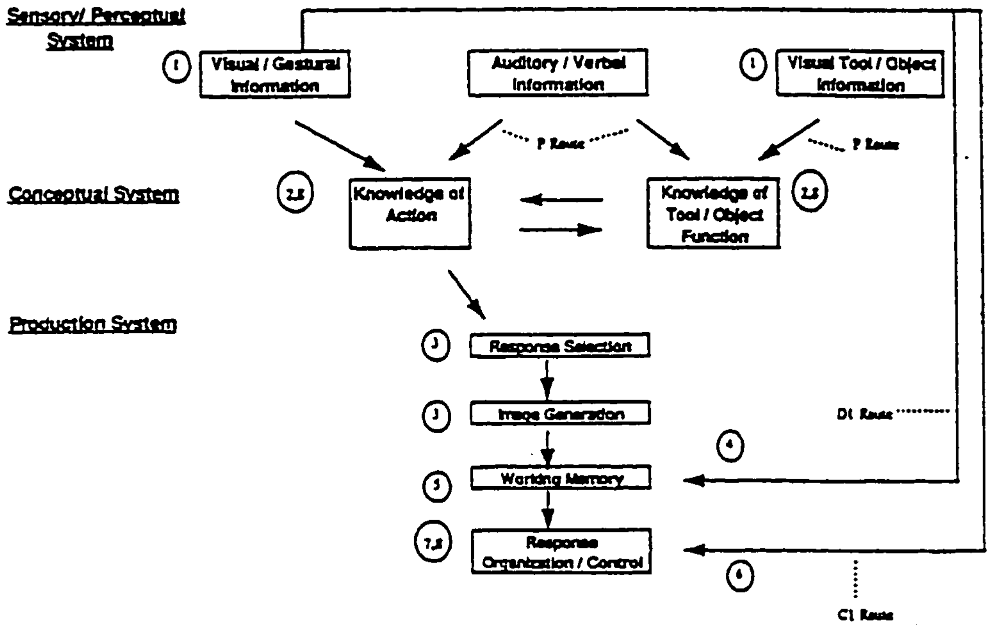
Heilman's model (1991, 1997) contains an analysis of sensory information (auditory and visual analyses), internal knowledge (object recognition, phonological, verbal and action lexicons all working through the semantics or action system) and the generation and control of gestures (innervatory patterns and motor systems). However, while equal emphasis is placed upon these three components in Roy's (1994) model discussed below, Heilman's model stresses more steps and processes at the internal knowledge level. It is imperative to note that the use of the words "lexicon and semantic" by Heilman's group does not actually include their more common language based meanings. In Heilman's case lexicon is defined as "movement memories or visuo kinesthetic motor engrams" (1997, p. 36) and semantic is defined as "conceptual knowledge" (1997, p. 41).

In contrast, Roy and Square (1994) first proposed a model based upon the various disruptions possible in a multi-modal motoric, more comprehensive approach. This model, while including disruptions to sensory and motoric systems of the brain, also included possible disruptions to other cognitive systems such as working memory. Roy's (1996) model led to the development of eight suggested patterns of performance (See Table 1) which would indicate the type of disruption in one of the components upon which praxis is based.

For both models the error in performance is measured consistently. However, Heilman's group (1997) and Roy's (1994, 1996) group do so differently. In each case the authors suggest that they have used similar systems to Stokoe (1960), who designed a system to describe the production of the gestures used in American Sign Language. In fact, a similar system had been employed by other researchers in the field of ideomotor apraxia (e.g.: McDonald, Tate, & Rigby, 1994). One note of caution must be added. McDonald, et al. suggest that when scoring praxis one must be cautious not to eliminate the qualitative aspects of movement thereby possibly increasing the amount of information. Only the FAB (Rothi et al., 1997) appears to gather such information, albeit in an arbitrary manner. In earlier versions of the WatAB (Roy & Square, 1985) the scoring system did allow for a more descriptive method. However, in the recent versions only the measurement of error is noted. For example, as ideational apraxia is partly defined by such actions as the misuse of objects (DeRenzi and Lucchelli, 1988) noting such errors as using the incorrect tool/object or using a body part as object is important and not obviously measured by the WatAB except incidently when recorded in the 'notes' section on each score sheet. Perhaps some addition of a more descriptive approach would benefit the WatAB (Roy et al.) and the addition of a more detailed system of analysis of error would benefit the FAB (Rothi et al.).Until large normative studies have been completed it might be rash to prematurely exclude possible sources of praxis information. However, in this body of work the WatAB as originally designed is used and the expanded error measurement is not included.

Roy and his colleagues (Roy & Square, 1994; Roy, 1996) (hereafter referred to as Roy's model) have further developed the work of others (e.g.: Liepmann, 1900, as cited in Travniczek-Marterer, et al. 1993; Benke, 1993) and proposed a more extensive systemic view of apraxia with gesture production being measured under several conditions: Pantomime of both Transitive (tool use) and Intransitive (used to communicate a specific meaning) gestures; and the Concurrent and Delayed Imitation of gestures as well as Imitation of nonsensical (nonrepresentational) gestures. Roy's (1996) work postulated that apraxia can be caused by a break down at any one of several places within a three component system: 1) The sensory/perceptual system analyses sensory input information, 2) the conceptual system, comprised of an internal knowledge base, and 3) the production system which generates and controls gestures (see Figure 1). This is similar to Rothi, Ochipa and Heilman's (1997) model which contains similar components although not as clearly labelled as belonging to these three major systems.

Figure 1: Roy's 1996 model of Apraxia



Note: P = Pantomime; CI = Concurrent Imitation; and DI = Delayed Imitation. The numbers within the circles refer to Roy's Patterns of Apraxic Performance (see Table 1). From "Hand Preference, manual symmetries and limb apraxia," by E.A. Roy, 1996, In D. Elliott and E. Roy (eds) Manual Asymmetries in Motor Performance. Boca Raton, Florida, CRC Press., pp 215-236. Copyright 1996 by E. A. Roy. Reprinted with permission.

In both Roy's (1996) and Heilman's (1997) model disruption of the sensory/perceptual system may affect the analyses of visual gestural information or the visual characteristics of a tool relevant to its function. Further, impairment of this system should predominantly have left intact the ability to Pantomime gestures while disrupting the ability to Imitate. If the communication between the sensory/perceptual system and the production system is disrupted, then the opposite pattern would be present (Imitation intact and Pantomime impaired). In the case of AD, Heilman (1997) would argue that the latter pattern of performance is impossible to clearly delineate due to the breakdown in the conceptual system, which overrides and can mask other disruptions and cause the same pattern with impairment only in pantomime.

Roy (1996) breaks down the Conceptual system into two areas which reflected the 'how' and the 'what' of tool and object use. Impairment in the 'what' part of the Conceptual system may have led a person to select the wrong tool but still have used it appropriately. Impairment of the 'how' may have led a person to be unable to detect their own errors in performance and/or to have incorrectly identified the movement(s) involved in a gesture. Hence, under Roy's model, Pantomime could be impaired while Imitation of gestures could be intact. Such impairments support Benke's (1993) contention of the presence of two forms of dissociable apraxia. Heilman's (1992) model and Roy's (1996) are again similar as they allow for a separation between the what and how of tool/gesture/object analysis. This is accomplished via measuring error on gesture and tool recognition and naming tasks separately from measuring the ability to produce gestures and use tools. In fact, whether changes in gesture based praxis were related to changes in the conceptual aspects of praxis became one theme of Study #1. One important factor in both these models is the use of Non-representational gestures or 'nonsensical' gestures. These gestures cannot rely on the conceptual system as there is no knowledge upon which the person can draw to elicit the correct imitation. When presented with one of these gestures only the Sensory/perceptual and Production systems are involved for analysis and gesture production. This allows for a method of determining some dissociation between the three systems and is another aspect investigated in Study #1.

Roy (1996) indicates eight possible patterns of apraxic performance (see Table 1). Disruption to the Sensory/perceptual system gives rise to impairment in the analysis of tool/object and visual gestural information. The most common manifestation of such impairment should be poor gesture and tool object recognition and poor Imitation (copying a gesture demonstrated by an examiner) of gestures in the presence of intact ability to Pantomime (generate from memory, in response to a verbal command, gestures). Disruptions to the Conceptual system are hypothesized to impair Pantomime performance and is often termed ideational apraxia. This latter term and the impaired performance in Pantomiming suggest the concomitant presence of poor performance on cognitive tasks designed to measure the integrity of the knowledge structures and also lead to poor gesture and tool/object identification.

Roy (1996) also postulated that apraxia may be a result of disruptions in the Production system. This system relies on the following components: response selection; working memory, image generation, and/or the spatial and temporal organization of movement. Depending upon where in the Production system disruption occurs, several different patterns of impairment in the conditions of Pantomime and Imitation are possible. Disruptions to the Production system are suggested by Roy as being the most numerous according to his model. Early in the production of gestures disruptions are most likely reflecting difficulties in the selection of a correct response and/or difficulties in generating a correct image during Pantomime. Such difficulties should lead to intact Imitation performance but impaired Pantomime performance. The difference in this case is that knowledge of gestures and tool/object function will remain intact which indicates that the Conceptual system has not been disrupted. Disruptions to the working memory stage of the Production system may result in a difficulty encoding visually based gestural information. This in turn should leave performance on Pantomime and Concurrent Imitation tasks intact, but cause difficulty in Delayed Imitation (examiner demonstrates the gesture and asks the participant to wait a specified number of seconds before trying the gesture). Another possibility is a breakdown in working memory where not only is gestural information, presented in Imitation, difficult to hold onto but the images generated in response to the Pantomime are also poorly held in working memory. Such a breakdown in working memory would indicate impaired performance in both Delayed Imitation and in Pantomime.

Disruptions to the later stages of the Production system, according to Roy (1996), should result in the maintenance of analysing visual gestural information, but an inability to use this information to organize and control movement as evidenced by intact gesture recognition skills but impaired Imitation skills. Therefore, this pattern of performance suggests a disruption in communication between the Production and Sensory/perceptual systems. At the very last phase of the Production system a disruption could indicate that while the knowledge of what a gesture should look like is intact, the information of how to produce the gesture even when directly presented (Imitation), is no longer accessible. This pattern would appear to be conceptually similar to ideomotor apraxia and is considered a pure production deficit where the ability to organize and control movement is impaired.

Table 1: Summary of major patterns of Apraxic Performance derived from Roy's Model (1996)

Pattern Number	Apraxia Performance Pattern	Gesture-Tool/ Object Recognition	System Affected	Nature of Disruption
1	P+ DI- CI-	Impaired	Sensory/ perceptual	Impaired ability to analyse visual gestural and tool/ object information
2	P- DI+ CI+	Impaired	Conceptual	Impaired knowledge of action and tool/ object function
3	P- DI+ CI+	Intact	Production	Impaired response selection and/or image generation
4	P+ DI- CI+	Intact	Production	Impaired encoding of visual gestural information into working memory
5	P- DI- CI+	Intact	Production	Impaired working memory
6	P+ DI- CI-	Intact	Production	Impaired ability to use visual information in the control of movement
7	P- DI- CI-	Intact	Production	Impaired response organization and control
8	P- DI- CI-	Impaired	Conceptual & Production	Impaired knowledge of action and tool/object function and impaired response organisation and control

Note: P indicates Pantomime, CI indicates Concurrent Imitation and DI indicated Delayed Imitation ;'-' indicates impaired; '+' indicates intact. From "Hand Preference, manual symmetries and limb apraxia," by E.A. Roy, 1996, In D. Elliott and E. Roy (eds) Manual Asymmetries in Motor Performance. Boca Raton, Florida, CRC Press., pp 215-236. Copyright 1996 by E. A. Roy. Reprinted with permission.

The last type of disruption suggested by Roy's model (1996) indicates impairment in both the Conceptual and Production systems. Impairments to these two systems would also disrupt performance in gesture, tool/object recognition, and leave a person impaired in all conditions (Delayed and Concurrent Imitation, Pantomime and gesture tool/object recognition). This indicates the most severe form of apraxia where the knowledge of just what the gesture should look like is not available even in the face of the information being directly presented (Imitation), and cannot be accessed via working memory in the case of Pantomime.

While apraxia is most commonly measured by gesture based assessments, supported by the models above, Schwartz & Buxbaum (1997) argue that the presence of a deficit, as measured by one of the apraxia tests, does not necessarily translate into difficulties for someone in his or her daily activities. In fact, they credit Liepmann (as cited in Schwartz & Buxbaum, p. 273) for emphasizing that during only the most complex tasks will apraxia become evident. Many persons who may score poorly on an apraxia test were able to successfully complete many fairly complicated tasks on a daily basis (e.g., eating). Schwartz and Buxbaum suggest that only when carefully observing a natural sequence of tasks, using various objects, can praxis difficulties be discovered. For these reasons, they are proponents of measuring praxis using 'Naturalistic Action' as opposed to other methods. Such other methods rely on analysis of error in gesture production, and Schwartz & Buxbaum suggest appear especially sensitive to picking up praxis errors in patients with lesions of the "dominant hemisphere" (pg. 276). Proponents of Naturalistic Action suggest that apraxia may not be evident when a person is tested using real objects within a real context due to the presence of cues not accounted for by the isolated gesture test methods used by others. Schwartz and Buxbaum suggest that one way to test whether the feel and touch of an actual object can aid in eliminating an observed apraxia is to present tests designed to systematically add more cues or information to complete the intended task. This was investigated in Study #5.

Apraxia has therefore been measured in different ways. While the use of Imitation and Pantomime are common in the literature, the various conditions (e.g., Pantomime) and the various gesture types (e.g.: Transitive vs Intransitive) vary considerably, but some important variations have not been tested. Such a lack of consistency may result from the fact that most of the apraxia tests used in the literature are not designed from a solid theoretical foundation (Roy, 1996; Heilman, 1997). In fact several authors do not clearly define the tests used, only offering a comment such as patients "exhibited clinical evidence of an inability to carry out purposeful or skilled acts ... which may result in imperfectly executed movements" (Yesavage, Brooks, Taylor, Tinklenberg, 1993, pg 744). No further description of the task or tasks presented to their participants was offered. Another example of this lack of information is found in Reid et al..'s 1996 study where the test of apraxia is defined in the methods section as "patient asked to perform actions" (pg. 1058). Comparing these results to others which are based upon a well developed model and test battery (eg: Roy or Heilman) is futile. Hence, a full extensive praxis battery was indicated for this research and the WatAB (Roy et al., 1998) was chosen as being the most complete battery currently available as Roy's model predicts differences between gestures and between different conditions.

Apraxia in Alzheimer's Disease

Apraxia in AD has not been well documented or well researched from Alzheimer to present. In fact Alzheimer discussed the role of motoric changes when he reported in 1907 that while he had not observed any initial motor disturbance in his patient he later observed that after four and a half years she was completely bed ridden in a foetal position and as such, devoid of movement (as reviewed in Frassen, Kugler, Torossian, & Reisberg, 1993). By 1911 Alzheimer's observations led him to suggest that apraxia was a component of AD (as cited in Benke, 1993). But few studies have looked at the development of apraxia during the progression of AD, although some interesting findings have been reported. One such study suggested that the presence of apraxia at earlier stages was found to be related to earlier death (Burns, Jacoby, Levy, 1991) and another reported that the presence of apraxia was related to faster decline in the patients (Yesavage, Brooks, Taylor, and Tinklenberg,1993). Benke (1993), in contrast to others (Rapcsak, Croswell & Rubens, 1989; and Della Sala, Lucchelli & Spinnler, 1987), presented evidence of the presence of apraxia in the early stages of AD. Ultimately information such as that collected by this series of studies could be used to determine motoric and cognitive changes during the progression of AD.

Whether apraxia in AD stems solely from a change in cognitive status or is due to a combination of cognitive and motoric process has received much attention. Heilman and colleagues (1997), while arguing for the recognition of two forms of apraxia - ideational and ideomotor, viewed apraxia in AD as primarily a conceptual disorder (Ochipa, Rothi & Heilman, 1992), which suggests that in AD, participants should display more errors in Pantomime than in Imitation conditions. Vitaliano, Russo, Breen, Vitiello and Prinz (1986) suggested that the functional decline noted during the progress of AD was attributed to cognitive impairment. However, Vitaliano et al., used tasks of daily living (or Activities of Daily Living: ADL), which indeed may be disrupted by apraxia, as the actual measures of apraxia. It is clear that their measures of praxis are quite different from more stringent criteria where the actual ability to Imitate and Pantomime gestures are measured in different conditions. As Roy (1996) indicates, the presence of apraxia disrupts the person's ability to complete many tasks of daily living as the person can no longer use necessary tools and objects.

Apraxia and other difficulties in motor performance are often suggested to be evident in AD due to the presence of aphasia or other problems with processing language as the cognitive decline progresses. LaBarge, Smith, Dick and Storandt (1992) attempted to separate motor performance changes, as measured by the graphic errors made in the writing of a simple sentence, from cognitive decline as measured by the presence of aphasia. However, agraphia is not a stringent test of apraxia as agraphia may be due to disruption in other processes e.g., language. This proves to be a somewhat unusual approach as the presence of aphasia is not necessarily indicative of changes in cognitive skills and agraphia is not necessarily an indication of apraxia. LaBarge and colleagues suggested in their sample of over 300 participants that while errors in spelling, punctuation, and maintaining a line were present in the writing of both AD participants and healthy elderly matched controls, the errors increased with the severity of the dementia, but did not correlate with measures of aphasia or other psychometric measures of language skills. LaBarge et al., concluded that the link between agraphia and aphasia in AD is not strong. In contrast Traviczek-Marterer et al., (1993) found significant correlations between ideomotor apraxia and aphasia when they measured apraxia with five pantomimed gestures and five imitated gestures. However, they included both transitive and intransitive tasks in the pantomimed tasks and only intransitive in the imitated tasks. Therefore their measures of apraxia, while more stringent than LaBarge et al., still were not as exacting as both Roy (1996) and Ochipa, Rothi and Heilman (1997) indicate as being important. Traviczek-Marterer et al., did find significant correlations between apraxia and aphasia as have others (for example: Foundas, Henchey, Gilmore, Fennell, Heilman, 1995). However, differing methods of measurement of both apraxia and aphasia may be contributing to the different findings.

Those who have studied some form of apraxia in AD have joined the debate of whether cognitive changes solely account for changes in praxis performance. Recently using only meaningless gestures Dobigny-Roman, Dieudonne, Tortrat, Verny, Forette (1998) designed a quick test for the early diagnosis of AD claiming a high correlation with the severity of cognitive impairment. However, they used limited methods for assessing cognitive impairment and only 10 gestures were included in their apraxia test. Others have reported the presence of constructional apraxia in AD as measured by a clock drawing task (Mendez, Ala, & Underwood, 1992). They further suggested the errors made in the task could be due to problems of attention, numerical knowledge, motor execution (their measure of apraxia and again suspect at best), language comprehension, and visuo-perceptual analysis. It was the latter which appeared the most commonly in their AD group. It should be noted that this proposed scoring system was based on data collected from other AD participants and was not based upon normative samples. Another issue of this research was that the scoring system was quite simple and focussed on the presence or absence of details in the drawing and did not allow for other important factors such as the quality of movement. Mendez et al.'s conclusions were in contrast to the findings where deficits in the AD participants' clock drawing were not due to constructional apraxia but reflective of a more general disturbance in the concept of time

(Tukko, Hadjistavropoulos, Miller, & Beattie, 1992). Both of these studies conclude that the clock drawing task is a useful adjunct to the diagnosis of AD, but only as an additional measure to a full cognitive battery to measure cognitive decline. But the clock drawing test is as much, if not more, dependent upon other cognitive constructs than it is on praxis.

Others have specifically studied the presence of apraxia as a factor in AD and have fuelled and compounded the cognitive vs motor debate by arguing for the existence of different types of apraxia. As mentioned earlier two broad classifications of apraxia (IA and IM) are generally used. Benke (1993) reviewed this body of research and suggested that most have been guilty of measuring only conceptual praxis (object/tool use and understanding symbolic gestures such as those used in pantomime). Others he suggested, have not analysed the relationship between meaningless and meaningful gestures. Benke postulated that if one measured the difference between meaningful and meaningless gestures under different conditions (Pantomime and Imitation), one could determine if more than one type of apraxia was present in AD. Although Benke does not suggest how to Pantomime meaningless gestures, it could be managed by first training the participants so that the meaningless gestures would be associated and initiated by a specific word, sound or hand signal. He concluded after analysing the errors made during gesturing, when two different systems of praxis are tested, (one relying on stored knowledge of object use and action, and the other concerned with the analysis of novel movements Imitation only), AD participants demonstrate two forms of apraxia. Meaningless gestures could therefore begin to offer some information on which processes are called into play during Imitation and Pantomime. For instance, by comparing the results of the representative and non-representative gestures, information might be gained as to whether one is relying on stored knowledge (i.e., how familiar is a gesture) or relying, at least at first, on visual-perceptual analysis when attempting to reproduce gestures in response to command or imitation. Unlike Rapcsak et al., (1989), Benke concluded that the two types of apraxia are dissociable and as such are evidence for the existence of both a conceptual (providing the semantic/symbolic representation of an action) and a structural system (which incorporates sensorimotor and spatial temporal components). He suggested that these two forms were based upon a dichotomy of motor knowledge and are "polymodal" (p. 723) in origin, as they feature impairment in such systems as: control of spatio-temporal movement, recall of movement images, loss of information required for bodily orientation, knowledge of both the object and the action, and problem solving. Each of these may be involved to a greater or lesser degree in either Imitation or Pantomime. Benke suggested further research to begin to understand which of the systems he listed and to what degree they are involved in the errors found when apraxia is measured by Imitation and Pantomime under various conditions.

As reviewed above, apraxia, at least in AD, is often viewed through the apriori hypothesis that any change in praxis will be only a result of changing cognition. Even Ochipa et al., (1992) considered apraxia in AD to be highly influenced by a conceptual disorder thereby suggesting that for the most part AD participants would perform with more errors in Pantomime than Imitation. While changes in cognitive systems may affect praxis performance, it may be possible that disruptions to other functions or to other systems involved may lead to apraxia.

Hence the need for a comprehensive battery to assess apraxia under any circumstance and especially in AD is evident. Recall from above that AD can affect many areas of praxis performance (e.g.: visuo-perceptual, language, memory). We need an extensive Apraxia battery to measure as many conditions and gesture types as possible to better determine when and where AD is affected by Apraxia. As indicated above, the WatAB was chosen for our research as it provides the most comprehensive battery available designed from a sound theoretical model. This is a reasonable choice as it is one battery based upon a multidimensional model. Additionally, we need to include the measurement of visuo-spatial skills as indicated by Binetti et al., (1998). The use of the WatAB and the Visual Object and Space Perception Battery (VOSP- Warrington & James, 1991) would be the most efficacious choices when exploring the effects of visuo-perceptual skills on praxis performance in AD.

STUDY #1

TO EXAMINE HOW AD AFFECTS GESTURE TYPE AND PERFORMANCE CONDITIONS IN APRAXIA

Introduction

a) Does the Performance Condition (Imitation vs Pantomime) affect performance in AD?

The Waterloo Apraxia Battery (WatAB) contains various performance conditions: Pantomime, Concurrent Imitation, and Delayed Imitation. This allows for a broader perspective on apraxia than that reported in the literature (for example see: Rapcsak et al., 1989; Lucchelli et al.,1993; Ochipa, Rothi & Heilman, 1992; Vitaliano, Russo, Breen, Vitiello & Prinz 1986; Della Salla, Spinnler, & Trivelli, 1996; Edwards, Deuel, Baum & Morris, 1991; and Rothi & Heilman, 1985). The three performance conditions (Pantomime, Concurrent Imitation, and Delayed Imitation) are important for the assessment of apraxia in AD as each can highlight disruptions to praxis in the three systems involved in complex motor movements: 1) Sensory/perceptual, 2) Conceptual, and 3) Production. According to Roy's model (1996), Concurrent Imitation reflects the ability to analyse the sensory/perceptual aspects of praxis. In this case participants are asked to, exactly and immediately, copy the gesture demonstrated for them. Should impairment be found on the Concurrent Imitation gestures, then one could surmise a disruption in the visual analysis process, or a disruption translating visual information into movement. In the case of Delayed Imitation the presentation is the same but the timing is different. Participants are expected to wait a short period of time (e.g., 10 seconds) before offering their imitation of the presented gesture. Therefore, the analysis of sensory/perceptual information is not enough as the gesture must be held in working memory (information is held and available for use without reliance on external cues) and then produced. For Pantomime, the participant is asked to demonstrate a gesture based upon the verbal instructions. Recall that Roy's model involves the integration of three systems: Sensory/perceptual, Conceptual, and Production. In the case of Pantomime, Roy's model predicts that performance depends upon the integration of all three systems - which begins with the understanding of the verbal instructions (Sensory/ perceptual system), to having the appropriate knowledge about the gesture (Conceptual system), to being able to produce the correct image or select the correct response of the gesture, and then being able to organize the correct motor sequences (Production system).

Given the above descriptions and the disruption in AD to language and memory systems (Appell, Kertesz, & Fisman, 1982; Reisberg, Mulloy, & Caldwell, 1998), it is apparent that for AD, the most accurate performance would be expected in Concurrent Imitation, followed by Pantomime and then Delayed Imitation. A review of the literature supports this prediction (for example see: Rapcsak et al., 1989; Lucchelli et al., 1993; Ochipa et al., 1992; Vitaliano et al., 1986; Della Salla et al., 1996; Edwards et al., 1991; and Rothi & Heilman, 1985). With the exception of one study, Concurrent Imitation is reported as providing the least difficulty for those with AD when compared to Pantomime performance. However, Travniczek-Marterer et al., (1993) indicated an unexpected finding of more error in Imitation than in Pantomime in their study using five Intransitive gestures with 23 AD participants. Travniczek-Marterer et al., concluded that their finding of poorer performance in Imitation was most likely due to the relatively short and incomplete (only Intransitive gestures) Imitation test they presented. This problem of incomplete praxis testing is countered in our work by using a large complete praxis battery is - the Waterloo Apraxia Battery.

What we cannot easily predict is where Delayed Imitation will fit in this hierarchical list of accurate performance. Roy's (1996) model would predict that if there is an impairment in working memory, that less accurate performance will be present because of the delay, than when gesturing is performed immediately after the demonstration. Delayed Imitation is not routinely reported in the literature. Consequently, there are no data from other sources from which to make a reliable prediction about whether performance in Delayed Imitation will be worse than in Pantomime. Furthermore, Roy's model predicts that the order could be, from best to worst performance: Concurrent Imitation, Delayed Imitation, and then Pantomime. This is because Roy's model shows us that Delayed Imitation does not involve the Conceptual system as does Pantomime, and Delayed Imitation does not rely only on visual gestural analysis as does Concurrent Imitation. However, it is also possible that any disruption to working memory as found in AD (Mulloy & Caldwell, 1998), could result in similar Pantomime and Delayed Imitation performance.

From the literature there is one clear prediction: that the Moderate AD group will be less accurate than the Mild AD and the Normal Controls (for example see: Rapcsak et al., 1989; Lucchelli et al., 1993; Ochipa et al., 1992; Vitaliano et al., 1986; Della Salla et al., 1996;

Edwards et al., 1991; and Rothi & Heilman, 1985). We will begin our examination of the characteristics of apraxia in AD by examining the various performance conditions (Imitation and Pantomime) and gesture types (Representational, both Transitive and Intransitive; and Nonrepresentational, i.e., novel gestures) included in the WatAB.

In this research it is predicted:

- that performance accuracy will decrease in AD as the task's reliance on memory and language comprehension increases. Accuracy of performance will be greatest in Concurrent Imitation and then decrease for Delayed Imitation and decrease again for Pantomime. The common pattern found in the literature is of Concurrent Imitation performance being more accurate than Pantomime.
- that the Moderate AD group will exhibit the least accurate performance on all conditions compared to Mild AD and Normal Controls, since AD is known to progress with most cognitive functions worsening over time.

b) Does the Transitive or Intransitive nature of a gesture affect performance in AD?

The WatAB allows for a comparison of how different gesture types may be affected by AD. Two of these types are Transitive and Intransitive gestures. Transitive gestures are those that rely on the use of a tool. For example, one could be asked to Pantomime or Imitate the gesture of using a hammer. Intransitive gestures are those that are used to communicate a specific meaning and are therefore akin to language. An example of an Intransitive gesture would be a wave good-bye. While both are reported in the AD literature, they are not as apt to be compared and usually the results are combined to give a diagnosis of apraxia (for example see: Travniczek-Marterer et al., 1993). Additionally, different specific gestures (e.g., waving goodbye vs. a salute) are used under the headings of Transitive and Intransitive (for example see: Rapcsak, Croswell & Rubens, 1989) and/or the gestures are not well delineated (for example see: Reid et al., 1996; or Yesavage, Brooks, Taylor & Tinklenberg, 1993). Due to these differences the literature is quite complex and comparisons between studies are not easy.

In AD, language is known to be disrupted quite early (Appell, Kertesz, & Fishman, 1982). This disruption includes both receptive (understanding what is said by another) and expressive (being able to produce correct and meaningful speech) language. Therefore, for Transitive gestures, which rely on the use of a tool, it may be that the presence of the tool is enough to elicit a correct response. Thus transitive gestures are predicted to exhibit more accurate performance in AD than will Intransitive gestures, which by their nature, rely more on intact language function.

In this research it is predicted:

- that for the AD group, the gesture type (Transitive and Intransitive) will influence performance in AD. Specifically, Intransitive gestures will result in less accurate performance than will Transitive ones, since the presence of a tool may be enough to elicit a correct response.
- that the Moderate AD group will exhibit the least accurate performance on both Transitive and Intransitive gestures compared to both Mild AD and Normal Controls,

since AD is known to progress with all functions worsening over time.

c) What is the relative frequency of apraxia in Transitive & Intransitive gestures across the three performance conditions ?

The frequency of apraxia is not well established in the AD literature and in fact is seldom reported. This may primarily be due to difference in the measurement of apraxia and the actual definitions of apraxia used. Apraxia is often defined by the inability to complete a few Imitation and perhaps some Pantomime gestures. The scoring, which ultimately leads to the calculation of the frequency of apraxia, is based upon the presence or absence of success (for example see Reid et al., 1996, or Yesavage et al., 1993). Others have relied on an accurate gesture being produced on the first, second or third attempt (Barbieri & De Renzi, 1998 for example) or on more detailed subjective means, which detail the nature of the gesture as in Heilman's Florida Apraxia Battery, (1997). McDonald, Tate and Rigby (1994) argue for the necessity of including all types of error information when determining the presence of apraxia. Only two researchers offer a comprehensive model, test battery and scoring system, although they also differ. The FAB (Rothi et al., 1996) criteria for scoring, as listed in Appendix A 5, allow for a descriptive label of the type of error as opposed to the degree of error as measured by the WatAB (Roy & Square, 1994) (See Appendix A 4). These are outwardly very different types of error measurement systems, and are not easily compared. In fact, the FAB (Rothi et al., 1997) system appears to depend heavily on well measured 'normal' performance (e.g.: timing - how and when was the normal speed measured?). This is of some concern as the source of the normative measurements are unknown. The WatAB (Roy,1996) uses clear detailed criteria for each movement and each error dimension (for example, see Appendix A 4).

From the calculation of the presence of error, Heilman's (1997) group and Roy (1996) use cut-off scores for the diagnosis of apraxia. These cut-off scores are derived from the mean and standard deviations of the Normal Control groups used in their research. The individual scores for the experimental group are compared to the mean and standard deviation of the controls and a z-score is calculated. Apraxia is considered present if the individual z-score is more than two standard deviations below the mean of the control group. On the WatAB these z-scores can be used to determine the frequency of apraxia in a particular group or for a particular gesture type, and can be calculated for each of: Concurrent Imitation, Delayed Imitation, and Pantomime, and/or the type of gesture (Transitive vs. Intransitive).

Since the frequency of apraxia in AD is not reliably measured or reported in the literature, it could be difficult to offer a prediction in the present study. Recall in our discussion of performance accuracy, we predicted that Intransitive gestures would result in less accurate performance than Transitive. With respect to apraxia, the same pattern should hold. That is, we might predict that the frequency of apraxia would be higher in Intransitive than Transitive.

In the results section the relative frequency of apraxia will be analysed separately for Transitive and Intransitive gestures but the implications for the predictions are discussed jointly.

In this research it is predicted:

- that as was found for the accuracy of performance analysis, there will be higher frequencies of apraxia for AD under the Intransitive gesture type than the Transitive gesture type, since Intransitive gestures are used to communicate a specific meaning (are related to intact language skills).

d) Are there context effects for Pantomime gestures in AD?

The WatAB allows the exploration of another interesting aspect of the characteristics of apraxia. It is possible that context, (defined herein as the degree to which the setting is natural - e.g., realistic context), in Transitive gestures (tool use) can affect Apraxia in AD. This is a logical assumption as it is known that cues (additional information, whether verbal or environmental) can enhance performance for persons with AD except in the cases of new learning and some aspects of language testing, which are not aided by the presence of additional cues (Herlitz & Littanen, 1991). Therefore, when participants are asked to perform familiar gestures, the presence of additional contextual cues might be effective in enhancing performance. Naturalistic Action (Schwartz & Buxbaum, 1997) also supports this hypothesis that a more natural or realistic setting and / or cues can affect AD performance on activities of daily living - where tools or objects are used. Proponents of Naturalistic Action suggest that apraxia may not be evident when a person is tested using real objects within a real context, due to the presence of cues not present during the isolated (e.g., no realistic/natural context) gesture test methods used by others. Schwartz and Buxbaum (1997) suggest that one way to test whether the feel and touch of an actual object can aid in eliminating an observed apraxia (diagnosed by a gesture-only test) is to present tests designed to systematically add more contextual cues.

The WatAB (Roy, 1996) contains four Pantomime tests that can be used to test the hypothesis that extra contextual cues can affect AD performance. The first test asks the participant only to think about which tool would be used to complete a stated action (Pantomime by Function). The second test asks the participant to imagine holding a named tool and to demonstrate using it (Pantomime by Tool). The third test shows the participant a picture of the tool and asks for a demonstration of how to use it (Object Use Picture). The fourth test shows the participant the actual tool and asks for a demonstration of how to use it (Object Use Show). Given the language and memory difficulties found in AD (Mulloy & Caldwell, 1998) one can see how difficult the first three tests could be for someone with AD.

In this research it is predicted:

- that AD performance will improve with the additional contextual cues found under the four Pantomime tests listed here in increasing order of contextual cues: Pantomime by Function, Pantomime by Tool, Object Use Picture, and Object Use Show, since Pantomime by Function uses no contextual information and the amount of contextual information increases until Object Use Show contains the greatest amount of contextual information.

- that the Moderate AD group will exhibit the least accurate performance on all four Pantomime tests compared to the Mild AD and Normal Controls, since AD is known to progress with all functions worsening over time.

METHOD

Participants

The AD group included 37 right handed participants (15 female and 22 male) and two left handed participants (one female and one male), with mild to severe probable AD as measured by the NINCDS/ADRDA diagnostic battery recruited from the AD study at the Behavioural Neurology Clinic at the Sunnybrook Health Science Centre (Sunnybrook). In keeping with the protocol of the larger study on AD at Sunnybrook, all participants had sufficient comprehension to co-operate in the testing procedures, did not show any magnetic resonance imaging (MRI) evidence of significant vascular disease, and did not have Hachinski ischaemia scale scores greater than four, thereby reducing the possibility of concomitant vascular causes of dementia. Reversible causes of dementia were screened for using the appropriate tests including: routine biochemistry and haematology, B12, folate, thyroid function, and Venereal Disease Research Laboratory (VDRL: a screening test for syphilis). Participants who demonstrated extrapyramidal symptoms, present in some participants with AD, or Lewy Body disease or participants requiring major tranquillizers were excluded since all of these could have confounded motoric performance. Participants who were clinically depressed with a Hamilton Depression Scale score greater than 11 were also excluded. Also excluded were any persons with the diagnosis of AD who were under the age of 65 as there is no clear indication if the early onset form of AD, commonly referred to familial AD, follows the same path as later onset AD (Wallin & Blennow, 1996). Exclusion criteria reduced the experimental group to 29 AD participants consisting of 17 Mild AD (MMSE scores from 20 to 25) and 12 Moderate AD (MMSE scores from 10 to 19) participants. The gender distribution of the AD group was 16 females and 13 males.

Healthy control participants, 28 right-handed persons (17 females and 11 males) and one left-handed female, were selected from a control subject pool at Sunnybrook to match as closely as possible the age and educational level and gender distribution of the AD participants.

Because of the relatively small number of left-handed participants in this study, all pertinent data were coded for the dominant hand.

Materials

All participants previously received the full battery of diagnostic medical, neurological and neuropsychological tests used as part of the Sunnybrook AD diagnostic process. However, only those tests that had been presented to all participants were included in this study (see Appendix A 6). The diagnosis of AD was determined by a neurologist using the NINCDS/ADRDA criteria and single positron emission tomography (SPECT). All other testing and scoring was completed by specifically trained research assistants.

Participants were required to Pantomime and Imitate, with their dominant hand, the full Waterloo Apraxia Battery (WatAB) (see Appendices B1 & B2), including all Transitive (e.g., use a hammer), Intransitive (e.g., show me how you salute) and Nonrepresentational gestures (e.g., please do this - hand on top of head with wrist rotating in counter clockwise direction). Each of the Transitive Imitation (Concurrent and Delayed) condition tests consisted of the same eight gestures. The Pantomime condition tests also used the same Transitive gestures. Each of the Intransitive Imitation condition (Delayed and Concurrent) and the Intransitive Pantomime condition used the same eight gestures.

Design and Procedure (See Appendix B1 & B2)

Participants were seated in a comfortable straight-backed chair with the examiner seated directly in front of them, and were videotaped during their one session in which the entire gesture battery was presented in a well illuminated, comfortable room. Mirrors were placed behind and to the sides of participants so that all aspects of their gestures would be seen in the videotape. In the Pantomime condition, the object or a picture of the object or the function of the object was presented to the participants and they were asked to Pantomime its use. In the Concurrent Imitation condition, the examiner demonstrated the gesture and the participant was asked to Imitate it while the examiner continued to demonstrate throughout the participant's attempt. For the Delayed Imitation condition the examiner demonstrated the gesture and then the participant waited 10 seconds before beginning his/her Imitation on a verbal cue from the examiner.

Scoring

The Imitation and Pantomime condition performance videotapes were scored for each participant on five dimensions: location of the hand in space relative to the body, posture of the hand, action (the movement characteristics of the gesture), plane of movement of the hand and orientation of the hand (see Appendix B 3). These performance dimensions were derived from the previous work of Roy and Square (1985), and were based upon the particular features of movement found by Stokoe (1972) to be important in manual signing. Each dimension was rated on a three point scale reflecting the degree of accuracy: two = correct, one = distorted, and zero = incorrect; (for an example see Appendix A 4). A high inter-rater reliability (kappa coefficient to be at least 0.93, Hartmann, 1977) was found on a randomly chosen subset of scores for 15 participants. A composite score was then derived for each gesture under each performance condition. This score reflected performance scores across the five dimensions and was expressed as a percentage of the total possible score (10) for each gesture.

Categories of apraxia were determined by reference to the healthy control participants' performance. For each AD participant six z-scores were calculated (Concurrent Imitation, Delayed Imitation and Pantomime for each of Transitive & Intransitive gesture types) from the total composite scores (expressed as a percentage of the total possible score from all the gestures) using the mean scores from the control group. The AD participants were considered to be non-apraxic if their z- scores fell within one standard deviation of the mean of the controls, borderline apraxic was defined as between one and two standard deviations, and apraxic was defined as greater than two standard deviations of the mean of the control group.

RESULTS

Demographics

To determine if there were any statistical differences between the groups an ANOVA was conducted on the demographic variables collected. The results indicated no significant differences between the groups for age (F (1,56) = 3.42 , p = .07), education (F (1,56) = .823, p = .368).

In the following results when the Levine's test for homogeneity of variance was found to be significant at .05, the adjusted degrees of freedom and other values (eg. t or p) are reported. Because of the rather large number of comparisons needed and to protect the experiment-wise error, the alpha value was set at 0.01, except where the number of comparisons indicates the use of Bonferroni's correction in which case it is reported.

a) Does the Performance Condition (Imitation vs Pantomime) affect performance in AD?

In order to examine if there were differences among performance conditions among the groups of Normal Controls, Mild AD and Moderate AD a three (Mild AD, Moderate AD and Normal Control) group by two (Transitive and Intransitive) gestures by three (Pantomime, Concurrent Imitation and Delayed Imitation) conditions ANOVA was completed on the scores of each of the tests. A group effect was found, F (2,320) = 45.88, p = <.001 (see Table 2). Post- hoc tests revealed that the Normal Control participants' performance was significantly more accurate than both the Mild AD, t (41.98) = 5.01, p = <.001, and the Moderate AD, t

(6.73) = 6.73, p=<.001, participants. The Mild AD participants' was significantly more accurate than the Moderate AD participants t (40.14) = 2.96, p = <.001.

In summary:

- Contrary to our prediction, no condition effect nor a group by condition interaction was found thus, there were no overall differences in the accuracy of the performance among the three conditions (Concurrent Imitation, Delayed Imitation and Pantomime). There was also no difference among these conditions in any of the groups.
- Consistent with our prediction, the Moderate AD group did exhibit the least accurate performance when compared to the Normal Controls and the Mild AD groups.

b) Does the Transitive or Intransitive nature of a gesture affect performance in AD?

Predictions concerning the Transitive and Intransitive gestures were assessed using the group by gesture type interaction of the previously described group by gesture type by condition ANOVA. An interaction effect was found for gesture (Transitive and Intransitive) and group, F (2,320) = 10.89, p = <.001. Post-hoc tests revealed that for both the Normal Control and the Mild AD participants there was no significant difference between the Transitive and Intransitive gestures. However, there was a significant difference between the type of gesture for the Moderate group, t (11.18) = 2.91, p = .01, with the Transitive gestures (M = 63.26) resulting in less accurate performance than the Intransitive (M = 83.00) gestures. Therefore there was no overall difference in gesture type, but there was a difference for Moderate AD.

Table 2: Mean Percentage Accuracy scores for Imitation and Pantomime Conditions on Transitive and Intransitive gestures for Normal Controls, and Mild & Moderate AD groups.

	Normal Controls	Mild AD	Moderate AD
Transitive	96.38	88.09	63.26
Intransitive	97.16	82.91	83.00

In summary:

- Contrary to our prediction, the Transitive gestures were less accurate but only for the Moderate AD group. For our moderate AD group, the use of tools was more difficult than was communicating a meaning. Also, contrary to our prediction, the Mild AD group did not exhibit less accuracy on Intransitive gestures than Transitive gestures.
- Consistent with our prediction, the Moderate AD group exhibited the least accurate performance on Transitive and Intransitive gestures as compared to Mild AD and Normal Controls.

c) What is the Relative Frequency of Apraxia in Transitive and Intransitive gestures across the three performance conditions?

The results as outlined in Table 3 indicate that for Transitive and Intransitive gestures there is no difference for Mild AD. However, for the Moderate AD the Transitive gestures exhibit a slightly higher frequency of apraxia than do the Intransitive gestures. Such a pattern is similar to that for the gesture performance accuracy data, where performance was less accurate for both the Moderate AD and the Transitive gestures.

Table 3: Percentage of Apraxia in AD for the Transitive and Intransitive Gesture Types for the Mild and Moderate AD.

	Mild	Moderate	Mean
Transitive	20	33	26.5
Intransitive	20	31	25.5

In summary,

- Consistent with our prediction, the pattern of results for frequency of apraxia is the same as it was for the accuracy of performance (e.g., Transitive gestures most problematic for the Moderate AD group).

d) Are there context effects for Pantomime gestures in AD?

To determine if there were differences within the tests classified as Pantomime, a three (Mild AD, Moderate AD and Normal Control) group by four (Pantomime by Tool, Pantomime by Function, Object Use and Object use with Picture) tests ANOVA was completed on the scores of each of the tests. The results indicate two main effects. Firstly, there was a main effect for group, F (2, 214) = 63.15, p = <.001. Post-hoc tests revealed that the Normal Control participants were significantly more accurate than from both the Mild, t (42.32) = 4.22, p = < .001 and the Moderate AD, t (32.91) = 7.11, p = <.001, participants, and the Mild participants were significantly more accurate than the Moderate AD participants, t (23.77) = 4.90, p = <.001. The results in Table 4 indicate that, according to our prediction, the most errors were made by the Moderate group (M = 67.24) as compared to the Normal Controls (M = 94.60) and the Mild AD group (M = 87.62).

Secondly, a main effect for test was found, F (3, 214) = 5.96, p = .001. Post-hoc tests for this effect indicated, that at an alpha of .01, Object Use Show was significantly more accurate than Object Use Picture, t (89.80) = 2.77, p = .007. Perhaps these results indicate the need to explore the role of context in Pantomime performance.

In summary:

- Consistent with our prediction that performance in Object Use Show was significantly more accurate from the Object Use Picture test. Contrary to our prediction there were no differences between Object Use Show and the other Pantomime tests at an alpha of 0.01.
- Consistent with our prediction, the Moderate AD group exhibited the least accurate performance compared to the Mild AD and the Normal Controls.

Table 4: Mean Pantomime Test Percentage Accuracy Scores for Normal Controls, Mild and Moderate AD.

TEST	Normal	Mild AD	Moderate AD	Test Mean
Object Use Show	97.41	94.07	77.48	92.12
Object Use Picture	93.62	83.46	57.38	82.96
Pantomime by Tool	93.66	83.46	66.93	84.99
Pantomime by Function	93.80	89.49	69.18	86.78
Total	94.60	87.62	67.24	

NOTE: Tests appear in decreasing order of contextual cues provided.

DISCUSSION

a) Does the Performance Condition (Imitation vs Pantomime) affect performance in AD?

Our findings indicate no differences between performance in the Pantomime and Imitation conditions. Overall our results were different from our prediction and reports in the literature in which performance in AD was almost always less accurate in Pantomime than in Imitation (for example see: Rapcsak et al., 1989; Lucchelli et al.,1993; Ochipa et al., 1992; Vitaliano et al., 1986). With the exception of one study, Concurrent Imitation was reported as being the least difficult for those with AD when compared to Pantomime performance. However, Travniczek-Marterer et al. (1993) indicated an unexpected finding of more error in Imitation than in Pantomime in their study using only five intransitive gestures with 23 AD participants. Travniczek-Marterer et al. (1993) concluded that their finding of poorer performance in Imitation was most likely due to the use of a relatively short and incomplete (only Transitive) Imitation test. As this cannot be the case with the WatAB tests, we are left wondering why there are no differences among the particular conditions tested? Therefore, we can hypothesize that perhaps the particular condition is less important than the specific gesture type. Whether the particular test is more important is examined below. However, as we predicted that Concurrent Imitation performance would be the most accurate in AD we must in the future explore why there is no protection for this particular condition. Our results suggest that maybe visual gestural analysis is impaired in Concurrent Imitation as well as are the memory processes associated with Pantomime. It could also be that the problem is more in the Production System, so this would result in poor performance on all tests. Roy's (1996) model indicates that the first place a disruption can occur in Concurrent Imitation performance is in the Sensory/perceptual system, where visual/gestural analysis occurs. Therefore, we suggest that exploring visuo-perceptual skills in AD might be a good place to start, and in fact is one of the areas on which we focussed in Study #5.

b) Does the Transitive or Intransitive nature of a gesture affect performance in AD?

Transitive gestures are those that rely on the use of a tool (pound a hammer).It may be that the mere reference to a tool is enough to elicit a gesture. We therefore predicted that performance would be more accurate for Transitive than for Intransitive (e.g., wave goodbye) (Roy & Square, 1994; Roy, 1996). However, in this study our prediction was not supported. In this study, using a tool (Transitive gesture) was more difficult than was using a gesture to communicate a meaning (Intransitive gesture), for the Moderate AD group. For the Normal Controls and the Mild AD groups there was no significant difference between Transitive and Intransitive gesture performance. Overall there was no difference between the gesture types except for the Moderate AD group. It is possible that our opposite pattern may have to do with movement complexity or sensory-motor integration (Halaand & Harrington, 1990).

The results of the examination of condition and gesture type effects (questions a & b above) lead us to ask, what processes in AD are affecting tool use (Transitive) more than signalling a specific message (Intransitive)? The results of this study indicate that more research is necessary to begin to understand why Transitive gestures result in less accuracy of performance, especially as AD progresses. Additionally, we were led to ask what AD processes account for similar performance between the Imitation and Pantomime tests? We predicted from the literature (for example see: Rapcsak et al., 1989; Lucchelli et al.,1993; Ochipa et al, 1992; Vitaliano et al., 1986; Della Salla et al., 1996; Edwards et al., 1991; and Rothi & Heilman, 1985) and from what is known about AD that performance on Imitation tasks would be relatively spared. According to Roy's (1996) model, no higher cognitive skills are called into Concurrent Imitation, as compared to Pantomime, which relies on the integration of the Sensory / Perceptual, Conceptual and Production systems. Further, we had anticipated that the AD performance on Pantomime would be different (less accurate) due to the impact of disruptions to memory systems. What then could be the factors influencing AD performance on these conditions (i.e., no differences in accuracy performance between Imitation and Pantomime)? In Roy's(1996) model Concurrent Imitation relies on the Sensory/perceptual system and specifically the analysis of visual gestural information which leads to our expectation that Imitation performance would be relatively spared in AD. In AD visual-gestural analysis is relatively spared (Binetti et al., 1996). Therefore, following this model, we proposed two areas of investigation. One is to explore if the frequency of apraxia is different between Transitive and Intransitive gestures as was done below. Secondly, we suggest an examination of the possible effects of visual perceptual skills in AD on imitating Transitive gestures as was done in Study #5.

c) <u>What is the Relative Frequency of Apraxia in Transitive and Intransitive gestures across the three performance conditions?</u>

We had found in a & b above that the performance condition (Concurrent Imitation vs.

Pantomime) was not as important in AD performance as was the gesture type. This finding lead to the prediction that a similar pattern would be found for the frequency of apraxia. We examined the frequency of apraxia under both the Transitive and Intransitive gestures for the Mild and Moderate AD groups. We again found that the Transitive gestures tended to be the most difficult for the Moderate AD group. These findings support our earlier hypothesis that in AD the performance condition is not as important as is the gesture type. Further, we are led to another examination as to why Transitive (Tool Use) gestures are most difficult (less accurate and higher frequency of apraxia) in AD. Again Transitive gestures became the focus of Study #5.

d) Are there context effects for Pantomime gestures in AD?

The Pantomime tests of the WatAB allow a unique exploration of the possible effect of adding context. Naturalistic Action (Schwartz & Buxbaum, 1997) suggests that the addition of more natural / realistic contextual cues can enhance performance in AD. Our results indicate as per our prediction, that when shown an object (Object Use Show) rather than seeing it in a picture (Object Use Picture), participants exhibited a difference in performance. The most accurate performance was for the Object Use Show test which perhaps indicates the importance of the tool or object part of context for Pantomime performance.

We were therefore lead to the question of what the effect would be of adding even more contextual cues. Again we can turn to Naturalistic Action (Schwartz & Buxbaum, 1997) for some clues. Naturalistic Action indicates that the more realistic the action performed, in the most realistic setting, the better the performance. The proponents of this philosophy and others (Roy, Square, Adams & Friesen, 1985) indicate that the appearance of apraxia can be eliminated when a person diagnosed by the common gesture tests is assessed with real world tools in a realistic setting. As in our findings, the effects of context were not unique to AD, therefore we need to further examine context in the hope of discovering at what point context affects AD performance. To that end we suggest the need for further research in this area, and propose to review the effects of context again when using a more realistic context in Study #5.

In summary the following are the objectives for Study #5 which came out of the findings of Study #1:

1) to examine the possible effects of visuo-perceptual skills in AD on Concurrent Imitation in Transitive gestures

2) to examine the effects of more realistic context on performance in Pantomime tests in AD

3) Transitive gestures which result in the higher frequency of apraxia for Moderate AD will be the focus of Study #5.

STUDY # 2

TO EXAMINE THE EFFECT OF AD ON THE NAMING AND RECOGNITION OF TOOLS AND GESTURES IN APRAXIA

In this second study we examined the question of whether AD affects gesture, tool and error recognition. By using the WatAB we would be able to determine which if any of the conceptual tests such as gesture recognition, tool action etc. (see Appendix B 1 & B 2 for full list and descriptions) were responsible for differences between the groups. The conceptual tests are not found in other batteries except for Heilman's FAB (Rothi, Ochipa & Heilman,1997); however these are represented to a lesser degree as only three tests are listed under the heading of Conceptual: Gesture Naming, Gesture Decision, and Gesture Recognition. As indicated earlier, the Conceptual tests from either the FAB or WatAB are designed to elucidate whether the knowledge system is intact even when the ability to produce gestures may be impaired (Roy, 1996). According to Roy's (1996) model (see Figure #1), the nine tests of the Conceptual part of the WatAB are designed to primarily determine the extent of functioning of Roy's (1996) second system - the Conceptual system.

The WatAB Conceptual tests (Roy, 1996) fall under three headings and are grouped as such to allow the examination of different aspects of the conceptual knowledge of praxis (i.e.: the knowledge of action and tool/object function). The Naming tests are designed to elicit the name of an object/tool or action in response to a picture or a verbal description. The Identification tests are designed to elicit the choice of the correct object/tool or action in response to a verbal description, picture or video picture. The last area assessed by the Conceptual tests (Recognition) involves the matching of a gesture to one from a series of gestures on videotape. The other Recognition test involves recognizing whether a gesture on videotape is correct or not. These nine tests are unique to praxis testing (for a comparison to the conceptual tests of the FAB see Appendix A 5). Each is designed to elucidate one aspect of the knowledge of tools / objects or actions and each tests the particular concept (Naming, Identification and Recognition) in a slightly different way. Either the method of presentation is varied (e.g., pictures vs. videotape) and / or the response demands (e.g., pointing or naming) are varied.

Given the above descriptions, it is possible that AD may affect performance on all of these tests. AD could lead to difficulties with: the visuo-perceptual analysis of an object, picture or video picture, memory for the correct action or object, and the analysis of the verbal instructions, recalling and speaking the correct word. Specifically, on the Naming tests the AD group could exhibit poorer performance due to language difficulties in understanding the instruction given (receptive language) and providing the correct word (word-finding difficulties). The AD group could display less accurate performance on the Identification tests due to: poor analysis of instructions (receptive language), poor visuo-perceptual analysis of the pictures or gestures, and difficulty in spatial orientation leading to inaccurate pointing (i.e.: correct identification but inability to point to the correct picture). The AD performance might be worse than that of the Controls on the Recognition tests due to difficulties in sensory/perceptual analysis which could again lead to errors in pointing, and/or in identifying gestural errors and actual gestures.

Ochipa et al., (1992) tested a group of AD participants with the FAB's Conceptual tests. They reported that all of their AD participants performed with significantly less accuracy than the Normal Control group on all of the Conceptual tests. As their Conceptual tests are fewer and not designed to test praxis knowledge in as many ways (as does the WatAB) and, as indicated earlier, the scoring systems used on the FAB and WatAB are very different, it is only with caution that we could compare our results to those of Ochipa et al. However, without any further and/or comparable testing available in the literature we cannot with any certainty predict if the three types of the WatAB Conceptual tests will lead to differences in performance between the Normal Control and the AD groups. However, given that the Moderate AD consistently perform less accurately on all tests, we can offer one prediction about the performance of this group.

In this research it is predicted:

- that the Moderate AD group will exhibit the least accurate performance on all of the Conceptual Tests (Naming, Recognition and Identification) compared to both the Mild AD and the Normal Control group, since AD is known to progress with all cognitive functions worsening over time

METHOD

Participants

The participants used in Study #1 were used in this study.

Materials

All participants received all nine (9) tests of the Conceptual section of the WatAB which included watching videotapes and identifying gestures. Additionally all participants were asked to identify tools by picture or by description. Actions were also to be identified by gesture or by corresponding tool. Gesture error was assessed by viewing an actual gesture or watching gestures on videotape (see Appendix B2).

Design and Procedure

Participants were seated in a comfortable straight-backed chair with the examiner seated directly in front of them. Relevant pictures were mounted on 8½ by 11 inch sheets of cardboard and videotape was presented on an 21 inch screen television in a comfortable and appropriately illuminated room.

Scoring

The tasks from the Conceptual Apraxia section of the WatAB were scored as correct or incorrect choices/matches or as correct yes or no responses and subsequently expressed as percentage correct of total for each test. The kappa coefficient (Hartmann, 1977) which measures the degree of agreement between the raters was found to be 0.93.

RESULTS

Demographics:

A separate ANOVA was performed for each of the nine Conceptual tests to determine if there were any group differences on any test. Because of the number of analyses the alpha level was adjusted to 0.006 via Bonferroni's correction .

Recognition Tests (See Table 5):

A group effect was found for the Gesture Recognition test, F (2, 47) = 18.70, p = <.001. Post-hoc testing revealed that the Normal Controls (M = 93.90) were only significantly different from the Moderate AD (M = 43.10) group (p =<.001). This indicates that the Moderate AD group had the least accurate performance compared to the Normal Controls and is therefore not exactly as predicted as there was no significant difference between the two AD groups.

A group effect was found for the Gesture Error Recognition test, F (2, 49) = 41.80, p = <.001. Post-hoc testing revealed that the Normal Controls (M = 80.50) were significantly different from the Mild AD (M = 48.56) group (p = <.001) and from the Moderate AD (M = 30.08) group (p =<.001). As predicted for the Gesture Error Recognition test, the Moderate AD group had the least accurate performance compared to the Normal Controls. Not as predicted, there was no difference between the Mild and Moderate AD groups.

In summary:

- Consistent with our prediction, the Moderate AD group performed with less accuracy on the Recognition tests than did the Normal Controls. However, contrary to our prediction, there was no difference in performance between the Mild and Moderate AD groups.

Naming Tests (See Table 5):

A group effect was found for the Action Name test, $\underline{F}$ (2, 55) = 33.14, $\underline{p}$ = <.001. Post-hoc testing revealed that the Normal Controls ($\underline{M}$ = 93.55) were significantly different from the Mild AD ($\underline{M}$ = 72.79) group ($\underline{p}$ = .001) and from the Moderate AD ($\underline{M}$ = 42.71) group ($\underline{p}$ =<.001). The two AD groups also were significantly different from each other ($\underline{p}$ = <.001). Therefore, this indicates that the Moderate AD group had the least accurate performance compared to the Mild AD and the Normal Controls (in increasing order) as predicted.

A group effect was found for the Tool Name test, $\underline{F}$ (2, 55) = 33.95, $\underline{p}$ = <.001. Post-hoc testing revealed that the Normal Controls ($\underline{M}$ = 98.71) were significantly different from the Mild AD ($\underline{M}$ = 79.85) group ($\underline{p}$ = .001) and from the Moderate AD ($\underline{M}$ = 52.08) group ($\underline{p}$ =<.001). The two AD groups also were significantly different from each other ($\underline{p}$ = <.001). The Moderate AD group had the least accurate performance compared to the Mild AD and the Normal Controls (in increasing order) as predicted.

For the Tool Name by Function test a group effect was found, $\underline{F}$ (2, 55) = 23.58, $\underline{p}$ = <.001. Post-hoc testing revealed that the Normal Controls ($\underline{M}$ = 97.41) were significantly different from the Moderate AD ($\underline{M}$ = 61.46) group ($\underline{p}$ = <.001). The Mild AD ($\underline{M}$ = 72.79) group was significantly different from the Moderate AD group ($\underline{p}$ = <.001). Therefore this indicates that the Moderate AD group had the least accurate performance compared to the Mild AD and the Normal Controls (in increasing order) as predicted.

In summary:

- Consistent with our prediction was that the Moderate AD group performed with less accuracy on the Naming tests (Action, Tool, and Tool by Function) compared to the Mild AD and Normal Controls.

Identification Tests (See Table 5):

A group effect was found for the Action Identification by Function test, $\underline{F}$ (2, 49) = 22.97, $\underline{p}$ = <.001. Post-hoc testing revealed that the Normal Controls ($\underline{M}$ =100.00) were significantly different from the Moderate AD group ($\underline{M}$ = 42.66) ($\underline{p}$ =<.001). The Mild AD group (M = 88.00) was significantly different from the Moderate AD group ($\underline{p}$ = <.001). The Moderate AD group had the least accurate performance compared to the Mild AD and the Normal Controls as predicted.

A group effect was found for the Action Identification test, $\underline{F}$ (2, 50) = 21.93, $\underline{p}$ = <.001. Post-hoc testing revealed that the Normal Controls ($\underline{M}$ = 98.41) were significantly different from the Moderate AD (M = 45.80) group (p =<.001). The Moderate AD group was also significantly different from the Mild AD (M = 79.82) group (p = .001). The Moderate AD group had the least accurate performance compared to the Mild AD and the Normal Controls (in increasing order) as predicted.

A group effect was found for the Tool Identification test, F (2, 55) = 9.53, p = <.001. Post-hoc testing revealed that the Normal Controls (M = 100.00) were significantly different from the Moderate AD (M = 72.79) group (p =<.001). The Moderate AD (M = 72.79) group was significantly different from the Mild AD (M = 83.23) group (p = <.001). The Moderate AD group had the least accurate performance compared to the Mild AD and the Normal Controls (in increasing order) as predicted.

A group effect was found for the Tool Identification by Function test, F (2, 55) = 10.81, p = <.001. Post-hoc testing revealed that the Normal Controls (M = 99.57) were significantly different from the Moderate AD (M = 42.71) group (p =<.001). The Mild AD (M = 72.79) group also was significantly different from the Moderate AD group (p = <.001). The Moderate AD group had the least accurate performance compared to the Mild AD and the Normal Controls (in increasing order) as predicted.

In summary:

- Consistent with our prediction the Moderate AD performed with less accuracy on the Identification tests than did both the Normal controls and the Mild AD.

Table 5: Summary Table of Mean Accuracy scores on the Nine Conceptual Sub-tests of the WatAB by Stage.

	Tool Name	Tool Name Funct'n	Action Name	Tool ID	Tool ID by Funct'n	Action ID	Action ID by Funct'n	Gesture Recog.	Gesture Error Recog.
Normal	98.71	97.41	93.54	100.00	99.57	98.41	100.00	93.90	80.50
Mild	79.85	80.59	72.79	97.39	95.35	98.57	88.00	73.14	48.56
Mod.	56.82	62.50	42.71	83.23	79.23	49.97	42.66	43.96	27.07

NOTE: "] " indicates the significant results at 0.006 and Funct'n indicates: Function.

DISCUSSION

Recall that the purpose of the Conceptual tests was to examine the knowledge of tool, gestures and error. Heilman et al., (1997) argued for the importance of Conceptual testing as they believe the most important influence on the cause of apraxia in AD is change in cognition. These Conceptual tests are used to determine if the knowledge, Sensory/perceptual, and conceptual systems are intact, even when the ability to produce gestures is impaired (Roy, 1996). The Conceptual tests fall into three categories: Naming, Identification and Recognition.

Of importance in this study was the finding that for all nine tests there were group differences. However, only the Naming tests (Action, Tool, and Tool by Function) could display significant differences among all three groups. These three tests are interesting as they provide both a visual (picture) and a verbal cue (instruction) which may offer some additional information as to the importance of context and task effects. In contrast, the Identification tests, which one might have predicted as being the easiest, have in fact quite a complicated design as in each case a series of gestures/tools is shown, which may be more difficult for the more impaired Moderate AD group. Further, this study indicates that the majority of the Conceptual tests (all Naming and all Identification tests) are sensitive to changes in AD, as they could distinguish between the Mild and Moderate AD. We predicted that there would be group differences for each of the Conceptual tests and in fact we found them - albeit not always amongst all the groups. But, according to our prediction the Moderate AD group consistently displayed the poorest performance of all the groups. One possible caution to using the Conceptual tests is that the instructions may be overly complex. Future research might examine whether simplifying some of the instructions could augment performance in AD.

The above results establish the importance of continuing to use the WatAB Conceptual tests in AD research. One further approach also should be noted. Heilman et al., (1997) and Roy (1996) define the Conceptual aspects of praxis as; the knowledge of gestures, objects and tools, a system which may be intact even when the ability to produce gestures may be impaired (Roy). However, Heilman et al., also add another dimension to the knowledge system. They indicate that beyond the measurement of Gesture Naming, Gesture Decision, and Gesture Recognition is the aspect of mechanical knowledge. Heilman et al., define mechanical knowledge in two ways. It is firstly, the ability to determine the necessary action when confronted with a task in which one cannot rely on 'associative tool-object information. An example of this type of ability is to use a tool in a correct manner to correctly complete a task even when the usual or most common tool is not available. The expectation would be that one would choose a tool that shares the necessary features of the correct or common tool. Secondly, mechanical knowledge is the ability to understand the goal of the task, the type of mechanical action required, and the type of tool necessary to complete the task. Mechanical knowledge is tested by solving mechanical puzzles and developing new tools to do so when necessary. Therefore, mechanical knowledge is measured by the ability to use tools in new, creative ways. The Conceptual tests of the WatAB do not allow for this type of testing. However, there is one part of the WatAB not typically included in the Conceptual tests and is not used as yet. The Tool Selection Task of the WatAB allows the testing of the correct choice of an alternate tool in more realistic settings; but it does not allow testing of the second part of mechanical knowledge, which as defined above appears to rely as much on creativity as it does on mechanical knowledge. Therefore, it is necessary to address Heilman's group's two notions of mechanical knowledge in Study #5.

In summary, the following are the objectives for Study #5 which came out of the findings of Study #2:

1) to examine whether another aspect of the Conceptual system as defined by Heilman's group (1997) as Mechanical Knowledge, can be tested via the use of the WatAB's Tool Selection Task.

2) To examine if the use of a measure of creativity can assist in determining the second part of Heilman's group's concept of mechanical knowledge.

3) to examine if the use of a measure of visuo-perceptual skills will help to explain the AD's poorer performance on Recognition tasks.

STUDY # 3

TO EXAMINE HOW COGNITION RELATES TO GESTURE PRODUCTION IN AD.

a) Comparison of Conceptual tests to Gesture tests

Recall from Study #2 above, that the Conceptual tests of the WatAB were designed to measure the more cognitive aspects of praxis: the knowledge of tools / objects; and the recognition of actions / gestures. The WatAB Conceptual tests (Roy, 1996) fall under three headings and are grouped as such to allow the examination of different aspects of the conceptual knowledge of praxis (i.e.: the knowledge of action and tool/object function). To review, the three headings are: Naming tests, Identification tests, and Recognition tests. To review, the Naming tests are designed to elicit the name of an object/tool or action in response to a picture or a verbal description. The Identification tests are designed to elicit the choice of the correct object/tool or action in response to a verbal description, picture or video picture. The Recognition tests involve either the matching of a gesture to one from a series of gestures on videotape, or recognizing whether a gesture on videotape is correct. These nine tests are unique to praxis testing (for a comparison to the conceptual tests of the FAB see Appendix A 5).

The WatAB tests under the three Conditions (Pantomime, Concurrent and Delayed Imitation) are also extensive and were also described earlier (see Appendix B2). Using the WatAB we can therefore examine which, if any, of the conceptual tests are related to the tests of gesture production. The literature (Ochipa et al., 1992; & Rothi et al., 1997) indicates that performance in AD generally will be more accurate on the Gesture tests (e.g., knowledge of action), particularly the Imitation condition, than on the Conceptual tests, due to less reliance on 'cognitive constructs'(e.g., knowledge of action) in the Gesture tests (Rothi et al., 1997). Because Rothi et al., claim that apraxia in AD is due to disruption of the conceptual system, they predict less accurate performance on the tests of conceptual knowledge relative to Concurrent Imitation and Pantomime with Tool. Even though the Pantomime tests by definition in Roy's (1996) model, rely on the integration of all three systems and include such cognitive constructs as, for example, language comprehension and working memory; Pantomime tests are still expected to result in more accurate performance than the Conceptual tests. However, review of the descriptions of the Conceptual tests indicates that only in two tests is the knowledge of gesture most similar to that required to complete a Pantomime task. Therefore, we predict significant correlations for all of the Pantomime-condition tests with the Conceptual tests of Action Name and Action Identification by Function (Identification Test).

Since each of the above two tests is from a different category of Conceptual tests, and as they so strongly share features, a review of the structure of the Conceptual tests and their categorization into the three areas will assist in future research. Each of these tests (Action Name and Action Identification by Function) asks for the name of a gesture (e.g., "Which one do you use to brush your teeth?" or "Which person is pretending to use a toothbrush to brush his/her teeth?") in response to being shown a series of objects or gestures. Review of the Conceptual tests also indicates that the tests most like the Concurrent Imitation condition are the two Recognition tests: Gesture Recognition and Gesture Error Recognition. Both of these tests rely on the matching (visual/gestural analysis) of a performed gesture to one presented on videotape and therefore are predicted as correlating significantly with all of the Concurrent-Imitation- condition tests. As suggested in the above studies, there is no literature available on Delayed Imitation. As there are no Conceptual tests that incorporate a delay in their presentation, prediction is difficult.

In this research it is predicted:

- that all of the Pantomime tests will be the most highly, significantly correlated with two of the Conceptual tests (Action Identification by Function and Action Naming), since these two Conceptual tests share features with the Pantomime tests (knowledge of gestures).
- that all of the Concurrent Imitation tests will be the most highly correlated with two of the Conceptual tests (Gesture Recognition and Gesture Error Recognition), since these two Conceptual test share features with the Concurrent Imitation tests (visual/gestural analysis).

b) Comparison of a general measure of Cognitive Status to Conceptual and Gesture tests.

Review of the literature confirms the variability of testing protocols used for both cognition and motor differences between persons with AD and the healthy elderly person. Most studies do use some form of a global rating scale. Such scales are also termed mental status examinations, and the most common one in use in the international AD literature is the Mini Mental Status Exam (MMSE) (Folstein, Folstein, & McHugh, 1975) (for example: Locascio, Growden & Corkin, 1995; Tierney et al., 1996; LaBarge, Smith, Dick & Storandt, 1992; Lucchelli, Lopez, Faglioni & Boller, 1993; or Reid et al., 1996). However, other possibilities exist and are used, e.g.: Abbreviated Mental Test Score (as cited in Burns et al., 1991); Dementia Rating Scale (as cited in Tierney et al., 1996); or the Global Deterioration Scale (as cited in Doraiswamy et al., 1997). Another complicating factor is that these tests often are used in the same study for the diagnosis and/or the staging of AD, in addition to being used as part of the research protocol. Only a few studies attempt to remove this possible confound and either do so by using one of the above named tests in the diagnostic process and another in the research battery or by having the research examiners blind to the status and therefore to the diagnosis of the participants (Tierney et al., 1996). As we used the MMSE to both diagnose and stage AD, we decided to use the Dementia Rating Scale (DRS: Mattis, 1976) as our test of general cognitive status.

The DRS (Mattis, 1976) is a brief test designed to measure mental status, to quantify the degree of dementia and to distinguish different types of dementia. This test is easy to administer and to score with many of the items drawn from those that were routinely used by neurologists to screen mental abilities (Spreen and Strauss, 1998). The items are arranged hierarchically so if performance on the initial question in a section is adequate then the examiner has the choice of discontinuing or continuing with the other items in that section. The DRS provides a global measure of dementia that is derived from the: attention, initiation and perseveration (perform alternating movements), construction (drawing), conceptualisation (similarities), and the verbal-nonverbal short-term memory sub-scales.

We predict that the particular correlations between the WatAB tests and the DRS will suggest which of the WatAB tests are sensitive to changes in AD. The indication of this relation would be if the correlations between the DRS and the individual WatAB tests were significant. Such correlations would suggest that as the scores changed on the DRS test so would the scores on the WatAB tests. We would therefore have some support for the continued use of the WatAB in AD research.

In this research it is predicted:

- that all of the Concurrent Imitation, Delayed Imitation, Pantomime, and Conceptual tests will be consistently correlated with the DRS, since praxis performance will change as AD progresses.

METHOD

Participants

The participants of this study were the same as for Study #1.

Materials

Participants were required to Pantomime and Imitate with their dominant hand, the full Waterloo Apraxia Battery (WatAB) (see Appendices B1 & B2), including all Transitive (e.g., use a hammer), Intransitive (e.g., show me how you salute) and Nonrepresentational gestures (e.g., please do this - hand on top of head with wrist rotating in counter-clockwise direction). Each of the Transitive Imitation (Concurrent and Delayed) conditions consisted of the same eight gestures. The Pantomime condition also used the same Transitive gestures. Each of the Intransitive Imitation conditions (Delayed and Concurrent) and the Intransitive Pantomime condition used the same eight gestures.

In addition, all participants completed the Conceptual section of the apraxia battery which included watching videotapes of gestures, which they were asked to identify. Additionally, all were asked to identify tools by picture or by description. Actions were also to be identified by gesture or by corresponding tool. Gesture error was assessed as was object use via a picture. (see Appendix B2)

All participants were administered the Dementia Rating Scale (DRS: Mattis, 1976). All items were administered to each participant.

<u>Design and Procedure</u>

The design and procedure were the same as for Study #1.

In addition, all participants completed the Conceptual section of the WatAB. Relevant pictures were mounted on 8½ by 11 inch sheets of cardboard and videotape was presented on a 21 inch screen television in a comfortable and appropriately illuminated room.

The DRS was presented in a comfortable, well-illuminated room. The examiner sat across the table from the participant. All relevant materials were presented as necessary (e.g.: pencil, paper).

Scoring

Performance on the gesture tests and the conceptual tests were expressed as z-scores as outlined in Study #1. These z-scores were used in the correlational analyses.

The test scores from the DRS remained in their original format out of a possible total of 144 and were calculated according to the specific directions of the test.

RESULTS

a) Comparison of Conceptual tests to Gesture tests.

In order to determine if there is any relation between the scores of the Gesture-based tests and the Conceptual tests a correlational analysis was completed (see Tables 6 & 7). Because of the large number of correlations, the alpha was adjusted using Bonferroni's correction to 0.0024.

Specifically, for the Pantomime tests (see Table 6), and somewhat like our prediction, only Action Identification by Function of the Conceptual tests was consistently and significantly correlated with all of the Pantomime tests. The Action Name test was significantly correlated with all of the Pantomime tests except for one: Pantomime Intransitive. Also, contrary to our prediction, the Gesture Recognition test was significantly correlated with all of the Pantomime tests. Other Conceptual tests were significantly correlated with some of the Pantomime tests (see Table 6). Two exceptions appeared; the Tool Identification and the Tool Name tests (Conceptual) were not significantly correlated with any of the Pantomime tests. All of the significant correlations between the Conceptual and the Pantomime tests ranged from .591 to .784. This indicates that as performance changes in Pantomime so does the performance on many of the Conceptual tests. For our two predicted tests, the significant correlations ranged from: .601 to .772 for the Action Identification by Function test, and from .618 to .704 for the Action Name test. The significant correlations for the Action Identification by Function test strongly indicate that as performance changes in this particular Identification test so does performance on all of the Pantomime tests.

Table 6: Summary table of AD Correlational analysis comparing the Conceptual Tests to the Pantomime Tests.

Test	Pantomime by Tool	Pantomime by Function	Object Use	Object Use - Picture	Pantomime - Intransitive
Action ID by Function	.772	.710	.662	.701	.601
Action Name	.679	.621	.704	.618	
Action ID	.751	.702	.	.660	
Error Recognition	.701	.664		.634	
Gesture Recognition	.784	.705	.654	.688	.591
ID by Function			.623		
Tool Name by Function	.668	.638	.612	.585	
Tool ID					
Tool Name					

Note: Empty cells denote no significant result and all others are significant at .0015.Short-forms used: ID = identification; non-rep = nonrepresentational.

For Concurrent Imitation (see Table 7), as per part of our prediction, the Gesture Recognition test was significantly correlated with all of the Concurrent Imitation tests. However, contrary to our prediction, the Gesture Error Recognition test was significantly correlated with all of the Concurrent Imitation tests except for one: Intransitive. This is a similar finding to the Pantomime results above. Also contrary to our prediction, the Tool Identification, the Action Identification by Function, Action Identification, and the Tool

Identification by Function tests were all significantly correlated with all of the Concurrent Imitation tests. Other Concurrent Imitation tests were significantly correlated with the Conceptual tests (see Table 7). In fact, each of the Concurrent Imitation tests was significantly correlated with at least two of the Conceptual tests. All of the significant Concurrent Imitation correlations with the Conceptual tests ranged from .589 to .812, indicating that as the performance changes in Concurrent Imitation so does the performance on many of the Conceptual tests. The correlations here are somewhat higher than those for Pantomime with the Conceptual tests. It is interesting that so many of the scores for the different Concurrent Imitation tests change with the scores for the Conceptual tests.

Although we did not offer any predictions for Delayed Imitation, it is apparent from the results listed in Tables 6 and 7 that the Action Identification by Function test is the only Conceptual test significantly correlated with all of the Delayed Imitation tests.

Perhaps the most interesting finding of this correlational analysis was that the Action Identification by Function test was significantly correlated with all of the Pantomime and all the Imitation (Concurrent and Delayed) tests. This indicates the relative importance of this Conceptual test in the use of the WatAB in AD.

Table 7: Summary table of AD Correlational analysis comparing the Conceptual tests to the Imitation tests.

	Concurrent Imitation				Delayed Imitation		
Test	Intransitive	Non-rep	Transitive	Verbal Cue	Intransitive	Non-rep	Transitive
Action ID by Function	.692	.806	.787	.742	.591	.771	.727
Action Name		.606		.607		.681	.649
Action ID	.632	.736	.741	.713		.657	.623
Error Recognition		.671	.698	.670			
Gesture Recognition	.675	.764	.812	.726		.743	.677
ID by Function	.684	.730	.586	.746		.599	
Tool Name by Function	.591	.593		.689			
Tool ID	.713	.732	.646	.789			
Tool Name		.674		.619			

Note: Empty cells denote no significant result and all others are significant at .0015. Short-forms used: ID = identification; non-rep = nonrepresentational.

In summary:

- Consistent with our prediction, all of the Pantomime tests were significantly correlated with the Action Identification by Function test of the Conceptual tests. However, contrary to our prediction, the Action Name test was not significantly correlated with all of the Pantomime tests. Another contrary finding was that the Gesture Recognition test was significantly correlated with all of the Pantomime tests.
- Consistent with our prediction was that all of the Concurrent Imitation tests were significantly correlated with the Gesture Recognition test of the Conceptual tests.

Contrary to our prediction, the Error Recognition test was not significantly correlated with all of the Concurrent Imitation tests. Also contrary to our prediction was that three other Conceptual tests (Action Identification by Function, Action Identification, and Tool Identification) were significantly correlated with all of the Concurrent Imitation tests.

b) Comparison of a general measure of Cognitive Status to Conceptual and Gesture tests.

A correlational analysis was completed in order to determine if there was any relation between the scores on the WatAB tests and the DRS. Due to the large number of correlations the alpha level was corrected, using Bonferroni's correction to 0 .002. The results (see Table 8) indicate that all but two of the WatAB tests were significantly correlated with the DRS. The two that did not meet our set alpha of .002 were Tool Identification by Function and Error Recognition.

Table 8: Summary Table of the AD Correlational analysis comparing all of the WatAB tests with the DRS.

Test Name	DRS
Action ID by Function	.674
Action Name	.667
Action ID	.653
Error Recognition	
Gesture Recognition	.640
ID by Function	
Tool Name by Function	.796
Tool ID	.739
Tool Name	.667
Pantomime by Tool	.719
Object Use	.740
Object Use - picture	.770
Pantomime by Function	.742
Pantomime - intransitive	.727
Concurrent Imitation - intransitive	.772
Concurrent Imitation - nonrepresentative	.772
Concurrent Imitation - transitive	.667
Concurrent Imitation - verbal cue	.799
Delayed Imitation - intransitive	.626
Delayed Imitation - nonrepresentative	.692
Delayed Imitation - transitive	.622

NOTE: Empty cells indicate no significant correlation, all others are significant at .0015.

In summary:

- Consistent to some degree with our prediction, all of the WatAB tests were significantly correlated with the DRS, except for two. Contrary to our prediction, the Tool Identification by Function and the Error Recognition tests were not significantly correlated with the DRS.

DISCUSSION

a) Comparison of Conceptual tests to Gesture tests

Our predictions were not as accurate as we had hoped. One (Action Identification by Function) of the two Conceptual tests (Action Name, Action Identification by Function) predicted to be significantly correlated with all of the Gesture tests was, in fact, so correlated. One of our predicted Conceptual tests was not consistently correlated with the Gesture tests. In the case of Pantomime, Action Identification by Function, and Gesture Recognition, these tests were highly correlated with all of the Pantomime tests. We had not chosen any test from the Recognition section of the Conceptual tests, as we hypothesized that the Recognition tests shared more features with Concurrent Imitation. Although we did find that the Gesture Recognition test was correlated with all of the Concurrent Imitation tests, we also surprisingly found three other Conceptual tests: Action Identification by Function, Action Identification, and Tool Identification.

Perhaps the most interesting finding of this analysis was that the Action Identification by Function test was significantly correlated with all of the Pantomime and all of the Concurrent and Delayed Imitation tests. This may make sense in that this test demands both Visual - Gestural analysing, as well as knowledge of the action. Therefore, it might be expected to correlate with all gesture tests. This finding will be useful in our next study in which we examine the Patterns of Apraxia derived from Roy's (1996) model. As this one Conceptual test is correlated with all of the WatAB tests, we will be able to use it alone in our calculations of the presence of apraxia instead of all nine Conceptual tests.

In this study, we unexpectedly found that many of the Conceptual tests were highly correlated with all of the Concurrent Imitation tests. Concurrent Imitation is defined by Roy's (1996) model as relying only on the analysis of visual/gestural information and therefore by-passing the Conceptual system. In contrast, the Conceptual tests while requiring Visual - Gestural analysis, actually place more emphasis on the knowledge of gestures / actions and objects / tools (Heilman et al., 1997) and are therefore reported as being particularly vulnerable to the cognitive changes in AD. Therefore in AD, the Concurrent Imitation tests would be expected to have very low to no correlation with the Conceptual tests. Contrary to these expectations, in Study # 3 there were more Conceptual tests correlated with all of the Concurrent Imitation tests than with all the Pantomime tests. Perhaps this supports our previous observation that there is no protection for Concurrent Imitation in our AD group. However, it is also possible that the Conceptual tests are not well designed for AD groups, or not well placed in one of the three categories (Naming, Recognition and Identification). Such examination of the Conceptual tests must become a focus of our future work.

The correlations comparing the Gesture-based tests and the Conceptual tests of the WatAB revealed that most of the WatAB sub-tests were highly correlated with each other, a finding that may indicate the need for future research to filter out some of the 21 tests so as to provide a comprehensive yet manageable battery.

b) Comparison of a general measure of Cognitive Status and Gesture Tests

A correlation matrix indicated that all but two of the WatAB tests were highly positively correlated with the Dementia Rating Scale - DRS (Mattis, 1976). As the DRS test is found often in the AD literature (for example: Tierney et al., 1996) and as it is known to be very highly correlated with the most commonly used cognitive measure, the Mini Mental Status Exam (Folstein et al., 1975), it was reassuring to find that most of the sub-tests of the WatAB provide scores that change as do the scores from the DRS. Further, these results indicate that as the disease progresses, the performance in gesture production and the conceptual aspects of praxis also decrease. However, the two tests that were not significantly correlated with the DRS were both from the Conceptual tests. They were the Tool Identification by Function and the Error Recognition tests. It may be advisable when reviewing the use of all nine of the Conceptual tests in our future AD research to examine closely the use of these two. If this measure of cognitive status (DRS) is as sensitive to changes in AD as it is reported to be (Spreen & Strauss, 1998; Lezak, 1995), then we have some support for the use of the WatAB in examining AD.

STUDY # 4

TO DETERMINE WHETHER ROY'S MODEL PREDICTS PATTERNS OF APRAXIC PERFORMANCE IN AD

The eight patterns of apraxic performance predicted by Roy's model (1996) are repeated at the end of this study for the reader's convenience in Table 1. In general they rely on the presence (+) or absence (-) of intact ability for Transitive gestures in each of: Concurrent Imitation, Delayed Imitation, Pantomime and the Conceptual tests. These patterns stem directly from Roy's (1996) model and are numbered accordingly Roy's 1996 model also appears at the end of this study). The patterns allow an exploration of which part(s) of the three systems (Sensory/Perceptual, Conceptual, and Production) may cause a particular form of apraxia. For example, in pattern #1 Pantomime performance remains intact whereas both Concurrent and Delayed Imitation show apraxia and the Conceptual tests also reveal apraxia. According to Roy's (1996) model the system affected in pattern #1 is the sensory/perceptual one, and the nature of the disruption is the impaired ability to analyse visual/gestural and tool object information. As the WatAB includes tests of all areas of Roy's model, we are able to assign each participant to one of Roy's apraxic patterns. Such patterning will allow us to determine the most common apraxic pattern in AD.

Because AD greatly impairs memory and language skills (Almkvist, 1996), we expect that the most frequent pattern(s) will be those that involve impairment in Pantomime, Conceptual tests and Delayed Imitation (likely patterns are 2, or 3, or 5, or 7). From the results of the previous two studies we can expect impairment on some of the Conceptual tests. According to the literature, the conditions of Pantomime and Delayed Imitation are commonly affected by AD due to cognitive change and the reliance of these conditions on working memory. However, of these possible patterns, based on the results of the frequency of apraxia in Study # 1 it is most likely that pattern 5 (P-/DI-/CI+/R+) will be the most frequent. Also according to the literature (for example see: Rapcsak et al., 1989; Lucchelli et al.,1993; Ochipa et al., 1992; Vitaliano et al., 1986; Della Salla et al., 1996; Edwards et al., 1991; and Rothi & Heilman, 1985), one can expect Pantomime to be impaired more often than Concurrent Imitation. Further, since it is likely from the literature that the presence of a delay will disrupt performance in AD on Imitation, then impairment will be found in Delayed Imitation, which supports the prediction of pattern 5 as being the most frequent.

In this research it is predicted:

- that pattern # 5 (P-/DI-/CI+/R+), will be the most frequent, since both the literature reports that in AD apraxia is more common under Pantomime than under Concurrent Imitation, because according to Roy's (1996) model Pantomime and Delayed Imitation are both thought to be dependent upon working memory.

METHOD

Participants

The same participants as those from Study #1 were used in this study.

Materials

The materials were the same as for Study #1.

In addition, all participants completed the Conceptual section of the apraxia battery which included watching videotapes of gestures that they were asked to identify. Additionally, all were asked to identify tools by picture or by description. Actions were also to be identified by gesture or by the corresponding tool. Gesture error was assessed as was object use by viewing a picture and by having the actual object placed in their hand (see Appendix B2)

Design and Procedure

The design and procedure were the same as for Study #1.

In addition, all participants participated in the Conceptual section of the apraxia battery. Relevant pictures were mounted on 8½ by 11 inch sheets of cardboard and videotape was presented on a 21 inch screen television in a comfortable and appropriately illuminated room.

Scoring

The scoring was the same as for Study #1.

Categories of apraxia were determined by reference to the healthy control participants' performance. For each AD participant, six z-scores were calculated (Concurrent Imitation, Delayed Imitation, and Pantomime for each Transitive) from the total composite scores (expressed as a percentage of the total possible score across the gestures) using the mean scores from the Normal Control group. The score for the Conceptual tests ('R' in the patterns) was calculated using the results of the previous study. Only the Action Identification by Function was highly and consistently correlated under all conditions in Study # 3 with all of the Conceptual and all of the Gesture tests of the WatAB. The composite score was therefore based upon the individual's scores on this Conceptual test. A z-score was then calculated for the Conceptual test as per above. Therefore, for all scores, the AD participants were considered to be non-apraxic if their scores fell within one standard deviation of the mean of the controls, borderline apraxic for between one and two standard deviations, and apraxic for greater than two standard deviations of the mean of the control group.

RESULTS

The patterns of apraxic performance predicted by Roy's (1996) model include eight possibilities (see Table 1). Of those eight patterns, our AD participants displayed four patterns of apraxic performance. The most common was pattern number eight (P-/DI-/CI-/R-) with 12 out of 20 (60%) apraxic participants with this pattern. The next most common patterns were numbers three (P-/DI+/CI+/R+) and five (P-/DI-/CI+/R+), each accounting for 15% of the apraxic participants. Lastly, pattern number one (P+/DI-/CI-/R-) represented 10% of the AD participants. Therefore, contrary to our prediction, the most common apraxic pattern was number eight, which, according to Roy's (1996) model indicates a breakdown in all three systems, the sensory/perceptual, conceptual, and production. According to Roy, this pattern is akin to global aphasia. Patterns 3 & 5 were predicted, but we did not expect them to account for such low percentages. Therefore in this AD group, apraxia is influenced by a breakdown in all systems.

In summary:

- Contrary to our prediction pattern # 5 (P-/ DI-/ C+/ R+) was not the most frequently found in our AD group. However, each of patterns # 3 and 5 accounted for 15% of the apraxic patterns. In contrast to our predictions, pattern #8 (P-/DI-/CI-/R-) was the most frequent.

DISCUSSION

As per Roy's model (1996), there are eight possible patterns of apraxic performance measured by the WatAB. They include apraxic deficits in Pantomime, Concurrent and Delayed Imitation, and the Conceptual tests. When reviewed, they assist in highlighting which of the three systems (Sensory / Perceptual, Conceptual, or Production) Roy's (1996) model indicates as being involved in causing the apraxia. By using the Conceptual tests, we are better able to determine which pattern is most prevalent as the presence or absence of dysfunction on these tests of the cognitive aspects of praxis are crucial for determining the differences between related patterns. For example, the only difference between patterns #2 and #3 is the presence of impaired performance on the Conceptual tests, with the Pantomime tests being impaired and both of the Imitation tests showing intact performance.

Of all the patterns predicted in Roy's (1996) model, the most prevalent we encountered, contrary to our prediction, was that (Pattern # 8) where AD participants were impaired on Concurrent Imitation, Delayed Imitation, Pantomime and gesture-tool-object recognition (Conceptual tests). Again, we do not find any protection for Concurrent Imitation. This supports our earlier findings in Study #1. From Study #1 we learned that AD led to equal impairment across conditions. Study #3 supported that the gesture based tests were highly correlated with the conceptual tests. Together these results suggest the exploration of the various aspects of praxis. As noted earlier, Roy's (1996) model indicates that the first place where Concurrent Imitation performance can be affected is via a disruption to visual - perceptual skills. Therefore, we will pursue the effect of visual - perceptual skills in AD praxis performance in Study #5.

According to Roy's model (1996), the pattern with impairment in all areas (Pattern # 8) suggests an impaired knowledge of action and tool/object function along with impairment in response organization and control. Hence, the disruption is occurring in the sensory, the conceptual and the production systems. This is perhaps the most severe form of apraxia and Roy (1996), suggests that it is similar to global aphasia. Given the kind of wide neural deterioration seen in AD (Almkvist, 1996, Braak & Braak, 1996), this form of apraxia is not surprising. But it may be unusual to find it in the Mild and Moderate stages of AD. Had the samples of each of the stages (Normal, Mild AD, and Moderate AD) been much larger and equivalent, a more detailed analysis of the effects of group on all of the WatAB tests would have been possible. Ochipa et al., (1992) have found the same pattern of impairment in all conditions (Pantomime, Imitation, and Conceptual) tested in their AD participants and conclude that AD affects praxis through the process of cognitive decline. Most likely the disconnection as suggested by Almkvist (1996) and/or plaque formation (Roy, 1996) in more centrally located areas (premotor, motor, and sensorimotor areas) is responsible for the impairment in control and programming of praxis movements. However, as plaques are not known to be correlated with dysfunction (Wallin & Blennow, 1996 and Wahlund, 1996), it may be that the presence of neuronal loss and other neurofibrillary changes are causing disruption to praxis.

A review of the apraxia patterns suggests that this sample of AD participants was unlike our prediction (most common pattern would show intact Conceptual skills). They were particularly impaired in the knowledge of objects, action and gestures, as 66% (19) of the participants were impaired on the WatAB Conceptual tests. According to Roy (1996), these tests are designed to measure the integrity of the knowledge structures. Heilman et al., (1997) suggests that deficits in conceptual praxis can cause the patterns of performance most commonly seen in AD and are due to a dysfunction in the action semantics (knowledge) system. Our findings, which reflect those of Heilman et al., (1997), indicate the need for further exploration of the knowledge of tools, objects and actions. Heilman et al., (1997) has proposed that such knowledge can also be tested via using a Tool Selection Task (TST), in which the choice of a correct tool indicates intact conceptual knowledge of tools. Subsequently, we decided to focus on the approach of using a TST in Study #5. Rothi and Heilman (1985) suggest that disruptions to the conceptual system are caused by damage to the left parietal lobe. In the future, the addition of SPECT data, also collected on our participants, could shed further light on the neuro-anatomical correlates of Roy's (1996) predicted patterns of performance.

In summary the following are the objectives for Study #5 which came out of the findings of Study #4:

1) to examine the possible effects of visuo-perceptual skills in AD on Concurrent Imitation

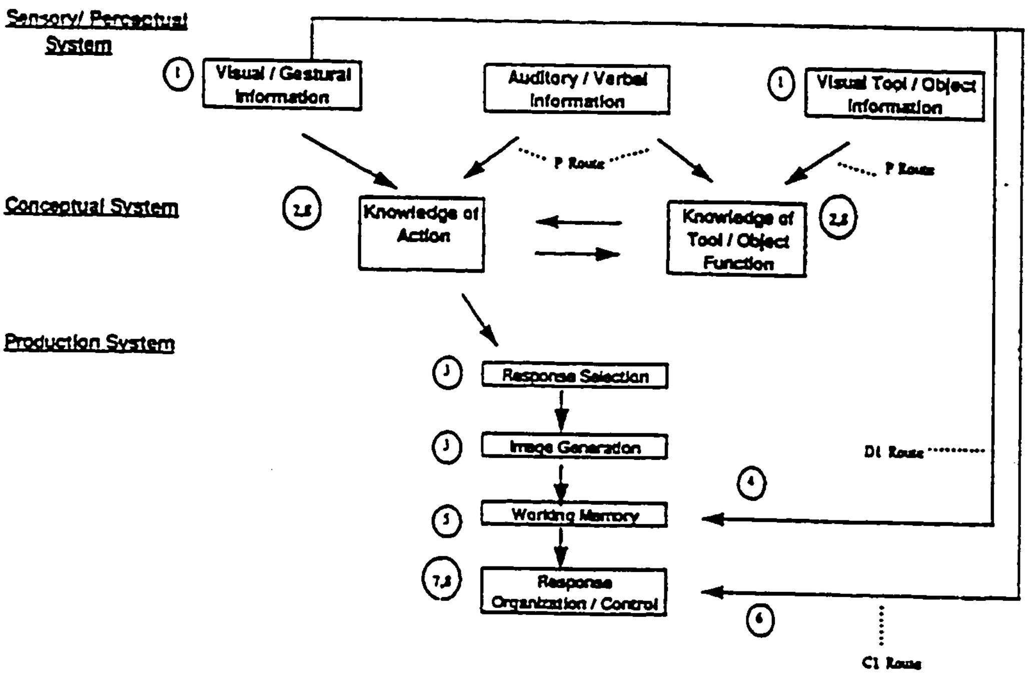
2) to examine the use of the Tool Selection Task as an indication of the conceptual knowledge of tools.

Table 1: Summary of major patterns of Apraxic Performance derived from Roy's Model (1996)

Pattern Number	Apraxia Performance Pattern	Gesture-Tool/ Object Recognition	System Affected	Nature of Disruption
1	P+ DI- CI-	Impaired	Sensory/ perceptual	Impaired ability to analyse visual gestural and tool/ object information
2	P- DI+ CI+	Impaired	Conceptual	Impaired knowledge of action and tool/ object function
3	P- DI+ CI+	Intact	Production	Impaired response selection and/or image generation
4	P+ DI- CI+	Intact	Production	Impaired encoding of visual gestural information into working memory
5	P- DI- CI+	Intact	Production	Impaired working memory
6	P+ DI- CI-	Intact	Production	Impaired ability to use visual information in the control of movement
7	P- DI- CI-	Intact	Production	Impaired response organization and control
8	P- DI- CI-	Impaired	Conceptual & Production	Impaired knowledge of action and tool/object function and impaired response organisation and control

Note: P indicates Pantomime, CI indicates Concurrent Imitation and DI indicated Delayed Imitation ;'-' indicates impaired; '+' indicates intact. From "Hand Preference, manual symmetries and limb apraxia," by E.A. Roy, 1996, In D. Elliott and E. Roy (eds) Manual Asymmetries in Motor Performance. Boca Raton, Florida, CRC Press., pp 215-236. Copyright 1996 by E. A. Roy. Reprinted with permission.

Figure 1: Roy's 1996 Model of Apraxia



Note: P = Pantomime; CI = Concurrent Imitation; and DI = Delayed Imitation. The numbers within the circles refer to Roy's Patterns of Apraxic Performance (see Table 1). From "Hand Preference, manual symmetries and limb apraxia," by E.A. Roy, 1996, In D. Elliott and E. Roy (eds) Manual Asymmetries in Motor Performance. Boca Raton, Florida, CRC Press., pp 215-236. Copyright 1996 by E. A. Roy. Reprinted with permission.

To summarize, the following are the objectives for Study #5 which came out of the findings of the first four Studies:

From study # 1: 1) to examine the possible effects of visuo-perceptual skills in AD on Concurrent Imitation in Transitive gestures

2) to examine the effects of more realistic context on performance in Pantomime tests in AD

From Study #2:

1) to examine whether another aspect of the Conceptual system as defined by Heilman's group (1997) as mechanical knowledge can be tested via the use of the WatAB's Tool Selection Task.

2) To examine if the use of a measure of creativity can assist in determining the second part of Heilman's group's concept of mechanical knowledge.

From Study #4:

1) to examine the possible effects of visuo-perceptual skills in AD on Concurrent Imitation

2) to examine the use of the Tool Selection Task as an indication of the conceptual knowledge of tools

STUDY # 5

TO EXAMINE THE EFFECTS OF ADDITIONAL CONTEXTUAL INFORMATION, CREATIVITY AND THE IMPACT OF VISUO-SPATIAL SKILLS IN AD

Introduction

Further analysis of apraxia under Pantomime and Concurrent Imitation

Recall from Study #1 the finding of no difference between the frequency of apraxia under the conditions of Imitation and Pantomime which is very contrary to the literature. In the discussion of that study we indicated that further investigation of this result was necessary. In the literature the most common finding is that Imitation performance in AD is always better than that for Pantomime (for example see: Rapcsak et al., 1989; Lucchelli et al.,1993; Ochipa et al., 1992; Vitaliano et al., 1986; Della Salla et al., 1996; Edwards et al., 1991; and Rothi & Heilman, 1985). We had therefore expected an advantage for Imitation because, unlike in the Pantomime condition, there are no demands on memory (at least for Concurrent Imitation) and other cognitive constructs such as language comprehension,. However, we found no differences in accuracy of performance between Imitation and Pantomime. This equality of performance could reflect a problem at the late stage of the production system, due to a problem with movement execution according to Roy and Square's (1994) (and Roy, 1996) model. From Roy's model it is also possible that our findings could reflect that the AD participants are unable to take advantage of the reduced processing demands on memory in the Imitation gestures because of:

1. A problem in carrying out the spatial transformations (left to right transformations) required in imitating a gesture demonstrated by the examiner; or

2. Poor ability in analysing visual gestural information due to visual perceptual deficits.

In order to determine if one of the above hypotheses could explain AD performance in Imitation we posed the following two questions. Each of the two questions will be addressed in turn.

a) Is there a difference in Imitation performance when AD participants do not have to do a spatial transformation vs when they do?

We propose to investigate this question by comparing AD Imitation performance in the normal Concurrent Imitation condition as we had used in our previous work and to use a new condition which removes the need for left-right (spatial) transformation. The new Concurrent Imitation condition involves asking the participants to imitate from the examiner's image seen in a mirror placed directly in front of them. Little is understood about spatial transformation errors in specific gesture testing. From Benton (1979) comes the evidence that such spatial errors occur under the influence of right hemisphere damage, which affects performance in correctly orienting one's self in response to an examiner's presented movement. Left-right transformation errors have been documented in AD (Lezak, 1995), albeit while not directly testing gestural praxis. Commonly spatial errors in praxis assessment are defined by Heilman's group (1997) and others (for example see: Benton, 1979) as being due to external limb configuration (how limb is held away from the body), internal limb configuration (how limb is held towards the body) and joint movement (use of shoulder, elbow and wrist). But what is not clear is how these errors could be specifically caused by a spatial transformation. This has not been studied in the apraxia literature. Given what little is known about spatial errors in praxis and in AD, we can only predict that, if there is a difficulty in AD with translating information from what appears to be coming from the left to action using the right side of the body, then the use of the mirror should provide the greatest accuracy when gesturing.

In this research it is predicted:

- that for the AD group, performance should be more accurate under the Concurrent Imitation Mirror condition than for the regular Concurrent Imitation condition, since the Mirror condition removes the impact of any spatial transformation.

The second question which may help us to address our unusual findings of at least equal frequency of apraxia in Imitation and in Pantomime is:

b) Do the AD participants exhibit poor visual perceptual abilities and are these related to imitation performance?

In Study # 2, AD participants were impaired in visual gestural analysis as demonstrated by poorer performance in gesture recognition, and gesture error recognition and so forth. As Roy's (1994, 1996) model indicates, the earliest point where disruption to Concurrent Imitation can occur is in the Sensory / Perceptual system. The above findings support the notion that our AD participants might have poor visual - perceptual abilities. Therefore, examining visuo-perceptual skills appears to be a reasonable place to begin to explore, why there are no differences between Concurrent Imitation and Pantomime?

Changes to visual-perceptual skills during AD have not been studied until recently. Binetti and colleagues (1996, 1998) suggested that while a wide range of changes in visual-spatial/perceptual skills has been reported in AD, there has not been any evidence of the biological mechanism responsible for such changes. Most commonly suggested by researchers is that AD patients encounter the most difficulty with figure-ground analysis (Mendez, 1990). More recently, reports of AD patients with a progressive visual impairment have been published (Della Sala, Spinnler, Trivelli, (1996). Almkvist in his 1996 review of the neuropsychological changes in different stages of AD, reported that visual spatial changes were progressive and could not be observed in the pre-clinical stage (before a diagnosis could reliably be made) of AD but were apparent by the mild stage of the disease. However, the common methods of measurement in this stage consist of block construction tasks or copying complex geometric designs, and are therefore not extensive and exclusive visual spatial batteries. Several of these tests also examine constructs (e.g., planning) more commonly attributed to frontal lobe function.

As indicated in Studies #1, 2 and 4 above, the addition of some form of visual-perceptual assessment would serve to assist our exploration of the less than expected performance on Imitation tasks. A battery of visual-perceptual tests which would measure various aspects of this broad area would seem most reasonable. Binetti and colleagues recommend including a broad battery of visual-spatial tests in any research into dementia as changes in visual-spatial skills are included in the diagnostic criteria for dementia. Such changes have also been well documented in AD (Almkvist, 1996). Binetti et al. (1996) would agree that changes in figure-ground analysis are apparent in most AD patients. Further, they indicate that there is good evidence for the deterioration of visual-spatial skills as AD progresses and are considered to reflect the neuropathological changes seen in AD. Almkvist would suggest that such progression is due to the disconnection of the posterior cortical areas from the limbic system due to the extensive changes to the transentorhinal regions of the medial temporal lobe. Others (Brun, Englund, 1981, Rogers, Morrison, 1985) suggest that such negative changes to visual spatial skills in AD are a result of neuropathological changes occurring directly in the visual association cortex as opposed to a straight disconnection hypothesis. Whether such changes are due to a disconnection or specific damage or a combination is beyond the scope of this study.

However, Binetti et al (1998) suggest that visual spatial skills are best understood if broken down into two broad categories. They looked at disorders of visual object perception and spatial disorders. Further they claim that each is mediated by a different neural system. The spatial disorders are believed to reflect the "where" system of the parietal lobe whereas the visual object disorders result from impairment of the ventral (temporal) visual processing stream.

Given that many of the measures used to assess visuo-perceptual changes in AD are not specific tests of visuo-perceptual skills, there is a possibility of the confounding effects of cognitive deficits and/or clinical variables (i.e.: actually measuring frontal constructs and not visual perceptual ones). Binetti et al (1996, 1998) recommend that measurement of visuo-perceptual skills in AD be completed by using a battery of tests specifically designed for that purpose. Of course given the coexisting cognitive changes in AD, the battery should not have high task demands, especially in the verbal domain. For these reasons we chose the same tool as Binetti et al. recommended - the Visual Object and Space Perception Battery (VOSP - Warrington and James, 1991). Binetti et al. report difficulty in only the Silhouettes subtest of the VOSP for their AD group.

Using this battery and given Roy's (1996) model, which indicates that the first place an impairment in Concurrent Imitation can occur is in the visual analysis of tools and gestures, we predict that the AD group will have less accurate performance than the Normal Control group on the visual object perception group of VOSP tests. Further, in our data analysis we will regress VOSP sub-test performance separately on Concurrent Imitation and Pantomime to see if impairments, as measured by the VOSP, selectively predict performance on Concurrent Imitation. Due to the definitions above we predict that the visual object sub-tests (Incomplete Letters, Silhouettes, Object Decision, and Progressive Silhouettes) will best predict Transitive Concurrent Imitation performance. In contrast we predict that as per Roy's model (1996) none of the VOSP sub-tests will predict Pantomime performance in AD.

In this research it is predicted:

- that the AD group will have less accurate performance than the Normal Control group on the visual object perception group of VOSP tests, since the literature suggests this is the most likely place to find changes in AD (Binetti et al. 1996, 1998).
- that the VOSP visual object sub-tests will predict Concurrent Imitation performance but no VOSP sub- tests will predict Pantomime performance.

Further analysis of the effect of Context on Pantomime performance

Another interesting finding of Study 1 (part 'c') saw an effect of context where performance in the Object Use Show condition was better than for the other Pantomime tests and as noted there became a focus of this study. To that end, in this study we want to examine this context effect more fully in two ways: i) Object Use Hold versus Object Use Show, and ii) full task context versus visual tool information only.

i) Object Use Hold vs. Object Use Show

Firstly, we decided to examine the effects of context by comparing our standard WatAB Object Use Show where participants just see the tool to the new version where participants actually hold the tool. In these Object Use conditions only the tool is present so there is no other contextual information involving the object on which the tool acts, or the task environment in which the participant actually does the task.

Recall that proponents of the Naturalistic Action theory suggest that while someone can be apraxic on specific gestural measures, there may be no comparable diagnosis when more natural testing methods are employed (Schwartz and Buxbaum, 1997; Schwartz Ochipa, Coslett, & Mayer, 1995). Naturalistic Action is based upon sequences of well learned and used movements and could therefore be considered a class of skilled movements. As it also involves completing some tasks with and upon other objects or tools, knowledge about function and use are inherent. Therefore, it is most reminiscent of conceptual praxis (as defined by Heilman's group, 1997). Additionally, Naturalistic Action relies on the cognitive constructs of planning, attention and working memory for success. Such methods can include asking a patient to use the available ingredients to make a sandwich or pack a full picnic lunch. Errors are scored in the areas of: content, gesture, space, omission, sequence, action substitution, and quality/quantity, and therefore share only a few elements with the error system used in the WatAB but many with the Florida Apraxia Battery (FAB).

As discussed earlier, the presence of additional cues can enhance performance in AD. Foundas et al. (1995) and Heilman & Rothi (1993) report that context can enhance the performance of apraxic persons when actual tools are used. However, others have reported no differences (for example: De Renzi, 1985). Naturalistic Action (Schwartz & Buxbaum, 1997) indicates that the more realistic the action performed in the most realistic setting, the better the performance. The proponents of this philosophy and others (Roy, Square, Adams, & Friesen, 1985) indicate that the appearance of apraxia can be eliminated when a person diagnosed by the common gesture tests is assessed with real world tools in a realistic setting

Given our findings in Study #1 and the above information from the literature we now ask the first question about context which is the third question in this study:

c) <u>Does actually holding the tool when Pantomiming improve performance relative to the Object Use task, where only vision of the tool is available or when no visual tool information is available?</u>

We therefore designed a new Pantomime test: Object Use Hold. In this case the instructions are the same as for Object Use Show ("Show me how you would use this",) but this time the actual tool is presented to the participants for them to hold and use in their demonstration. We predict the comparison of the performance on the standard Object Use Show to the Object Use Hold tests will reveal less accuracy on the Show version than on the Hold version for the AD group.

In this research it is predicted:

- that the AD group as compared to the Normal Control group will exhibit less accuracy on the Pantomime by Tool and Object Use Show than the Object Use Hold Pantomime tests, since the addition of the context (holding the actual tool) will enhance performance.

(ii) Full task context versus visual tool information only

Secondly, in our continued look at context we want to compare Object Use Hold which involves the minimal context to a task where the most context lies. Maximum context would exist when the object and task conditions are present (i.e.: correct tool and the item upon which the object is commonly used). The use of such a high level of context is supported by Naturalistic Action. The WatAB also has a more naturalistic sub-test: the Tool Selection Task (TST). However, this test uses as its tasks extensions of the other items used in the more general praxis sections of the WatAB. The only difference in the TST is that the items such as eating are specific and the presentation of each task provides more cues as to the action required. That is, rather than ask someone to pretend they are eating (whether shown the implement or not) they are now asked to actually use the correct tool to eat some of the pudding placed in front of them. It is therefore possible that no instructions are necessary, as the presence of the pudding and a spoon could be enough to trigger the correct action. However, in the WatAB as well as the FAB, the TST is not that simple, as the person is asked to pick up and use the correct tool from a choice of a few tools. The foils are chosen based upon their relative shape or function as related to the correct tool. We can further vary the number of contextual cues available as the same tasks (e.g., eat some pudding) are presented again, but this time the correct tool is not amongst the foils. Instead there is a next best alternative, which is chosen based on the broad features of the correct tool. Three foils are again present which indicates the need for the participant to understand the correct action and locate a tool which can allow this action. In the example of eating pudding the correct tool choice is a spoon and the correct choice in the alternative presentation is a tongue depressor.

This leads us to our fourth question of this study and addresses part 'ii' of our further analysis of context :

<u>d) Does providing full task context, as in the TST, enhance gesture performance relative to when only visual tool information is available?</u>

Given the above descriptions we predict that when comparing the Object Use Show and Object Use Hold and TST real and TST alternate tasks, there will be a gradient of increasing accuracy for only the AD groups.

In this research it is predicted:

- that in AD there will be a gradient of increasing accuracy in the following order: Object Use Show: Object Use Hold: TST alternate: TST real, since this order reflects a gradient of increasing context.

Further exploration of Conceptual Praxis Knowledge via the TST

Study # 2 indicated the importance of Conceptual knowledge in praxis performance in AD. Heilman's group (1997) suggest that one other conceptual aspect not previously tested in the literature which may impact on praxis performance is mechanical knowledge. Both Heilman and Roy (1999) have devised a Tool Selection Task (TST) to examine mechanical knowledge by comparing performance in the real and alternative conditions.

In order to determine the presence of conceptual apraxia there must be a loss of knowledge of the types of actions used with tools, a loss of associative knowledge dealing with tools and the objects which receive their action, and a loss in the mechanical knowledge of tools (i.e.: nature of tools and their specific advantages). Content errors (for example: using the incorrect tool in the correct gesture or using their hand as the tool) should be most commonly seen (Heilman, et al 1997) if conceptual apraxia is a disruption of the conceptual system as proposed by Roy (1992). To test this hypothesis Heilman et al. (1997) used his TST to test the associative knowledge of tools with action. Additionally, an alternate form where the correct tool was not present but a reasonable and functional alternative was present amongst the foils was used to test the mechanical knowledge component of the action semantic (as phrased by Heilman et al., 1997, and Ochipa et al., 1992). Their reasoning indicated that choosing the best alternative tool was a measurement of mechanical knowledge because the choice would be based upon the critical attributes necessary to complete the task, and thereby providing a mechanical advantage when the tool/object knowledge cannot be used to solve the problem. Ochipa and colleagues (1992) suggested that AD patients with apraxia were most impaired on the alternative selection task although they were also poor in all measures of conceptual apraxia.

On Roy's (1998) version of the TST, the choice of a correct tool is also recorded, but then the participant is expected to actually use the chosen tool to complete the task. In the WatAB version, it is possible to determine not only whether the correct tool was chosen, but also the amount of time spent choosing a tool and the accuracy of the gesture used. The WatAB's TST thereby allows the examination of gesture performance in terms of both accuracy and time (Reaction, Selection and Action) and to ask how differences between these conditions are expressed. This is also the only place in Roy's battery where the more subjective measurement of error is used (i.e., correct tool chosen?) an approach which is more routinely included in the error system of Heilman's group's (1997) Florida Apraxia Battery.

As per the above descriptions of the WatAB TST we can now pose our fifth question of this study:

e). Does the Alternate condition differ from the Real in terms of performance accuracy and temporal measures?

Heilman's group (1997) report that in stroke patients the most salient measure of mechanical knowledge was that of the selection of a correct tool in the alternate condition. We propose to measure not just the accuracy of the movement used to complete a task and the time spent choosing a tool, but whether the correct tool was chosen. We would therefore predict from Heilman's work the qualitative measures of selecting a correct tool and our measure of selection time will indicate group differences with the AD group presenting the most difficulty in gesture performance.

In this research it is predicted:

- that the alternate condition of the TST will show less accuracy than the Real condition of the TST, since the absence of the correct tool will increase the number of errors made by the AD group.
- that in the alternate condition the AD group will take longer to chose the appropriate tool than will the Normal Controls, since the ability to select a tool in the alternate condition is defined by Heilman's group (1997) as a measure of mechanical knowledge.
- that the AD group will select the incorrect tool more frequently in the Alternate condition and require more prompts than will the Normal Controls.

Further analysis of the effect of Conceptual Praxis Knowledge using a Measure of Creativity

Additionally, Heilman et al. (1997) suggested that persons with impaired mechanical knowledge may not be able to understand the mechanical character of problems, and therefore such persons would be unable to solve novel mechanical problems. However, the test used to try to measure this hypothesis was one in which participants were asked to solve mechanical puzzles where the goal was to retrieve a wooden block. Each puzzle had two versions - one where fingers were enough to solve it and the other where a tool must be devised and used. While indeed these tasks would logically appear to measure mechanical knowledge/ability, they could also be measuring the amount of creativity a person can apply to solving any problem. It is possible that the more creative a person is the greater the number of possibilities he/she will envision, regardless of whether he/she has the skill to employ any of the possibilities. Further, it is possible that creativity may be a function of selecting a tool in the alternative condition of the TST. Therefore, instead of using mechanical puzzles we decided to test the creativity theory and added such a measure to this study.

The method of measuring creativity we chose comes from Guilford's Measures of Creativity (1978). The particular measure chosen was the Alternate Uses Test (AUT), as it asks participants to name new uses for common household items. Therefore, there is some similarity to the TST alternate condition which also asks for a common tool to be used in new ways. Of course there is a major difference in that the AUT relies on verbal responses, and the

TST only on motoric responses. The addition of the AUT leads to the sixth question of this study:

f) Does AD performance on the Alternate condition of the TST relate to creativity as measured by the AUT?

We propose to address this question in two ways. Firstly, we will compare group performance on the Alternate Uses Test. For that analysis we predict that the AD group will be less successful in generating alternate uses for common objects than the Normal Control group. Secondly, we will determine which TST measures relate to performance on the AUT via regressing the Reaction, Selection, and Action times for each of the two conditions (real and alternate) on the AUT score for the AD group.

In this research it is predicted:

- that on the Alternate Uses Test (AUT) the AD group will generate fewer alternate uses for common objects than will the Normal Control group.
- that Selection time in the Alternate condition will predict AUT performance in AD, as per our interpretation of the Heilman group's (1997) hypothesis.

METHOD

Participants:

The AD group of 12 participants (8 females and 4 males), including three mild, seven moderate and two severe probable AD as measured by the NINCDS/ADRDA diagnostic battery were recruited from the Geriatric Assessment Team of the Willett Hospital, Paris. All potential participants were first selected based upon the additional criteria: that the diagnosis of AD had been made at least one year ago, thereby ensuring that the participants had been seen at least twice by the Team's staff; that a computerized tomography (CT) scan had been completed to confirm atrophy in the medial temporal lobe(s); and that other possible diagnoses and complicating conditions had been ruled out by the Team's Geriatrician. The diagnosis of AD was determined by a Geriatrician using the NINCDS/ADRDA criteria, the Modified Mini Mental State Exam (3M, Folstein, Folstein, and McHugh, 1975), Geriatric Depression Scale (GDS, Brink et al, 1982) and Computerized Tomography (CT). Written consent was obtained from the appropriate source (person with Power of Attorney and/or the possible participant) by the Team's Nurse Practitioner prior to the names being released to the researcher. Research sessions were subsequently booked either by the Nurse Practitioner or the researcher. Testing was completed in one session wherever possible, unless the participant requested continuation at another time.

Twelve healthy control participants, (8 females and 4 males) were recruited from a variety of local Paris Senior's Groups, to match as closely as possible the age and educational level distribution of the AD patients. All were asked to complete a health survey during the recruitment process so as to ensure that no possible complicating (motor, biological and emotional) conditions were present. Written consent was obtained from each control group member as the first part of the research session.

Due to the relatively small number of left-handed participants (one) in this study, all pertinent data was coded for the dominant hand.

Materials:

All AD participants previously received the full battery of medical, neurological and neuropsychological tests used as part of the Willett Hospital's Geriatric Assessment Unit. All other testing and scoring was completed by the researcher, or specifically trained research assistants. The Nurse Practitioner assisted with greeting, escorting, and with some participants, the completion of the Mini Mental State Exam (MMSE, Folstein 1975) under the supervision of the researcher. Cognitive status was assessed at entry to the study via the MMSE. As part of the agreement with the Willett Hospital all MMSE scores of their patients were, with the relevant consent, added to the appropriate medical record at the conclusion of the study.

All participants received part of the WatAB and the entire TST. For the WatAB, only the eight Transitive, Representational gestures were presented for Pantomime by Tool and Concurrent Imitation. There were two new additions to the standard WatAB. In the new Concurrent Imitation Mirror condition, the same instructions and gestures were used, but the participant was asked to imitate from the reflection of the examiner in the mirror placed directly in front of the participant. To perform the gestures the examiner stood immediately behind the seated participant. Additionally, the same Transitive Pantomime gestures were presented under the new Object Use Hold condition, when the unnamed object is actually handed to the participants to use in their pantomime.

The TST presented eight different tasks, each under two conditions presented in a randomized order (see Appendix A 3). Participants were presented with a tray of four tools and asked to pick up and use the best tool to, for example, eat some pudding (e.g., spoon). In the alternate condition, four tools were also presented, but this time none of the tools was the proper one but one was something that could be used to complete the task (e.g., tongue depressor). All items necessary to complete the task were present under each condition (i.e.: pudding of the participant's choice was available, or a cup of room temperature coffee/tea was placed directly in front of the participant). The eight tasks were: eat pudding, put sugar in tea, put jam on a slice of bread, style or fix your hair, stir a cup of coffee, pound a nail into a board, turn a screw, and put or transfer dirt into a pot. Prompts were given to participants if they did not move or touch a tool 10 seconds after the end of the instructions. Prompts were also given during the selection and completion of a task whenever no movement was noted for 10 seconds. Prompts were given in the form of: repeating the original instructions, providing a shorter version of the instructions "Pick the best tool to . . .", or to encourage completion of a task "Please eat some pudding". When the task involved eating, all participants were given a choice of pudding and all puddings were dietetic.

In this study, the Visual Object and Space Perception Battery (VOSP, Warrington and James, 1991) was completed by all participants. All sub-tests in this battery have few response demands with pointing or a one word answer sufficing. Each sub-test was designed to minimize the reliance on other cognitive skills, while testing one aspect of visual perception. The initial screening test of this battery was designed to assess shape detection via the detection of a degraded 'X' superimposed upon random patterns. A defective score on this initial test precludes the presentation of further tests. Scoring of all other tests was completed as per the test manual and consisted of recording the number of correct responses. The battery consists of eight other tests as follows:

■ Visual Object sub-tests

1.) Incomplete Letters requires the naming of degraded letters, constructed by photographing a letter through a random pattern, so that either 30% or 70% of the letter is obliterated.

2.) Silhouettes requires the naming of black silhouettes drawn from the outline of 15 inanimate objects and 15 animals rotated through varying degrees of the lateral plane.

3.) Object Decision requires pointing to the one out of four silhouettes most like a real object. The other three are similar looking distractors. Two-dimensional silhouette drawings of objects were produced from the original three-dimensional shadow images by tracing the projected out-line of the object at an angle of rotation, at which 75% of a Normal Control group could identify it.

4.) Progressive Silhouettes requires the naming of an object which is presented as a series of

10 silhouettes constructed by varying the angle of view from a rotation of 90° to 0° along the lateral axis.

■ Spatial sub-tests:

1) Dot Counting requires counting the number of black dots on a white card.

2) Position Discrimination requires detecting which dot is centred when presented with two adjacent squares. Each square has a black dot printed within, one is exactly centred and the other is close to centre.

3) Number Location requires identifying the number with the corresponding position to a black dot shown in an vertically adjacent square. Of these two squares, one contains a black dot and the other contains randomly placed numbers.

4) Cube Analysis requires counting blocks from black outline representations of three dimensional arrangements of square blocks.

Additionally, the Alternate Uses Test (AUT) was completed by the participants. This test was originally designed as part of Guilford's 1978 Measures of Creativity battery, which according to Lezak (1995) assesses flexibility of thinking and can be used to distinguish convergent from divergent thinking. The AUT requires that the participant list as many uncommon uses for a common object (and therefore bears some similarity to the TST, which uses common household tools) as possible within the four minute time limit. There are two sets of three objects each: shoe, button, key, and pencil, automobile tire, eye glasses. This measure was added to try to determine if creativity, as measured by the AUT, would bear any relationship to the score on the alternate choice form of the TST.

Design and Procedure

Participants were required to Pantomime and Concurrently Imitate with their preferred hand, eight Transitive Representational gestures (e.g., use a hammer). Participants were seated in a comfortable straight backed chair with the examiner directly seated in front of them and videotaped during his/her one session, in which the entire 40 gestures were presented in a well illuminated, ventilated comfortable room. Mirrors were placed behind and to the sides of participants so that all aspects of their gestures would be seen in the videotape. In the Pantomime condition, the object was shown to the participant and he/she was asked to pantomime its use. In the Imitation condition, the examiner demonstrated the gesture and the participant was asked to imitate it, while the examiner continued to demonstrate throughout the participant's attempt. In the new Imitation condition the mirror was moved to rest directly in front of the participant with the examiner standing directly behind in clear reflected view of the participant. All gestures were presented by the examiner as per above with the reminder to the participant to use the same hand as was the examiner. In all cases the examiner used the dominant hand of the particular participant.

For the TST, all participants were seated at a table of comfortable height in the same room as above. Mirrors were again positioned so that all aspects of the gestures would be seen on the videotape. Trays were placed within six inches of the table edge. Participants were encouraged to place their hands on the table edge within view of the camera. Items for the individual tasks were placed in front of the participant on the tray when space allowed or on the table directly in front of the participant (i.e.: dirt transferred).

All other testing was completed with the examiner sitting directly across the table from the participant who was again seated in a comfortable chair, in a well illuminated and ventilated room. Within the limits of each test, the instructions were presented as simply as possible, and task demands kept to a minimum.

Scoring:

The performance videotapes for all but the TST portion of the WatAB were scored for each participant on five dimensions: location of hand in space relative to body, posture of hand, action (the movement characteristics of the gesture), plane of movement of the hand, and orientation of the hand (see Appendix B 3). On the TST, only three error dimensions for tool use were scored: action, orientation, and location, all of which were thought to best highlight the causes of error under the more "natural" and highly cued conditions of the TST. All of these performance dimensions were derived from the previous work of Roy and Square, (1985) and were based upon the particular features of movement found by Stokoe (1972) to be important in manual signing. Each dimension was rated on a three point scale (two = correct, one = distorted, and zero = incorrect), reflecting the degree of accuracy and exhibiting a high inter-rater reliability (0.93). A composite score was then derived for each gesture under each performance condition. This score reflected performance scores across either the five or three dimensions and was expressed as a percentage of the total possible score (six or 10) for each gesture/task.

Also for the TST, the number of frames of videotape were measured for the following: 1) Reaction time as defined by the number of frames from the end of the verbally presented instructions to the point where the participant's hand was lifted above the table, 2) Selection time as defined by the number of frames from the end of reaction time to the point where the participant picked a tool off the tray to the point where the entire chosen tool was observed on the videotape to be off the tray, and 3) Action time as defined by the number of frames from the end of Selection time to the point where the conditions of completing the task were complete (e.g., two revolutions of the spoon for stirring).

For the AUT overall score and for the VOSP individual sub-tests' scores were kept as per the instructions of the authors of the battery.

RESULTS

Demographic Information:

An ANOVA was performed to determine group differences with respect to the demographic variables, the AUT, and the MMSE. The results are summarized in Table 9. No differences between the AD and control groups were noted for age, and education. As the groups were matched for gender it was not included in the analysis. An earlier ANOVA had indicated a difference between the groups for education. Plotting of there data resulted in the identification of one outlier in the control group with 19 years of education. When this person's educational level was removed from the analysis no differences were noted and this is reported below. Group differences were found for the MMSE scores, which indicates that the AD group performed at significantly lower levels than did the control group.

Table 9: Main Demographic and Non-praxis Features of Alzheimer's Disease (AD) group and Normal Elderly Controls.

TEST	AD	CONTROLS	F	p
Age (years)	80.69	78.74	0.677	ns
Education (years)	10.92	12.73	3.49	ns
MMSE (score)	16.75	29.08	42.80	.000

Although the original intention was to analyse the data of this study wherever possible by stage (normal, mild AD, and moderate AD), the very few participants in the severe category (two) and the relatively small sample size of this study made this plan infeasible. Due to the rather large number of comparisons needed and to protect the experimental error, the alpha value was changed to 0.01 except where number of comparisons indicates the use of Bonferroni's correction and it is reported therein. Lastly, in the following results where the Levine's test for homogeneity of variance was found to be significant at 0.05, the adjusted degrees of freedom and other values (eg. t or p) are reported. Further, all performance was videotaped and later scored by the researcher and one highly trained assistant. The inter-rater reliability on a randomly chosen subset of scores for 10 participants indicated a significant degree of agreement between the raters with the kappa coefficient (Hartmann, 1977) to be at least 0.93.

a) Is there a difference in Imitation performance when AD participants do not have to do a spatial transformation vs. when they do?

To see if manipulating the presentation of the Concurrent Imitation test by having the participant look at the examiner's reflection in a mirror would enhance gestural performance, a two by two ANOVA with group (AD and Control) and task (Concurrent Imitation Normal and Concurrent Imitation Mirror presentation) as the between the subjects' factor was completed on the composite scores of these tasks. Only a main effect for group F (1,43) = 16.26, p = < .000 was found, which again reveals more accuracy for the Normal Control participants (M = 95.30) than the AD participants (M = 87.21). These results (see Table 10) indicate that as the presence of a mirror does not enhance performance, a spatial transformation may not be involved in our findings of no protection for Concurrent Imitation.

Table 10: Mean accuracy Composite Scores for Concurrent Imitation Normal & Mirror

	Concurrent Imitation Normal	Concurrent Imitation Mirror
AD	88.12	86.22
Normal Controls	95.49	95.1

Note: Con. Imitation Mirror represents the modified Concurrent Imitation task presented in this study where the individual was to imitate the examiner's reflected image.

In summary:

- Contrary to our prediction, the Concurrent Imitation Mirror condition does not result in more accurate performance for the AD group than on the Normal Concurrent Imitation presentation.

b) Do the AD participants exhibit poor visual perceptual abilities and are these related to imitation performance?

(i) Group comparisons on the VOSP:

No participant was excluded from the complete VOSP battery due to poor performance on the screening test, and in fact no statistical difference between the groups was found for performance on the screening test. With respect to the other eight sub-tests of the VOSP battery, the ANOVA by group (Normal Controls and AD) did indicate differences which suggests that the AD group encountered more error in the number location and silhouettes Sub-tests than did the control group (see Table 11). The Silhouettes test is from the Visual Object class while the number location test is from the Spatial class of sub-tests. Review of the means indicates that as predicted, the AD group consistently performed with less accuracy than did the Normal Control. This occurred only to a significant extent on 2 sub-tests. This result offers some confirmation that poorer visuo-perceptual skills may be influencing AD performance. As we had predicted and as Binetti et al. (1996) had reported, the AD group did specifically have difficulty in the Visual Object class of tests (Silhouettes). However, our results also indicate that in our sample of persons with AD, difficulty occurred in both the Spatial and the Object Classes of Sub-tests. At this point, it is not clear if AD selectively impairs spatial abilities as measured by the VOSP, nor are we able to determine which particular spatial perceptual skill is affected, since the VOSP has not been accepted as a standard in its field.

Table 11: Mean Accuracy Performance scores of the VOSP Sub-tests for Normal Controls and AD.

VOSP (score)	AD	Control	F	p
Screen:	17.67	19.67	3.9	ns
Visual Object Sub- tests				
Incomplete Letters	14.83	19.50	5.48	ns
Silhouettes	8.75	16.25	21.56	<0.01
Object Decision	12.67	15.58	3.83	ns
Progressive Silhouettes	15.33	12.67	4.81	ns
Spatial Sub-tests:				
Dot Counting	9.08	9.83	1.23	ns
Position Discrimination	16.83	19.33	2.29	ns
Number Location	4.67	8.83	14.47	<0.01
Cube Analysis	5.58	8.08	6.07	ns

(i) Regression of the VOSP on Imitation and Pantomime:

All of the VOSP tests for the AD group were regressed on the total composite score for the Concurrent Imitation and Pantomime tests using a step-wise forward regression analysis. Additionally, the VOSP silhouette sub-test was further split into two scores: one for animals and one for objects. In order to reduce multicollinearity we examined the intercorrelation matrix of the scores of the VOSP tests and planned to eliminate variables with correlations of ≥0.80. However, none were found. The results of the regression analysis are summarized in Table 12 and indicate that the best predictors of group performance in the Concurrent Imitation condition are Dot Count from the Spatial category of Sub-tests and the Object Decision sub-test of the Visual Object category from the VOSP.

Table 12: Multiple Regression Model of VOSP sub-tests on Concurrent Imitation tests (Stepwise Method).

Variables in the Equation	B	Standard Error of B	β	T	p
Object Decision	0.612	0.177	0.509	3.45	0.003
Dot Count	0.453	0.197	0.311	2.21	0.04
Constant	158.05	17.43		9.07	0.00

The results of the regression analysis on the Pantomime test indicate that no model was found in the analysis, suggesting that none of the VOSP sub-tests could predict AD Pantomime performance. This result is consistent with our prediction that, while Pantomime performance may still be poor in AD, it is not influenced by visuo-perceptual skills as measured by the VOSP.

In summary:

- Somewhat consistent with our prediction, the AD group exhibited less accurate performance than the Normal Control group but on only one (Silhouettes) of the visual object perception group of VOSP tests. Contrary to our prediction, the AD group also exhibited less accurate performance than the Normal Control group on one of the spatial sub-tests (Number Location) of the VOSP. These results support Binetti et al.

(1996, 1998) as we also find the Silhouettes sub-test to exhibit group differences. These results do not support Binetti et al. (1996, 1998) as we also found that the Number Location sub-test displayed group differences.

- Only partially consistent with our prediction, was that only one of the VOSP Visual Object sub-tests (Object Decision) predicts Concurrent Imitation performance. Contrary to our prediction, one of the Spatial sub-tests (Dot Count) also predicts Concurrent Imitation performance in AD. Consistent with our prediction none of the VOSP sub-tests predicts Pantomime performance.

c) Does actually holding the tool when Pantomiming improve performance relative to the Object Use where only vision of the tool is available or when no visual tool information is available?

In order to compare performance on the three Pantomime tests, a two by three ANOVA with group (AD and Control) and task (Pantomime by Tool, Object Use Show & Object Use Hold) as the between the subjects' factors was completed on the composite scores of these tasks. Only a main effect for group, F (1,62) = 7.71, p = .007, was found. Review of the means revealed that the AD group (M = 77.92) had significantly lower accuracy than did the control group (M = 92.77). Although not significant at our adjusted alpha level, a main effect for task (Object Use Hold: M = 92.91; Object Use Show: M = 86.88; and Pantomime by tool: M = 76.31) was found to be significant at an alpha of 0.05, F (2,62) = 3.81, p = .027. A power calculation revealed that the task effect would have been significant with a N of 29. The results are summarized in Table 13. However, a review of the means indicates that, as predicted, an increase in contextual cues enhances performance for AD (in increasing order: Pantomime by Tool (61.68), then Object Use Show (61.88), and then Object Use Hold (80.36)).

Table 13: Mean accuracy Composite Scores for Concurrent Imitation Normal & Mirror, Object Use Show & Hold and Pantomime by Tool

	Object Use Show	Object Use Hold	Pantomime by Tool
AD	61.88	80.36	61.68
Normal Controls	96.88	91.68	90.73

Note: Object Use Hold represents the modified Pantomime task where the tool was actually held by the participant.

In summary:

- Consistent with our prediction, even if not statistically significant in this study, is the trend of the AD group exhibited less accuracy on the Object Use Show than the Object Use Hold Pantomime tests, since the addition of the context (holding the actual tool) enhanced performance.

d) Does providing full task context, as in the TST, enhance gesture performance relative to when only tool information is available?

To examine whether the addition of tactile and visual (contextual) cues can affect error scores on related apraxia tests, a two by four ANOVA with group (AD and Control) and test

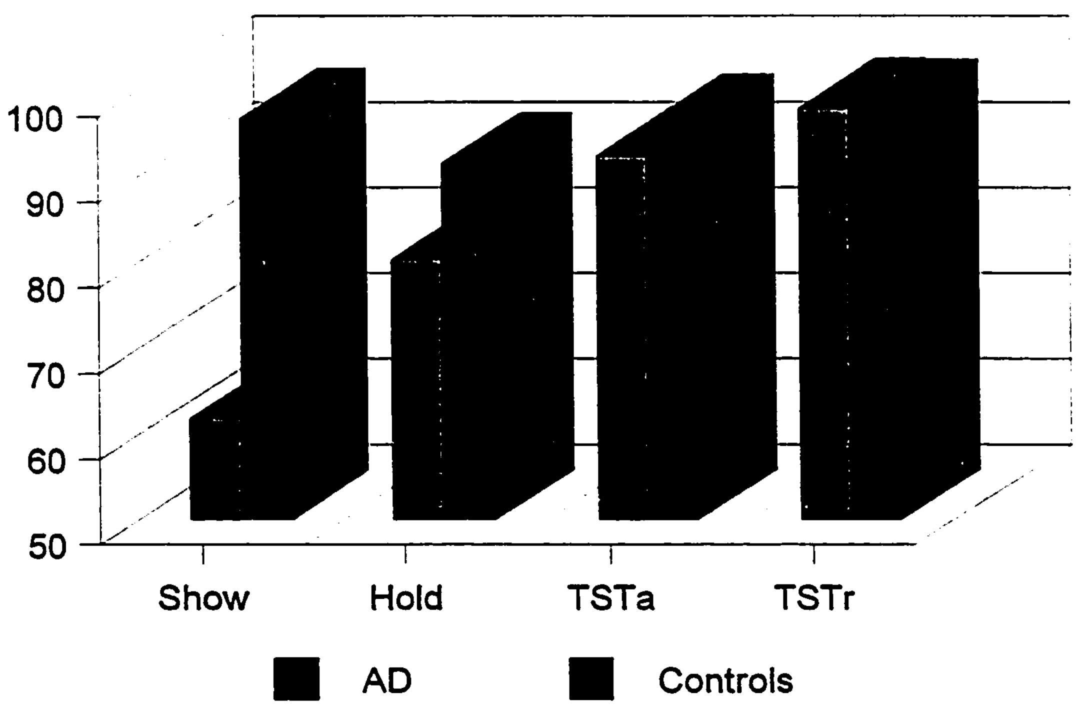
(TST alternate condition, TST real condition, Object Use Show and Object Use Hold) as the within subjects factors was completed on the composite scores for each test. An interaction effect for group and test was found, F (3,88) = 4.56, p = .005 (see Tables 14 and 15). Post-hoc testing indicated that the tests were significantly different from each other for the AD group, F (1.21, 13.33) = 6.032, p = .002, group, but not for the Control group. Within the AD group, there were significant differences between the following: Object use Show vs both TST Real and Alternate, and Object Use Hold versus both the TST Real and Alternate conditions (see Tables 14, 15 & Figure 2). This indicates that only for the AD group does performance change across the tests, with a trend for accuracy increasing for Object Use Show to Object Use Hold and then to TST alternate and real conditions. Therefore as per our hypotheses the addition of cues did appear to enhance performance in AD across Pantomime and more Naturalistic settings.

Table 14: Mean percentage accuracy composite scores for the AD and Controls on the TST alternate and real tests and the Object Use Show and Hold tests.

	Object Use Show	Object Use Hold	TST alternate	TST real
AD	61.68	80.36	92.47	98.03
Control	96.88	91.68	96.20	97.91

Table 15: Summary table of the post-hoc results of differences between the two Object Uses Tests and the TST conditions for the AD group.

	t	df	p
Object Use Show vs TST alternate	0.25	11	0.029
Object Use Show vs TST real	2.85	11	0.016
Object Use Hold vs TST alternate	0.481	11	0.001
Object Use Hold vs TST real	3.92	11	0.002



Note: Show and Hold stand for Object Use Show and Object Use Hold.

Figure 2: Graph of the mean accuracy performance of the AD and Control groups for the Object Use Show and Hold and the TST alternate and real tests.

In summary:

- Consistent with our prediction in AD there is a trend of increasing accuracy in the following order: Object Use Show: Object Use Hold: TST alternate and TST real. These results indicate the importance of increasing context in AD performance.

e) Does the Alternate condition differ from the Real in terms of performance accuracy and temporal measures?

(i) Using composite scores:

In order to examine differences between the groups across conditions and tasks, a two by two by eight ANOVA was completed with group (AD and Control) as the between subjects' factor and condition (real and alternate) and task (spread jam on bread {bread}, dig dirt {dig}, comb hair {hair}, pound a nail {nail}, eat some pudding {pudding}, turn a screw {screw}, stir a cup of tea {stir}, and spoon sugar into cup of coffee {sugar}) as the within subjects' factors on the composite error scores of each of these tasks. No significant main effects or interactions were found for any of the factors. It was then decided to use the time data to see if group differences existed therein, and if there were any significant differences between the alternate and real conditions (see Table 16 and Appendix C 1).

Table 16: Summary of the Mean Accuracy Sores for the Error Dimensions on the TST for both the Real and Alternate Conditions.

Task	*Alternate Condition*	*Real Condition*
Bread	96.97 / 98.61	97.00 / 98.66
Dig	89.39 / 100.00	98.66 / 100.00
Hair	95.46 / 97.22	91.66 / 96.97
Nail	93.33 / 100.00	95.80 / 100.00
Pudding	98.49 / 100.00	100.00 / 100.00
Screw	84.72 / 90.28	94.45 / 97.17
Stir	96.67 / 100.00	98.62 / 95.33
Sugar	95.46 / 98.61	100.00 / 100.00

Note: All values are listed as means of AD / Control.

(ii) Using temporal data:

In order to examine whether Reaction time, Selection time, and Action time differed by Real or Alternative presentation or group performance, a two by two by three ANOVA with group (AD and Control) as the between subjects' factor and condition (Real tool and Alternate tool presentation) and Time (Reaction, Selection and Action) as the within subjects' factors was completed on the composite scores of the eight tasks for each of the times (number of frames of videotape). Unfortunately with our alpha cut-off as set at 0.01, no significant results were found. While no post-hoc tests could be completed on these non-significant results the means are presented in Table 17. Reviewing the means indicates certain trends. Firstly for the AD group the average number of frames of videotape ($\underline{M} = 231.90$) was higher in the Alternate condition than for the Real condition ($\underline{M} = 134.70$), except for the Action time where the means were both high but similar. Secondly, the Control group had an almost equivalent number of frames across these two conditions (M = 124.03 and M = 126.72 for alternate and real conditions respectively). The means also indicate that for the AD group the alternate selection times appear quite large as opposed to those of the real condition, thereby indicating that the Alternate Selection time for the AD was the longest as per prediction. These suggestions are offered as indicators of directions for future research. To determine at what point a larger sample would have provided significant results at the 0.01 alpha level, we completed a power analysis using the observed power for the time main effect of 0.740 and concluded that our results would have been significant with a N of 26. We therefore suggest that the analysis of differences in temporal TST data should not be ignored in future research with set of at least 26 participants.

Table 17: Mean Number of Frames of videotape for Reaction, Selection & Action Times in the TST Real and Alternate Conditions.

Real Condition:	Reaction	Selection	Action	Overall Mean
Normal Control	60.24	40.51	191.38	126.72
AD	102.26	110.45	216.42	134.70
Alternate Condition:				
Normal Control	140.26	91.54	140.29	124.03
AD	178.34	271.72	245.93	231.90

(iii) Using subjective error data:

The more qualitative types of errors made by participants on the TST were coded and scored for the respective group. Individual tests were completed with an adjusted alpha of 0.01, with only significant results being included in the following.

Of particular interest was the greater number of prompts (verbal encouragement to try or continue the task) required by the AD group on the TST tests. The AD group ($\underline{M}$ = 20.5) required significantly more prompts, $\underline{t}$ (3.35) = 11.13, $\underline{p}$ = .006, in the Alternate condition than did the Normal Controls ($\underline{M}$ = 1.3). The results for the Real condition, while not significant at 0.01, do indicate that the AD group ($\underline{M}$ = 9.0) still required more prompting than did the Controls ($\underline{M}$=1.58).

Ninety-eight percent of the 16 tasks were completed by the Control group, compared to 88.55% of the AD group. Comparison of the groups' performance for selecting the incorrect tool at least once revealed a significant difference, $\underline{F}$ (1, 22) = 27.407, $\underline{p}$ = < .001. In the AD group, the incorrect tool was selected at least once on two percent of the tasks for the Real condition and 20% for the Alternate condition. The Control group selected the incorrect tool at least once on none of the tasks in the Real condition and only six percent of the tasks in the Alternate condition.

In the Real condition, the correct tool was successfully used by 100% of the Controls, as opposed to 95% of the AD group. For the Alternate condition, 92.2% of the Control group used the correct tool as opposed to 80.21% of the AD group, $\underline{F}$ (1, 22) = 20.98, $\underline{p}$ = .000. In this latter condition, most of the error was accounted for on one task - turning the screw, where the Alternate tool array included a skewer which had one flat side which did fit into the slot in the screw. Since the skewer was larger and reportedly easier to see than the correct choice (a dime), it was chosen and used as the correct tool by members of both groups.

All of these more subjective measures of error are presented here although they are not part of the regular Error System of the WatAB. In fact these measures are more like the ones used in Heilman's group's (1997) Florida Apraxia Battery (FAB). As the TST was used in this research for the first time we decided to review the more subjective error types. The presence of the differences between groups on these types of error indicates the need to develop a comprehensive error scoring system (objective and subjective) so that we could better determine the full extent of errors made in AD on all parts of the WatAB.

In summary:

- Inconsistent with our prediction, the Alternate condition of the TST did not show less accuracy than the Real condition of the TST, as there were no significant differences found.
- Consistent with our prediction, in the Alternate condition the AD group did display a trend to take longer to chose a tool than did the Normal Controls, since the ability to select a tool in the alternate condition is defined by Heilman's group (1997) as a measure of mechanical knowledge.
- Consistent with our prediction, the AD group selected the incorrect tool more frequently in the Alternate condition than did the Normal Controls.

f) <u>Does performance on the alternate condition relate to creativity?</u>

i) Group Comparison on AUT:

An ANOVA by group was completed on the results of the Alternate Uses Tests (AUT). The results indicate a group difference with the means indicating that the AD group was able to generate significantly fewer uncommon uses for familiar everyday items than was the Control group, $\underline{F}$ (1,13)= 32.99, p = < .001.

ii) Regression of the TST Time data on the AUT:

Prior to the regression to reduce multicollinearity, we examined the intercorrelation matrix and eliminated any of the six time scores (real and alternate: Reaction, Selection & Action) which were correlated above 0.8. None were found. The AUT was regressed on the Real and Alternate Reaction, Selection and Action times. The results indicate that the best prediction of AD AUT performance was Alternate Selection time (β = 1.004, $\underline{t}$ = -5.371, $\underline{p}$ = .003).

In summary:

- Consistent with our prediction, on the Alternate Uses Test (AUT), the AD group generated fewer alternate uses for common objects than do the Normal Control group.
- Consistent with our prediction, Selection time in the Alternate condition predicts AUT performance in AD.

DISCUSSION

a) Is there a difference in Imitation performance when AD participants do not have to do a spatial transformation vs when they do?

Our first attempt to address our previous uncommon finding of at least as much apraxia in AD under the conditions of Concurrent Imitation and Pantomime (for example see: Rapcsak et al., 1989; Lucchelli et al.,1993; Ochipa, Rothi & Heilman, 1992; Vitaliano, Russo, Breen, Vitiello & Prinz 1986; Della Salla, Spinnler, & Trivelli, 1996; Edwards, Deuel, Baum & Morris, 1991; and Rothi & Heilman, 1985) was to modify the method of presenting the Concurrent Imitation test. The new version consisted of having the participants imitate the gestures from the examiner's presentation being reflected in a mirror. We then intended to compare the results of this new version of Concurrent Imitation (mirror) with the usual version from the WatAB. We had predicted that if spatial transformations (i.e.: confusing left for right) were interfering in gesture production, then the new Mirror version would produce less error than would the Concurrent Imitation Normal version. This proved not to be the case. We can then conclude that, at least as measured by imitating a reflected gesture, spatial transformations do not appear to be contributing to our unusual finding of at least as much apraxia in Imitation as in Pantomime in AD. This finding led the investigation of visuo-perceptual skills. We had hypothesized that, according to Roy's (1996) model, some AD changes in visual analysis could be contributing to the lack of protection of gesturing under Concurrent Imitation. When we eliminate spatial transformation problems, we are left with the need for a more extensive review of visuo-perceptual skills.

b) Do the AD participants exhibit poor visual perceptual abilities, and are these related to Imitation performance?

Recall from above that we wished to focus next on visual perceptual skills which, as per Roy's (1994, 1996) model, could possibly be affecting AD performance in Concurrent Imitation. Our results, while promising are not conclusive. The results indicated that the AD group performed with less accuracy on only two of the sub-tests of the Visual Object Space Perception Battery (VOSP - Warrington & James, 1991), than did the Normal Controls. Almkvist (1996) and Binetti (1996, 1998) indicated that deficits in visual-spatial skills were a part of even the early stage of AD. Furthermore, they indicate that there is good evidence for the deterioration of visual-spatial skills as AD progresses and this is considered to reflect the neuropathological changes seen in AD. Our results support part of Binetti et al.'s (1996, 1998) work. We found that one Spatial sub-test of the VOSP did indicate group differences with the AD group exhibiting the most error in performance. We found, as did Binetti et al. (1996, 1998) that the Silhouettes test (where participants were required to name the object or animal depicted as a silhouette rotated through varying degrees from the lateral axis) was a source of significantly different performance between the AD and Normal Control groups. This task has fairly low task demands as it only required labelling the silhouette. Because of needing a verbal label, it is possible that the group differences are more reflective of the common AD difficulty with finding and using the correct word (Mulloy & Caldwell, 1998). However, unlike Binetti et al. we also found one of the Visual-Spatial sub-tests to display group differences - Number Location. In this sub-test, the requirement is to match the position of a dot with the position of a number in an adjacent identical box. It is not surprising that this test displayed group differences. The instructions are quite complex, as it is not an easy task to explain simply, or even mime what is required. However, there are two sample trials and correction of incorrect performance is allowed on both. Before we proceeded to present the actual test stimuli we ensured that, as per the manual, performance was at least approximately correct on the samples. But the group difference seen here may therefore be indicative of a failure on the part of the AD group to learn the task and/or to remember how to complete the task. Having a larger sample and either having equal numbers of Mild and Moderate AD or only focussing on Mild AD (as did Binetti et al. with 27 Mild AD and 21 matched Controls), may have indicated different results. From the results of the comparison of group performance on the sub-tests of the VOSP, we are unable to determine if in fact there are differences in visuo-perceptual skills between the AD group and the Normal Controls. It may be likely that the differences found were due to difficulties in language comprehension and expression. Nor can we determine if spatial or object recognition factors are more likely in AD, because we found only one sub-test from each category (Spatial and Visual Object). Therefore, we have an indication of the possible importance of both Visual-Spatial and Visual-Object tests and therefore of the need for further exploration of the use of the VOSP in AD.

Another reason why we cannot yet determine if in AD there is a Visual Object or Spatial type of defect, is that even with the regression analysis Concurrent Imitation performance in AD was best predicted by one test from each of the two classes of the VOSP. Even more interesting was that the two tests found by the regression were different from what our earlier analysis had indicated as those sub-tests displaying group differences. The regression indicated that the Object Decision (required to point to the most "real" object out of the four silhouettes) and the Dot Count (count the number of randomly placed dots on the page) sub-tests best predicted Concurrent Imitation performance in our sample of AD participants. Object Decision is listed in the VOSP (Warrington & James, 1991) manual under the Visual object sub-tests, while the Dot Count is listed under the Spatial Sub-tests. These two tests are thought to be the easiest on the VOSP, especially for AD groups. The Object Decision task does not rely on any verbal response from the participant, only pointing after analysing the features which indicate a "real" or common object (e.g.: purse, teapot etc). This should make it easier for persons with AD as they didn't have to name the object. The Dot counting task should not prove too difficult for AD as counting (up to at least 10 on the VOSP) is a skill known to be fairly well preserved in AD (Mulloy & Caldwell, 1998; Lezak, 1995).

What we can conclude from this work is that while there are two of the VOSP sub-tests which can predict AD performance in the Concurrent Imitation condition of praxis testing, none of the VOSP sub-tests can predict AD performance in the Pantomime condition. This indicates that there is something special about the Concurrent Imitation condition which is influenced by visuo-perceptual skills. Such a connection had been suggested by Roy's (1996) model and is confirmed herein, that at least for the Concurrent Imitation condition, the impact of changes in visuo-perceptual skills in AD is related to performance. This is, however, only a first step in understanding the relation between Concurrent Imitation and visuo-perceptual skills. More studies to replicate our findings will be necessary. Such research must include much larger and matched groups of Normal Controls, Mild and Moderate AD. Understanding how AD affects performance in Pantomime will have to be left for future work.

c) <u>Does actually holding the tool when Pantomiming improve performance relative to the Object Use task where only vision of the tool is available, or when no tool information is available?</u>

Our results indicate that as predicted, there is a trend that increasing the contextual cues enhances performance for the Transitive Pantomime tests of the WatAB. We found a trend which indicates that in our future work we should replicate this analysis with larger groups and preferably groups of equal size (Normal Controls, Mild and Moderate AD). The trend of as the context increases over the Pantomime tests (in increasing order of context: Pantomime by Tool, then Object Use Show, and then Object Use Hold) so does the accuracy of performance. Reviewing the means indicates that this appears true only for the AD group, since the means for the Normal Control group appear relatively stable. We can conclude that holding a tool enhances performance in AD on Pantomime tests.

Such performance can be explained by Naturalistic Action (Schwartz and Buxbaum, 1997) as this theory denotes the importance of the effect of context on performance. As AD is known to interfere with the comprehension of language even in early stages (Lezak, 1995), the addition of the contextual cues may allow persons with AD to by-pass the Conceptual system (defined by Ochipa, Rothi and Heilman, 1997, as being the most impaired in AD) and proceed directly to Roy's (1996) Production system. It may therefore be possible that the presence of a tool, by itself, elicits the correct motor sequence to complete a gesture. Whether this pattern of increasing accuracy of performance as context increases is true when an actual task is present to complete is investigated in the following question.

d) Does providing full task context, as in the TST, enhance gesture performance relative to when only tool information is available?

Above we found evidence that as the amount of context increased with respect of tool knowledge, performance improved in AD. We then wondered if the same pattern would hold when even more contextual cues are added. The extra cues would come from the opportunity to not only hold the correct tool, but also to complete the appropriate task given that tool. Such an opportunity is found on the WatAB's Tool Selection Task (TST). Recall that Naturalistic Action (Schwartz & Buxbaum, 1997) indicates that apraxia may not be present when tested under real life conditions, even when apraxia is diagnosed when tested under the more traditional gesture based methods (i.e., the opportunity to make a real sandwich compared to miming how to spread jam on a piece of bread). Our results in question # 3 above supported the idea for AD, i.e., the addition of tool information (being able to hold the tool) augments performance; and the results in question # 4 provided evidence that the addition of as natural a context as possible further augments performance. Using the TST we have demonstrated that as per our prediction, only for the AD group, does the addition of more naturalistic context improve Pantomime performance. This latter finding leads further support to our previous report of the trend of increasing context improving performance in AD. Schwartz and Buxbaum (1997) would suggest that our findings are not at all surprising as Naturalistic Action would have predicted that the greater the context and the more natural the setting the better the performance.

e)Does the alternate condition differ from the real in terms of performance accuracy and temporal measures?

Recall from Study #2 that we discussed the importance of exploring all of the concepts of Conceptual Apraxia. While Roy's (1996) model outlines the processes involved in the conceptual aspects of praxis, Heilman's group (1997) offers quite detailed explanations of the components which they define as part of conceptual apraxia. In study #2 we explored the first parts of the roles of cognitive processes: knowledge of gestures, objects and tools. Heilman's group (1997) has developed this knowledge one step further and includes an opportunity to explore mechanical knowledge: the nature of tools and their specific advantage. Mechanical knowledge is defined by Heilman's group (1997) as the ability to determine the necessary action when confronted with a task where there is no opportunity to rely on the most common or correct tool. Mechanical knowledge is also the understanding of: the goal of the task, the type of the mechanical action required, and the type of tool necessary to complete the task. Under this question we can address the first part of the Heilman group's (1997) definition - the ability to complete a task even when the correct tool is absent. Heilman's group (1997) predicted that the best measure of this type of mechanical knowledge would be found in the ability to select the best alternative tool in a naturalistic setting. However, Heilman's group (1997) only allow the selection of the correct tool, as the expectation is for the participants to point to their choice. Roy's (1998) TST goes further and has the participant select and use the tool to complete the actual task (e.g., select and use a spoon in the real condition or a tongue depressor in the alternate condition to eat some pudding).

We hypothesized that not only would our AD participants select the incorrect tool more often in the alternate condition, but that they would take longer to actually select the tool they would use to complete the task. We thereby had both subjective error and temporal measures of mechanical knowledge. While not significant at our set alpha of 0.01, the power analysis indicated that at only a slightly higher sample size (26), we would have had statistical evidence to support our prediction. However, a review of the means and the more subjective error data indicate that as per our prediction, the AD group appear to have both the longest Selection time in the Alternate condition of the TST, and the greater frequency of selecting the incorrect tool in the Alternate condition. We recommend that in the future, larger groups with balanced number of participants in each group (Normal Controls, Mild and Moderate AD) be used in our AD praxis research. Further, because the more subjective types of error are not routinely measured on the WatAB, we recommend that a more comprehensive error system be developed which would keep all the measures currently used, as well as add ones to measure the qualitative aspect of error (for example: body part as tool error = use hand to comb hand instead of pantomiming using a comb or brush).

f) Does performance on the alternate condition relate to creativity?

Recall from above that Heilman's group (1997) defined mechanical knowledge in more than one way. Above we examined the knowledge of tools and actions by whether a participant could select a tool even when few of the features of the common or correct tool are present in a useable but uncommon tool. Heilman's group (1997) also define mechanical knowledge as the ability to understand and solve mechanical puzzles. We hypothesized that creativity might equally be involved in solving mechanical puzzles. To that end, we employed a test of creativity which asks for uncommon uses of common household items, making it similar to the alternate condition of the TST. We wondered if it is possible that the AD group might be unable to envision using a tongue depressor as a spoon, and are more likely to view each object as capable of its most common function. Some evidence for this hypothesis came from the significant differences between the AD and control group's ability to generate new uses for common objects on the Alternate Uses Test (AUT). The AD group produced far fewer responses in all. Whether fewer responses are due to a lack of creativity or the well documented AD difficulties in word finding tasks is not clear at this time. However, what influence memory could have is not clear and should be the focus of further research. Holding onto the name of the common object for which they were asked to provide alternate uses may have been too demanding for the AD group, especially given the four minute time limit. No prompts (i.e.: repetition of instructions or the name of the common object) were given, and if used in the future, perhaps could assist to examine this issue of memory affecting performance on the AUT.

We had introduced the AUT as a measure of creativity for using common objects in new ways, much like the alternate condition of the TST. Consistent with our prediction, the best predictor of AUT performance in AD was Selection time in the Alternate condition. We now have additional confirmation of the importance of both Selection time in the Alternate condition in AD, and the continued use of the temporal measures on the TST. However, whether the use of the AUT was better or equivalent to the use of the mechanical puzzles used by Heilman and colleagues (1997) is not clear. In fact, we cannot compare our results to Heilman's group (1997) as different types of tests were used. We do know that to combine both mechanical puzzles and the AUT in future research would allow the examination of similarities or differences between mechanical puzzles and AUT. Therefore, for future research it is recommended that the use of mechanical puzzles such as the Heilman group (1997) used, might be best augmented by the AUT given with prompts for memory.

GENERAL DISCUSSION

Objective #1: Apraxia in AD

In keeping with our first objective, the five studies in this text were designed so as to explore some aspect of the presence of apraxia in Alzheimer's Disease. The first study examined Benke's (1993) suggestion that two forms of apraxia were present and dissociable in AD. In study number 1, we found confirmation of Benke's hypothesis that indeed different patterns of general apraxic performance exist. However, contrary to the literature (for example see: Rapcsak et al., 1989; Lucchelli et al., 1993; Ochipa et al., 1992; Vitaliano et al., 1986 and Rothi et al., 1997) our studies revealed that AD impairment was greater when tasks require the use of tools (Transitive), than when a gesture is used to communicate a specific meaning (Intransitive). Additionally, we found that there was no difference between AD performance under the conditions of Pantomime and Imitation.

Dissociation of types of apraxia was certainly suggested by Benke, 1993, and Rothi, Ochipa, & Heilman (1997). In fact the latter group suggest that in AD, the most common cause of apraxia may be due to a breakdown in the Conceptual system. This system includes knowledge of tools, objects, and actions. Roy (1996) suggests that a pattern where such conceptual information is lost or unavailable for use is indicated by a pattern of deficits in: Pantomime and Delayed Imitation, along with a failure to indicate awareness of tools, objects, and gestures), but an intact ability to concurrently Imitate gestures (P-, DI-, CI+, R-). Roy's

(1996) model goes one step farther than that of Rothi, Ochipa and Heilman (1997), as the pattern most commonly found in our research was one of more global impairment (P-, DI-, CI-, R-). Roy (1996) suggests that a pattern of deficits in all areas is due to a breakdown in all systems (i.e., Sensory-Perceptual, Production and Conceptual systems), where not only knowledge is impaired but also the response organization and control systems. Both models offer similar neuro-anatomical correlates for this pattern of apraxic response. The most likely condition under which this pattern would appear is when there is a diffuse and extensive neuronal degeneration such as that seen in the dementias. Almkvist (1996) offers that the deterioration in AD would cause a dissociation between the posterior association areas and the limbic system, which would leave the system which analyses gestural information (parietal lobe) disconnected from the system which produces gestures (motor cortex).

In our work, we found that the actual condition (e.g., Pantomime, Imitation) was not as important in AD performance as was the gesture type (Transitive vs. Intransitive) . This was a contradictory finding to that of the literature. Most authors (for example see: Rapcsak, et al., 1989; Lucchelli et al., 1993; Ochipa et al., 1992; Vitaliano et al., 1986) report AD performance differences between the two conditions, with less accurate performance under Pantomime as compared to Imitation. We then wondered why, in our AD sample, there was not protection for Concurrent Imitation? As we had evidence of an AD performance difference between gesture types, we began to explore this lack of protection for Concurrent Imitation by concentrating on Transitive gestures. While not frequently reported in the literature, Transitive gestures are considered to have an advantage (Rothi et al. 1997), as the presence of a tool may be enough to elicit the correct gesture. However, this fact alone may not be enough to explain our findings, as the presence of a tool may, according to Roy's (1996), model also engage the visual analysis system. It is therefore possible that there are some other factors influencing performance with Transitive gestures. We used this finding, and the finding that the most common AD pattern of performance was that of deficits in all areas, to suggest a path for future research. Apraxia under all conditions, according to Roy (1996) suggests a disruption among the sensory-perceptual, conceptual, and production systems. In fact, the first place where such a disruption can occur in Roy's (1996) model, is when the analysis of visual gestural information is not accurately completed. Hence, we began to explore the possibility of the role of visuo-perceptual skills in praxis performance.

We decided to begin to explore this possibility in two ways. Firstly, we examined whether our findings were a result of a simple spatial transformation (i.e, left - right confusion). Our results indicated that this explanation was not satisfactory, as we found no differences in AD performance between the standard presentation and the presentation using a mirror. Secondly, we examined visual-perceptual skills which are subsumed under Roy's (1996) heading of the sensory perceptual system. We concluded that the inclusion of a battery of visuo-perceptual tests was important for future work. Indeed the use of the VOSP demonstrated group differences on two out of eight of its sub-tests and allowed the identification of the Object Decision test as an important predictor of performance in Concurrent Imitation. Our findings provide an indication that object recognition is important in AD. Binetti et al. (1996,1998) suggest that disorders of object perception are associated with disruption to the temporal (ventral) visual processing stream and that spatial disorders are considered to reflect changes to the "where" system of the parietal lobe. Both processes are reminiscent of our finding that object decision and dot count are most predictive of Concurrent Imitation. It is possible that the Transitive gestures are particularly sensitive to detecting early changes in visuo-perceptual skills in AD. The sub-tests of a specific visuo-perceptual battery do support this hypothesis. Both tests which best predicted Concurrent Imitation performance relied on something other than simply left/right analysis of visual information, including shape discrimination and analysis of position in space, which are presumed crucial to the analysis of tools and gestures. Therefore it is recommended that a battery such as the VOSP remain a part of any future research on the WatAB in order to gather more information to either support or negate this hypothesis.

Another important finding of our work was that the particular Gestural test from the WatAB was not as important as was the group (Normal Controls, Mild AD and Moderate AD). However, we did find an indication of the importance of one of the Pantomime tests - the Object Use Show test. Significantly more error in the AD group was found on the Object Use Show version than on the picture based version. This lead to the hypotheses in the last study and our third objective that context could be affecting AD praxis performance. In the last study we modified the Object Use tests by presenting the Show version and a new version (Object Use Hold), where the tool was actually handed to the participant. We hoped to indicate that the more visual and tactile cues present, the greater the accuracy in gesture performance. We were indeed able to do so. In the future perhaps the results of including all three forms of the

Object Use tests (Show tool, Picture of tool, and Hold tool) might be important comparisons.

Objective #2: Relationship between Cognition and Apraxia

The second and third studies examined the relationship between cognition and apraxia. This was done via looking at both the Conceptual tests of the WatAB and the Dementia Rating Scale (DRS, Mattis, 1976), in conjunction with the Gesture based tests of the WatAB. The DRS is an accepted measure of cognitive status in AD (Tierney et al., 1996, Spreen and Strauss, 1998) and is used as part of a larger AD study at Sunnybrook Health Science Centre (Sunnybrook). The results of the correlational analysis indicated that the WatAB tests (both Gesture and Conceptual tests) were primarily highly and significantly correlated with each other and with the DRS. If the DRS is as effective as claimed (for example: Tierney et al., 1996; Spreen and Strauss, 1998) in its current form at contributing to a diagnosis of dementia such as AD, then the continued use of the WatAB in AD research is supported. With the exception of only two of the Conceptual tests, all of the Gesture based and Conceptual tests' scores changed as did the DRS scores. Such high correlations could provide some internal reliability to research based upon the WatAB tests, and suggest some further close examination of the use of the two tests which were not highly corelated with the DRS (Tool Identification by Function and Error Recognition).

Further, we consistently found that of the Conceptual tests, the three Naming tests (Tool Name, Action Name, and Tool Name by Function) were able to discriminate among the

Normal Controls, Mild, and Moderate AD. Together they represented a breakdown in what both Roy (1996) and Rothi, Ochipa, and Heilman (1997) would term conceptual praxis. It is also possible that the Naming tests, while designed to examine the knowledge or 'conceptual" aspects of praxis, may be negatively influenced by other issues such as word finding difficulties. We therefore recommend that future research include measures to ascertain the effects of verbal fluency changes in AD and to examine the possible influences such changes in verbal skills could have on performance on the WatAB. However, it is also possible that some aspect of visual-spatial dysfunction was also influencing the results of these three tests as all rely on some form of decoding a picture of an object. Whether this last component is a possible confound was beyond the scope of this research but could be examined in future work.

Objective #3: Addition of Context and Creativity

In keeping with the preliminary investigative nature of our research, Roy's (1999) TST (Tool Selection Task) was used here for the first time. The design of the TST stemmed from an attempt to gather information about tool knowledge and use, in another way than analysing object/tool and gestural information. Ochipa, Rothi and Heilman (1992) have devised a similar task which they have used with stroke patients. This was the first time the WatAB's TST had been used on a group of persons with AD. There are differences between these tests. In Roy's (1998) version the goal is to pick up and use the best tool to actually complete a task. In comparison, in Ochipa, Rothi and Heilman's (1992) version the goal is to point to the correct task. Given that Naturalistic Action suggests that a person can be apraxic on general tests of praxis but may not show any indications of apraxia in completing his/her activities of daily living (Schwartz, Buxbaum, 1996), completing an actual task would appear to be the better choice. Schwartz and Buxbaum (1996) suggest that actions completed with real tools in real situations may be bypassing gesture-motor or space-time processes in favour of motoric systems specialized for overly learned, automatic reactions subsumed by the supplementary motor system of the basal ganglia. Or, as per Liepmann's (1905) suggestion, it is possible that performance improves (becomes more accurate) as right hemisphere structures are brought into play, in response to the concrete nature of naturalistic action.

We examined the increase of contextual cues (Object Use Show, Object Use Hold), choose the best alternative (TSTa) and then choose the real object (TSTr)) and did find that greater amounts of contextual information improved performance. However, it is possible that while the method of measuring error remained the same over the tasks with an increasing number of cues, the tasks themselves were not completely identical. Only two were identical except for one manipulation: the difference between being shown an object and actually holding it. The third and fourth tests (TSTa & TSTr) involved similar tasks but the instructions were slightly more detailed than for the Object Use tests. Additionally, the TST tests actually provided additional cues in the instructions as to what task was expected (compare: "Show me how you would use this", to: "Pick up and use the best tool to slice bread"). Of importance was that the TST tests also differed in whether the correct tool was one of the choices or not, and the presence of the object to be acted upon (e.g.: nail partially driven into a piece of wood). We did find that more error was made in the Alternate condition than in the Real condition, again supporting that the presence of additional correct contextual cues increases accuracy of performance. To what extent these factors may have influenced our outcomes remains to be investigated. Schwartz and Buxbaum (1996) suggest that increasing the number of cues does not necessarily improve performance, although they also argue that the more natural the context the greater the accuracy in performance.

The definition of mechanical knowledge suggested by Heilman et al. (1997) includes the ability to solve mechanical puzzles and the ability to use familiar objects in new ways. Given this definition we added a measure of creativity to our last study. Creativity was chosen as it may be an important factor in the ability to solve mechanical puzzles and certainly to use familiar objects in new ways. Our method of measuring creativity asked persons to list new ways to use familiar objects. We found that the AD group performance was significantly poorer than was that for the Normal Controls. The AD group were unable to generate as many novel ways of using the objects as were the Normal Controls. Whether such differences in performance were due to word finding difficulties, a common symptom of AD (Appell et al., 1982), is not clear at this time and is recommended for future research. However, the use of the AUT may not be enough. It is recommended that in future the AUT and some form of mechanical puzzles (Heilman et al., 1997) be included.

One last key finding of the present work was the importance of selection time on the TST for the AD group. Our research supports the definition of Heilman et al., (1997), which suggests that the ability to select the correct best alternative to complete a common task is a measure of intact conceptual knowledge of tools. In that case, our findings with the AD group suggest that AD disrupts the conceptual knowledge of tools, not just as measured by the conceptual tests of the WatAB but also via the trend of longer selection times on the TST - especially for the alterative condition. Therefore, we have evidence to support Ochipa et al.'s (1992) hypothesis that apraxia in AD is primarily a cognitive disorder.

<u>Limitations of the Studies:</u>

Because of the preliminary nature of our research, in all of our studies presented here, the possibility exists that our findings are influenced by the small sample sizes. Even the much larger sample of the first study was not perhaps as large as it needed to be, to best determine which tests predict group membership. However, given the relative difficulty of recruiting persons with AD, especially when they must also otherwise be in good health, often means that research must be conducted whether as large a sample as desired is available or not. Research with larger and equivalent samples of Normal Controls, Mild, and Moderate AD is warranted to test all of our findings.

Other possible confounds for this work include the possibility that some of the AD group were receiving medication and some were not. When data collection first began at Sunnybrook, none of the AD participants were receiving any of the new medications. By the middle of 1998 when data collection ceased, many of the newly referred persons were receiving medications, especially if the disease was felt to still be in an early stage. Therefore it is possible that we have a mixed group for the first studies, and no information as to the type of medication prescribed. Again, in the second study a similar situation may have arisen. While many of the mild AD group had been prescribed a medication for their AD, some were taking it and some had refused, while others had stopped taking it either due to the progression of their disease or because of specific side-effects. This may be a variable for which we cannot easily control. Because the newer medications for AD are supposed to slow down the progression of the disease and enhance memory function, the picture of changes in skills in early AD may also be changing. Additionally, if the drugs are working, then some of our participants may be skewing the results towards less error. Given the number of new medications now available and the differences in their use for different genders (ie: estrogen is recommended for women and not for men), another potential problem is highlighted. The concept of medication being a possible confound is offered here as a caution for others and for our future work.

In keeping with the more naturalistic theme of the TST it could be argued that the TST, which uses real life situations to measure praxis performance, could be used as a measure of activities of daily living (ADL's). In order for the TST to be used as a measure of performance in ADL's several criteria must be met. Law and Lettes (1989) reviewed the existing methods of assessing ADL's and concluded that most did not have reliability (the extent to which a particular instrument measures true differences in ADL functions among persons). They claim that a good measure of ADL's must have good internal consistency and that the observer and test-retest reliability are essential. We have some preliminary indications which support Law and Lettes' criteria in that the error measures on the TST are highly and significantly correlated with each other, and with the gesture based tests. Evidence is also found in our high inter-rater reliability of scoring. Next Law and Lettes suggest that ADL tests should have validity, which is the degree to which a test measures what it was designed to measure. More research would have to be conducted to address this point, as the TST was designed more as a measure of praxis under natural conditions than as a measure of ADL's.

The error system of the WatAB is missing some very important measures. Rothi, Raymer, and Heilman in their 1997 description of the FAB (Florida Assessment Battery) review the error system used (please see Appendix A 5). They classify error quite differently from the system used in the WatAB. They suggest measuring content errors which include perseverations, related (playing a trombone is pantomimed when asked to pantomime playing a bugle), non-related, and hand (the hand is used as the tool - comb hair with fingers). Raymer and Ochipa (1997) have indicated the importance of content errors in praxis performance. Such errors suggest whether they are semantically related (trombone for bugle) or semantically unrelated (action of shaving is substituted for playing a bugle). However, all such errors indicate a loss of knowledge about tools/objects or actions related to them (similar to Roy and Square, 1985). Next Raymer and Ochipa suggest measuring the temporal aspects of error which include sequencing, timing, and inappropriate number of times the action occurs (too few or too many). The WatAB uses different measures to try to obtain some of this information by scoring it as correct if an action is completed within a specified number of movements. A form of timing is collected on the TST as a function of the number of frames of videotape necessary to complete some portion of a task, but not as part of the rest of the

WatAB. Rothi, Raymer and Heilman also suggest measuring the spatial nature of error which is similar to Roy's five error dimensions (action, orientation, location, plane and position). There is one exception, body part used as the tool is not collected in Roy's error system, although it could easily be done as part of analysing the videotapes. Other errors suggested by Rothi, Raymer and Heilman (1997), include no response or unrecognizable responses, again not routinely scored in Roy's error system. Therefore, it is recommended that some blending of the two systems occur in future research on the WatAB, as we may be missing several potentially important aspects of error. It is suggested that the FAB would also benefit from adopting the detailed error analysis over five dimensions as used in the WatAB, for the same reason of possibly missing some key aspect of error.

Controversy exists as to whether apraxia is caused by damage to the left hemisphere. Heilman, Watson and Rothi (1997) indicated that left-brain damage was the cause of the inability to perform skilled movements of the limbs on either side of the body in the majority of their patients. Patients with apraxia may make errors when asked to imitate, pantomime tool use or meaningful gestures. But the errors are no longer apparent when overly learned behaviours are tested. Such behaviours include reaching, grasping, and tapping (Geschwind, and Demasio, 1985), which led some to suggest that apraxia involved only the higher level of motoric control (i.e.: selection of an action is impaired but not the process by which correctly conceived actions are translated into motoric programmes). Skilled movements may suffer deficits due to subtle changes in the speed and accuracy of a movement, or even the cognitive demands of selecting a particular movement. To elucidate, catching a ball will place more demands on the co-ordination of muscles and joints than waving goodbye. However, catching the ball will also place fewer demands on the cognitive processes than will being asked how to wave goodbye (Spatt and Goldenberg 1997). The research herein is not able to specifically address these issues. However, in the future, the addition of the MRI data available on all of our participants could facilitate the exploration of the neuroanatomical correlates of Apraxia in AD.

Summary

Our work has supported the work of others that apraxia is found in AD (for example see: Almkvist, 1996; Raymer & Ochipa, 1997; Rothi, Ochipa & Heilman, 1997). As per Raymer and Ochipa (1997) and Rothi et al. (1997) a pattern for praxis performance in AD can be found. This pattern is consistent with that suggested by Roy (1996) indicating a disruption in the Sensory-perceptual, Conceptual, and Production systems, which leads to errors under the conditions of Imitation and Pantomime and in the area of knowledge of tool/object action and function. Because the most severe form of apraxia (a sort of 'all or none' pattern) is the most common pattern seen in our samples of AD, it may be that while the Transitive gestures are sensitive to early changes in visuo-spatial skills that overall, the tests used in the WatAB are not as sensitive to other errors in praxis in AD. Hence the recommendation of including the more qualitative error measurement system of the FAB.

Additionally, the present work indicates that the TST may assist with developing a more finely tuned definition of apraxia. It may prove that future research will indicate that apraxia is, as suggested by Schwartz and Buxbaum (1997), not necessarily apparent on tasks completed in the natural setting and context. Our results do indicate support for the suggestion that increased cues can facilitate performance. The addition to our future work of a battery of tests to measure visual spatial information will assist in determining whether the concurrent imitation sub-tests are sensitive to early changes in visual perceptual skills in AD. As it is fairly well established that such changes do occur (Almkvist, 1996, Binetti et al 1998), it is important to continue to investigate this hypothesized relationship. Binetti and colleagues suggest that the progression of visuo-spatial impairment that they measured may be correlated with the extension of neuropathological changes from the temporal associative cortex towards the parietal lobes.

Alzheimer's disease is therefore, a disease of the entire brain. Cognitive skills are impaired as the number of neurofibrillary events occur. The same is true for most other skills. Praxis is therefore also affected. We offer some evidence that apraxia can be measured by the WatAB in some AD participants even in the early stage of the disease, but more commonly when impairment of motor control and the conceptual aspects of tool object knowledge have progressed. We found support for the Naturalistic Action model when we discovered that as the amount of contextual information increases so does AD praxis performance. We suggest that early changes in visuo-spatial skills can influence praxis performance measured by the WatAB. However, as this is preliminary research, perhaps the most important contribution we offer are more indications of directions for future research.

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APPENDICES

Appendix A: Items relating to the Introduction

Appendix B: Items relating to Studies 1 to 4

Appendix C: Items relating to Study 5.

Appendix D: Items relating to Apraxia and to AD

APPENDIX A

Appendix A 1

NINCDS - ADRDA Criteria for the Diagnosis of Alzheimer's Disease

Criteria for the clinical diagnosis of probable AD:

- Dementia established by clinical examination and documented by the MMSE, BDS, or other similar examination, and confirmed by neuropsychological tests.
- Deficits in two or more areas of cognition
- Progressive worsening of memory and other cognitive functions
- No disturbances of consciousness
- Onset between 40 and 90, most often after age 65
- Absence of systemic disorders or other brain diseases that could account for the progressive deficits in memory and cognition

The diagnosis of probable AD is supported by:

- Progressive deterioration of specific cognitive functions such as language (aphasia), motor skills (apraxia) and perception (agnosia)
- Impaired activities of daily living and altered patterns of behaviour
- Family history of similar disorders, particularly if neuropathologically confirmed
- Laboratory results of: Normal lumbar puncture as evaluated by standard techniques; Normal pattern or non-specific EEG changes; Evidence of cerebral atrophy on CT with progression documented by serial observation

Other clinical features consistent with probable AD, after exclusion of other causes of dementia:

- Plateaus in the course of progression of the illness
- Associated symptoms of depression, insomnia, incontinence, delusions, illusions, hallucinations, catastrophic verbal, emotional or physical outburst, sexual disorders, and weight loss
- Other neurological abnormalities in some patients, especially those with more advanced disease, including motor signs such as increased muscle tone, myoclonus, or gait disorder
- Seizures in advanced disease
- CT normal for age

Appendix A 1 (cont'd)

Features that make the diagnosis of probable AD uncertain or unlikely:

- Sudden, apoplectic onset
- Focal neurological findings such as hemiparesis, sensory loss, visual field deficits, and incoordination early in the course of the illness
- Seizures or gait disturbances at he outset of symptoms or very early in the course of the illness

Diagnosis of possible AD:

- May be made on the basis of the dementia syndrome; in the absence of other neurological, psychiatric; or systemic disorders sufficient to cause dementia; and in the presence of variations in the onset, presentation or clinical course
- May be made in the presence of a second systemic or brain disorder sufficient to produce dementia but not considered to be the cause of dementia
- Should be used in research studies when a single, gradually progressive, severe cognitive deficit is identified in the absence of another identifiable cause

Criteria for diagnosis of definite AD

- Clinical criteria for probable AD
- Histopathological evidence obtained from biopsy or autopsy

Subtype classification for research purposes:

- Familial occurrence
- Onset before 65
- Presence of Trisomy 21
- Co-existence of other relevant conditions such as Parkinson's Disease.

Appendix A 2

A Comparison of the Tests of the Waterloo Apraxia Battery* and the Florida Apraxia Battery**

Waterloo Apraxia Battery	The Florida Apraxia Battery
Tool Name	Tool Naming
Tool Name by Function	
Action Name	Gesture Name (can ID action or tool)
Tool Identification	
Tool Identification by Function	
Action Identification	Gesture Naming (can ID action or tool)
Action Identification by Tool	Gesture Naming (can ID action or tool)
Gesture Recognition	Gesture Recognition
Gesture Error Recognition	Gesture Decision
Pantomime by Tool	FAST-R
Pantomime (intransitive)	FAST-R
Object Use by Picture	
Object Use A (view object)	Gesture to Visual Tool
Object Use B (handle object)	Gesture to Tactile Tool
Pantomime by Function	
Imitation - Delayed (transitive)	
Imitation - Delayed (intransitive)	
Imitation - Delayed (nonrepresentational)	
Imitation - Concurrent (transitive)	FAST-R & Gesture Imitation
Imitation - Concurrent (verbal cue)	
Imitation - Concurrent (intransitive)	FAST-R
Imitation - Concurrent (nonrepresentational)	FAST-R & Nonsense Praxis Imitation
Tool Selection Task	Tool Selection Task

Note: Listing of a similar task does not indicate that the tasks are necessarily identical.For further description please see Appendices XXX and XXX and pp xx - XX.*From: Roy, E.A. (1998). The Waterloo Apraxia Battery. Unpublished manuscript, University of Waterloo at Waterloo.**From Rothi,L.J.G., Raymer, A.M.; & Heilman, K.M. Limb Praxis Assessment. In L. Rothi & K. Heilman (Ed.s)., Apraxia: The Neuropsychology of Action (pp 61-73). London: Psychology Press.

Appendix A 3
TST Instructions from the WatAB

Normal Instructions	Simplified Instructions	Tools and Layout on Tray (Left to Right)
Here are 4 tools. Pick up and use the best tool to eat some pudding.	Pick up a tool and eat some pudding.	pliers, screwdriver, skewer, spoon
Here are 4 tools. Pick up and use the best tool to put some sugar in a cup of tea.	Pick up a tool and put sugar in the tea.	dime, spreader, fork, paintbrush
Here are 4 tools. Pick up and use the best tool to put jam on a slice of bread.	Pick up a tool and put jam on the bread.	shoe, fork, knife, pliers
Here are 4 tools. Pick up and use the best tool to eat some pudding.	Pick up a tool and eat some pudding.	pliers, t. depressor, skewer, screwdriver
Here are 4 tools. Pick up and use the best tool to do your hair.	Pick up a tool and do your hair.	spreader, fork, paintbrush, shoebrush
Here are 4 tools. Pick up and use the best tool to stir a cup of coffee.	Pick up a tool and stir the coffee.	popsicle stick, comb, dime, skewer
Here are 4 tools. Pick up and use the best tool to pound a nail into the wood.	Pick up a tool and pound the nail.	comb, spreader, hammer, spoon
Here are 4 tools. Pick up and use the best tool to turn the screw.	Pick up a tool and turn the screw.	skewer, screwdriver, paintbrush, t.depressor
Here are 4 tools. Pick up and use the best tool to put dirt in this pot.	Pick up a tool and put dirt in the pot.	skewer, shoebrush, hammer, soup ladle
Here are 4 tools. Pick up and use the best tool to put sugar in a cup of tea.	Pick up a tool and put sugar in the tea.	dime, spoon, fork, paintbrush
Here are 4 tools. Pick up and use the best tool to turn the screw.	Pick up a tool and turn the screw.	t. depressor, skewer, paintbrush, dime
Here are 4 tools. Pick up and use the best tool to put jam on a slice of bread.	Pick up a tool and put jam on the bread.	shoe, fork, spatula, pliers
Here are 4 tools. Pick up and use the best tool to do your hair.	Pick up a tool and do your hair.	comb, spreader, paintbrush, fork
Here are 4 tools. Pick up and use the best tool to put dirt in this pot.	Pick up a tool and put dirt in pot.	shoebrush, skewer, hammer, trowel
Here are 4 tools. Pick up and use the best tool to stir a cup of coffee.	Pick up a tool and stir the coffee.	comb, spoon, dime, skewer
Here are 4 tools. Pick up and use the best tool to pound a nail into the wood.	Pick up a tool and pound the nail.	shoe, comb, spreader, spoon

Appendix A 4: An Example of Scoring Praxis Error on the WatAB

able 4. Scoring Criteria in Each Performance Dimension for Hammer Gesture

Performance Dimension	Criteria for Scoring Categories: 2	1	0
Location	Ipsilesional side between shoulder and hip	Too high or too low on	Contralesional side beyond midline
Action	Repetitive movement at elbow and wrist	Exaggerated repetitive movement with shoulder included Distortion to smoothness of movement	No repetition Any other kind of movement, includimg rotation
Plane[1]	Z-X (sagittal) plane	45 degrees out of sagittal plane	Greater than 45 degrees out of sagittal plane
Orientation	Palm facing the midline	Palm slightly out of orientation with midline	Palm facing the ground
Posture	All three features[2] are showing and correct	One of the features[2] is missing or is wrong	Two or all features[2] are missing or are wrong

\xes
- Z axis (vertical)
- X axis (to and away from body)
- Y axis (medial-lateral)

.ist all three features of hand posture
- Fingers curled
- Thumb along hammer base
- Grasp slightly open to allow space for handle

Appendix A 5: Error Scoring on the FAB

Praxis error types

Content

- P = Perseverative—The patient produces a response that includes all or part of a previously produced pantomime.
- R = Related—The pantomime is an accurately produced pantomime associated in content to the target. For example, the patient might pantomime playing a trombone for a target of a bugle.
- N = Non-related—The pantomime is an accurately produced pantomime *not* associated in content to the target. For example, the patient might pantomime playing a trombone for a target of shaving.
- H = Hand—the patient performs the action without benefit of a real or imagined tool. For exL.nple, when asked to cut a piece of paper with scissors, they pretend to rip the paper. Another example would be turning a screw by hand rather than with an imagined screwdriver.

Temporal

- S = Sequencing—Some pantomimes require multiple positionings that are performed in a characteristic sequence. Sequencing errors involve any perturbation of this sequence including addition, deletion, or transposition of movement elements as long as the overall movement structure remains recognisable.
- T = Timing—This error reflects any alteration from the typical timing or speed of a pantomime and may include abnormally increased, decreased, or irregular rate of production.
- O = Occurrence—Pantomimes may characteristically involve either single (e.g. unlocking a door with a key) or repetitive (e.g. screwing in a screw with a screwdriver) movement cycles. This error type reflects any multiplication of characteristically single cycles or reduction of a characteristically repetitive cycle to a single event.

Spatial

- A = Amplitude—Any amplification, reduction, or irregularity of the characteristic amplitude of a target pantomime.
- IC = Internal configuration—When pantomiming, the fingers and hand must be in a specific spatial relation to one another to reflect recognition and respect for the imagined tool. This error type reflects any abnormality of the required finger/hand posture and its relationship to the target tool. For example, when asked to pretend to brush teeth, the patient's hand may close tightly into a fist with no space allowed for the imagined toothbrush handle.
- BPT = Body part as tool—The patient uses his/her finger, hand, or arm as the imagined tool of the pantomime. For example, when asked to pretend to smoke a cigarette, the patient might puff on the end of an extended index finger.
- EC = External configuration—When pantomiming, the fingers/hand/arm and the imagined tool must be in a specific relationship to the object receiving the action. Errors of this type involve difficulties orienting to the object or in placing the object in space. For example, the patient might pantomime brushing teeth by holding his hand next to his mouth without reflecting the distance necessary to accommodate an imagined toothbrush. Or, when asked to hammer a nail, the patient might hammer in differing locations in space reflecting difficulty placing the imagined nail in a stable orientation.

TABLE 2
(Continued)

Content

- M = Movement—When acting on an object with a tool, a movement characteristic of the action and necessary to accomplishing the goal is required. Any disturbance of the characteristic movement reflects a movement error. For example, when asked to pantomime using a screwdriver, a patient may orient the imagined screwdriver correctly to the imagined screw but instead of stabilising the shoulder and wrist while twisting at the elbow, the patient stabilises the elbow and twists at the wrist or shoulder.

Other

- C = concretisation—The patient performs a transitive pantomime not on an imagined object but instead on a real object not normally used in the task. For example, when asked to pretend to saw some wood, they pantomime sawing on their leg.
- NR = No response
- UR = Unrecognisable response—a response that is not recognisable and shares no temporal or spatial features of the target.

SOURCE: Rothi et al., 1988, with modifications reported in Greenwald, Rothi, Mayer, Ochipa, Chatterjee, and Heilman, 1992; and Ochipa et al., 1992).

From: Rothi, L.J.G.,Raymer, A.M., HeilmanK.M. (1997). Limb praxis assessment. In L.G.J. Rothi and K. Heilman (Eds.), Apraxia: The Neuropsychology of Action (pp29-49). London: Psychology Press. Reprinted with permission

Appendix A 6

Lists of Neuropsychological Tests used from Sunnybrook AD Study

- Mini Mental State Exam (MMSE)
- Dementia Rating Scale
- WMS - R: Visual Reproduction 1
- Boston Naming Test
- Western Aphasia Battery
- FAS
- Rey Complex Figure Copy
- Digit Span - Forwards and Backwards
- California Verbal Learning Test
- Wisconsin Card Sorting Test
- WAIS-R: Vocabulary scale
- Disability Assessment in Dementia Scale
- Cornell Depression Scale
- Grooved pegboard

APPENDIX B

Appendix B 1

List of Eight Tasks used in the Praxis testing section of the WatAB.

Transitive:

- Slice a piece of bread
- Pull out Splinter
- Eat your food
- Brush your teeth
- Pound a nail
- Flip and egg
- Style your hair
- Pour some water

Intransitive:

- Scratch your ear
- Cream on face
- Salute
- Hold nose
- Wave
- Beckon
- Okay sign
- Hail a cab.

Appendix B 2

Protocol for Waterloo Apraxia Battery (WatAB)

TASK	TASK PROCEDURE
Tool Name	Subject is asked to name the object in the picture provided. For example the examiner would show a picture and ask "what would you call this?"
Tool Name by Function	Subject is asked to name the tool whose function is being described by the examiner. For example the examiner would say "what would you call the object used to cut a piece of wood in half?"
Action Name	The subject is shown a series of 4 pictures of objects and asked to name the one which would be most associated with an action. For example the examiner would say "which one do you use to brush your teeth?"
Tool Identification	A set of four pictures are shown to the subject. The subject is then asked to point to the tool that has been named. For example the examiner would say "point to the hammer".
Identification by Function	A set of four pictures are shown to the subject. The subject is asked to point to the picture of the tool which has been described by it's action. For example the examiner would say "out of these four pictures I would like you to point to the object you would use to pound a nail".
Action Identification	The subject is shown a series of gestures on a video screen and asked to identify them. The examiner tells the subject about one gesture and then asks the subject to identify the gesture from a group of five that are presented one at a time on the video screen. The subject answers yes or no depending on whether or not the gesture on the screen and the one described match. For example the examiner would ask "which of the following gestures shows the subject (person on the video screen) pretending to use a toothbrush to brush their teeth?"
Action Identification by Function	The subject is shown a series of gestures on a video screen and asked to identify the gesture associated with the tool that is presented to them. The actual tool is placed in front of the subject. The subject answers yes or no depending on whether or not the gesture being performed on the screen would be associated with the tool that is in front of them. For example the examiner would say "which of the following gestures is associated with this tool?"

Gesture Recognition	The subject is shown a series of gestures on the video screen. The examiner demonstrates a gesture and the subject is asked to identify the same gesture from a group of five presented one at a time on the video screen. For example the examiner would ask "which of the following gestures shows the subject (person on the video screen) performing the same gesture as me?"
Gesture Error Recognition	The subject is shown a series of gestures on the video screen. The subject is shown gestures one at a time and asked to identify if the gesture being demonstrated is done correctly or not. For example the examiner would ask "is the person pretending to use a hammer to pound a nail correctly or not?" Those of one form demonstrations include errors in body part as object, location errors or action errors.
Pantomime by Tool (transitive representational)	The subject is told the name of the object and it's action and then asked to pretend that they are holding the object in their hand and then they are asked to demonstrate how they would use the tool. For example the examiner would ask "show me how you would use a hammer to pound a nail".
Pantomime by Function (transitive representational)	The subject is told about the function of an object. The subject is then asked to think about what object would be used to carry out that function and then is asked to pretend to use the object. For example the examiner would ask "show me how you would brush your teeth".
Pantomime (intransitive representational)	The subject is asked to demonstrate some gestures that are used in activities of daily living. For example the examiner would ask "show me how you would wave goodbye".
Object Use by Picture	The subject is shown a picture of an object and then asked to pretend they are holding that object in their hand. They are then asked to show the examiner how they would use it if it really was in their hand. For example the examiner would ask "show me how you would use this (picture is shown)".
Object Use	The subject is shown the actual object and then asked to show how they would use it. For example the examiner would say "how would you use this (show the object)".
Imitation - Delayed (transitive representational)	The examiner demonstrates a gesture to the subject. After a ten second delay the subject is asked to do the same gesture that was shown to them.
Imitation - Delayed (intransitive representational)	The examiner demonstrates a gesture to the subject. After a ten second delay the subject is asked to do the same gesture that was shown to them.

Imitation - Delayed (intransitive non-representational)	The examiner demonstrates a meaningless gesture to the subject. After a ten second delay the subject is asked to do the same gesture that was shown to them.
Imitation - Concurrent (transitive representational)	The examiner demonstrates a gesture to the subject. The subject is asked to copy the examiner right away. For example the examiner would ask "do this (gesture is demonstrated)".
Imitation - Concurrent with Verbal Cue (transitive representational)	The examiner demonstrates a gesture to the subject. The subject is asked to copy the examiner right away. As the examiner does the gesture, he/she also indicates the gesture being imitated. For example the examiner would say "show me how you would brush your teeth (the gesture is being done at the same time)".
Imitation - Concurrent (intransitive representational)	The examiner demonstrates a gesture to the subject. The subject is asked to copy the examiner right away. For example the examiner would ask "do this (gesture is demonstrated)".
Imitation - Concurrent (non-representational)	The examiner demonstrates a gesture to the subject. The subject is asked to copy the examiner right away. For example the examiner would ask "do this (gesture is demonstrated)"

<u>Complete Example of one sub-test</u>: Pantomime by Function:

"I am going to tell you about an object. I would like you to think about what the object is and I would like you to pretend you are holding that object in your hand. Then I would like you to show me how you would use it if it was really in your hand. Do you understand? For example, show me how you would open a can (tool to use in pantomime: a can opener). Good, let's continue."

Present sample item 2: "Show me how you would cut a piece of wood (saw).

Present test tasks: "Show me how you would . . . "

1) Brush your teeth (toothbrush)
2) Pull out a splinter (tweezers)
3) Flip an egg (flipper/spatula)
4) Eat your food (fork)
5) Pound a nail (hammer)
6) Slice a piece of bread (knife)
7) Pour some water (watering can)
8) Style your hair (comb)

Appendix B 3
Performance Dimensions in Assessing Apraxia

Dimension	Description
Orientation	Orientation of the hand
Action	Characteristics of the movement
Posture	Posture of the hand
Plane of Movement	Major plane of movement of the hand
Location	Location of the hand in space

APPENDIX C

C 1: Summary Table of the Results of the TST Error Composite score ANOVA

Appendix C 1

Summary Table of the Results of the TST error composite score ANOVA

	F	p
Alternate: Bread	.257	.618
Dig	2.168	.156
Hair	.232	.635
Nail	3.967	.060
Pudding	1.096	.307
Screw	.461	.504
Stir	1.212	.284
Sugar	.475	.498
Real: Bread	.458	.506
Dig	1.000	.328
Hair	.333	.570
Nail	1.941	.177
Pudding		
Screw	.846	.368
Stir	1.158	.294
Sugar		

APPENDIX D

D 1: Overview of AD - History and Neuroanatomy

D 2:Overview of apraxia - History & Types

Appendix D 1

Alzheimer's Disease.

Alzheimer's disease (AD) continues to represent an increasing health care, emotional and financial burden on society. The need for early diagnosis is quickly becoming more important with the availability of new pharmaceuticals which appear to be most effective at slowing down the progression of the disease (Molloy, Caldwell, 1998). Although there are over 60 recognized causes for dementia the most common by far is AD. One estimate places AD as accounting for 75% of all patients diagnosed with dementia (Molloy, Caldwell). Of course as the incidence of AD is directly related to age and as our population continues to live longer the estimates of the incidence of all forms of dementia and especially AD rise dramatically. In Canada alone, by the year 2030 three-quarters of a million cases of dementia are anticipated. This figure represents an increase of over 300 percent over 1998 figures with an accompanying population increase of only 40 percent. The cost of caring for those with dementia is higher than that for stroke and cancer combined and, while in 1991 the cost was estimated at $3.9 billion, by the year 2030 it is expected to rise to $12 billion in Canada.

Research into AD has focussed more on the cognitive changes, especially memory rather than all other aspects affected such as motor, and sensory. It is commonly known in the clinical literature that persons with AD develop difficulties completing some simple and basic activities of every day living (Molloy, Caldwell, 1998) so that, for example, they may at first be unable to consistently and accurately use the remote control for the television. Such difficulty with the completion of so called 'technical tasks' is not often included as part of a research project on AD. Instead, potentially more complex motor tasks, such as drawing, are used to measure a person's ability to complete purposeful movements (praxis). However, neither situation brings us any closer to understanding the motoric changes in AD. One situation, as identified by Molloy and Caldwell, relies on simple tasks and another uses tasks known to rely on many other cognitive constructs (e.g.: drawing tasks which rely on working memory, visual-perceptual analysis, grapho-motor skills; etc.) which could easily confound the results. What is needed is a systematic approach which uses common gestures and tasks to study praxis performance in AD. The study of apraxia (the inability to perform purposeful and skilled movements) is quite well documented in the stroke literature but not as well for AD.

AD as understood from a neuroanatomical perspective is caused by changes in the CA1 cell field of the hippocampal formation, specifically Ammon's horn. Four different types of damage can be measured upon autopsy in the AD brain (Braak, and Braak, 1996): senile plaques (SP); neurofibrillary tangles (NFT's); neuropil threads (NT's); and neuritic plaques (NP's). Extracellular deposits of a specific insoluble amyloid protein (AP) are common in the aging brain. They appear to be first deposited in the basal parts of the isocortex. These deposits are termed diffuse senile plaques (SP). Eventually these plaques increase in number until the entire cortex and sub-adjacent portions of the white matter become very densely filled with amyloid. Braak and Braak concluded and as recently supported by Giannakopoulos et al (1998) that the deposit of amyloid has not yet been proven to result in any specific brain dysfunction. Another change occurs to neurons and is believed to be caused by the abnormal phosphorylation of other insoluble proteins - tau proteins. Neurofibrillary changes are often found prior to any plaques. In general it is only in the later stages of AD where both are found in abundance. Neurofibrillary changes (NFT's, NT's, and NP's) all have in common extensive structural changes as they appear and then they eventually disappear, leaving the familiar 'holes' seen in some forms of neuro-imaging which can lead to difficulties in accurately quantifying the AD pathological changes, as the holes are not included in the count of neuro-pathological changes. Neurofibrillary changes are measured upon autopsy to officially diagnose AD. The authors conclude that about 50 years pass between the first appearance of a NFT in the transentorhinal cortex to the end stage of AD.

Braak and Braak in their 1996 research indicated that under normal conditions there is a stream of isocortical information converging via a number of cortical relay points upon the entorhinal region which in turn projects to the hippocampal formation. Information then enters the entorhinal and transentorhinal areas (input). The outermost cellular layers of the entorhinal area project into the hippocampal formation and thereby transfer both isocortical and limbic information. Next a feedback loop exists in the subiculum to one of the deeper entorhinal layers, which in turn transfers data to the isocortical association areas (output). Braak and Braak suggest that there are six stages of AD. In general their model indicates that AD disrupts the stream of information between the hippocampal formation and the entorhinal region. Specifically they offer that in stages one and two patients present with no obvious intellectual impairment as the changes are confined to the transentorhinal region. Such changes represent the pre-clinical phase of AD during which the neurofibrillary changes occur gradually. Stages three and four are termed the limbic stages, as clinical changes can begin to be seen as the formation of neurofibrillary tangles (NFT), and neuropil threads (NT) increase while still being relatively confined to the external entorhinal layer. This layer normally generates the perforant path via which isocortical and limbic information are transferred to the hippocampus. Stages three and four are considered to indicate incipient AD. The last two stages proposed by Braak and Braak occur with the presence of fully developed AD. At this point the isocortical association areas are extensively destroyed, macroscopic atrophy can be detected and there is a marked decrease in brain weight. This stage corresponds to the neuropathic diagnosis of AD as all areas of the cerebral cortex contain a high density of neurofibrillary changes.

Almkvist (1996) suggests that the early clinical stage as outlined by the neuroanatomical changes reported by Braak and Braak (1996) is understandable. He proposes that some early changes in AD with respect to contrast sensitivity are most likely due to the pathology developing in the visual association areas, a somewhat surprising suggestion as contrast sensitivity is considered a relatively basic process. Skills such as drawing, copying complex figures and reasoning based upon increasingly more complex geometric drawings which must first be analysed, are suggested by Almkvist as visuo-perceptual skills which suffer marked impairment in the early stage of AD. Those skills also perhaps rely on bilateral posterior association areas as measured by neuroimaging techniques. To support this claim Almkvist cites evidence from lesion studies even though usually the right hemisphere is suggested as primarily subsuming such skills. In particular, Almkvist suggests that in Braak and Braak's incipient stage of AD impairment of verbal abilities, attention, executive functions and visuo- perceptual skills are due to the extensive changes to the transentorhinal regions where posterior cortical areas of both hemispheres are being disconnected from the limbic areas and scattered NFT's are present in the frontal, temporal and parietal lobes. The later stage of so called 'fully developed' AD involves the continuation of the damage with the result of greater impairment in the areas listed above. Hence, Almkvist suggests a sequential process of decline in AD.

A sequential pattern of impairment is reminiscent of Reisberg's (Reisberg, Ferris, deLeon, & Crook, 1982) stages of AD in which he proposes that the neurological changes in AD, as measured by cortical, extrapyramidal, and pyramidal signs all of which become more apparent as the disease progresses, are similar to the normal forward neurological developmental pattern of humans. In a 1993 paper, Reisberg and colleagues suggest that the characteristics of the neurological decline are different from that of other neurological disorders. By way of an example they offer that the extrapyramidal signs (e.g.:slow resting tremor, decreased arm swing, slow walking speed, shuffling gait) seen in the later stages of AD are different with respect to the amount of each sign and most importantly in the timing from those signs seen in Parkinson's disease where resting tremor is often one of the earliest symptoms of Parkinson's Disease. Extrapyramidal signs have been quite well documented usually in the later stages of AD with the incidence varying from 62% (Pomara et al., 1981) to 92% (Molsa, Martitila,& Rinne, 1984). Such signs have been linked with a more rapid functional and intellectual decline as compared to those without the extrapyramidal signs (Yeu-Chen, Stern, Sano, & Mayeux, 1991). Further they suggest that the signs studied are more indicative of the progression of AD than indicators of disease sub-types.

Appendix D 2

Apraxia

Apraxia was first described in 1900 by Liepmann in a patient with left supramarginal gyrus lesions (cited in Travniczek-Marterer, Danielcyk, Simanyi, & Fischer, 1993) and continues to be defined as a disorder of skilled movements not caused by other muscular and/or neurological factors (e.g., weakness, akinesia, aphasia, cognitive decline, or visual problems) (Roy & Square,1994; Roy & Square, 1985; Poeck, 1986). Liepmann further indicated after studying 83 patients that apraxia was separate from language dysfunction even though he noted that 20 of his patients presented with both aphasia and apraxia. Discussion as to the relationship between these two dysfunctions continues to the present time (Rothi, Ochipa, & Heilman, 1997). However, Liepmann did suggest for the first time that praxis (the ability to produce skilled movements) for both hands was mediated by the left hemisphere for right handed persons. He postulated that the left sensorimotor cortex controlled not only the 'arm centre' for the right arm but also the left arm because of connections through the corpus callosum. Liepmann, in addition to the more recent work of Heilman (1996) and Roy (1996) has postulated that such control for arm movement is found more towards the parietal lobe. Heilman suggested that the involvement of the parietal lobe in movement as discussed by Liepmann in his movement formulae should be re-named visuo kinesthetic engrams. Liepmann's model of apraxia involved three components: movement formulae; innervatory patterns; and the kinetic memories. The relationship between these three constructs was hierarchical with the movement formulae being at the highest level. Liepmann's three components included learning the general course of a movement based on sensory and visual information (movement formulae). In the next stage the innervatory patterns were defined as learned over time with practice and served to translate the movement formulae into direct positioning and movement of the limbs. Lastly, the kinetic memories referred to a functional link among innervations which by running their course lead ultimately to the execution of a movement. These ideas were later enhanced by other researchers and lead to the development of two similar models for apraxia, one by Heilman and colleagues (1995) and Roy (1994), and will follow in more detail.

Geschwind (1965) echoed the responsible role of the left hemisphere for praxis in right handed persons and suggested the neural pathways by which praxis would be mediated. Further he indicated that pantomiming to a given command (i.e.: show me how you would wave good-bye) relied on information flowing from the auditory pathway through Heschyl's gyrus on its way to Wernicke's area of the superior temporal lobe. The ultimate destination for this information was the motor association cortex for control of the right hand, and again information for the left hand flowed via the corpus callosum. However, recently Ochipa, Rothi and Heilman (1997) have suggested that the pre-motor area acts as the final destination of pantomiming information. One important inconsistency in Geschwind's theory is that if a disconnection occurs between posterior language areas and the anterior motor association cortex he postulated that imitation of gestures (i.e.: "Do this") would be intact while pantomime would be impaired as Wernicke's area is spared. Therefore, persons with such a disconnection should be able to comprehend verbal commands but not perform gestures in response to verbal commands. Rothi et al. (1997) indicate that if the disconnection is only between Wernicke's area and the motor association cortex then imitation should be intact but they report it is not in their patients. In answer Geschwind suggested that fibres which pass through the left hemisphere's arcuate fasciculus are responsible for the visuo-motor connections on their way from the visual association area to the pre-motor cortex. Therefore any disruption to the arcuate fasciculus would cause disconnections in both the auditory and visual pathways and result in impairment in both imitation and pantomime, but not necessarily the identification of the use of the object. Some evidence for the role of these pathways comes from the observation that when actually using a tool or object, performance often appears normal (Rothi, Ochipa, Heilman) and in some cases performance will be better than when asked to imitate or pantomime. However, it must be remembered that use of the actual tool provides many other kinesthetic (touch, weight etc.) cues not normally available during imitation or pantomime and thereby error is reduced. Some investigation of this improvement in performance of actual tool use over pantomime performance is included in the second study of this body of work. It is also well established that even while performance is often better when using real implements that performance in imitation and pantomime conditions can still be impaired (DeRenzi, Lucchelli, 1988, for example). Geschwind later suggested that perhaps somatosensory information was passed to the premotor area via the visual pathway which would leave object use intact but still allow impairment under the conditions of imitation and pantomime.

Much of our understanding of apraxia comes from the testing and/or observation of stroke patients with 'discrete lesions'. Support for the left hemisphere's role, as first suggested by Liepmann (1900, as cited in Travniczek-Marterer, Danielcyk, Simanyi, & Fischer, 1993) comes from the finding that apraxia is much more frequent in patients with left hemisphere damage than those suffering from damage to the right hemisphere (Travniczek-Marterer et al. 1993, and Papagno, Sala, Basso, 1993). Apraxia is therefore often found in combination with aphasia as most left hemispheric stroke patients are both apraxic and aphasic. However, it is also known that aphasia can be found on its own without the presence of apraxia (Foundas, Henchey. Gilmore, Fennell, Heilman, 1995). Foundas et al propose two principle explanations for this dissociation. One offers that the neuroanatomical network mediating praxis is more localized than that which mediates language, and hence, the praxis system is more at risk of injury. The second suggests that praxis in right-handers may not be as strongly lateralized as is language, thereby leaving less room for recovery after a left hemisphere accident (Foundas, et al). Of course most information from lesion studies comes from the results of having a part of the brain removed or from damage to some part(s). It is not yet possible to engineer a truly discrete lesion as the neural and vascular networks are not completely understood and indeed it most likely is not true for the lesions created biologically. Foundas and colleagues suggested that Wada testing (the process of testing for lateralization when one hemisphere is anaesthetized) would be a more efficacious approach. Their findings support Liepmann and Papgno, et al. (1993) in that the left hemisphere did in fact mediate language in all of the nine right handed persons studied and proved their hypothesis that language was more likely to be lateralized to the left hemisphere. However, only seven of the nine right-handed participants were significantly more apraxic with anaesthetized left-hemisphere as opposed to right hemisphere injection. They concluded that as per their hypothesis praxis would be less strongly lateralized to the left hemisphere. This conclusion was based on the result that no participants were measured as apraxic with unilateral right injection without also becoming apraxic with left hemispheric injection. Further Foundas, et al. suggest that one way of understanding hemispheric distribution of the various component systems which must all be smoothly integrated in praxis was to review the types of errors made. Such errors are believed to reflect the particular component no longer being used by the praxis system. In accordance with Rothi, Ochipa and Heilman's 1997 suggestion of a distributed modular network for praxis, Foundas et al. suggest that where complete lateralization for praxis is not present then the patterns of errors may inform us about how the various components of praxis are distributed between the two hemispheres. Foundas et al. (1995) further suggest that their Wada testing elicited the possibility that the two hemispheres may be contributing differently to the control of skilled arm movements. The left hemisphere may be responsible for mediating the spatial aspects of movement as more spatial (e.g.:body part as tool, movement and amplitude) errors were recorded during left hemisphere injection. Injection into the right hemisphere elicited more temporal errors (e.g.:timing, and sequencing) which may indicate the right hemisphere's responsibility for temporal aspects of praxis. As they suggest, further testing of this hypothesis must be completed on a much larger sample than nine participants before such claims can be reliably upheld.

Others who have studied apraxia in stroke have focussed on imitation (i.e.: "Do this"). Haaland and Flaherty (1984) compared patients with errors in imitating gestures with either right hemisphere damage (RHD) or left hemisphere damage (LHD). Their stroke groups displayed significantly more error in the majority of gestures. The finding of apraxic performance with both RHD and LHD may have been mediated by the fact that Haaland and Flaherty only tested imitation especially as the type of visual analysis necessary for imitation may be affected by damage to either hemisphere. More recently, Roy, Black, Blair and Dimeck (1998) suggest that the results of their study of RHD and LHD stroke patients is consistent with that of Haaland and Flaherty and DeRenzi (1988). Roy et al (1998) suggest that in imitation RHD may have more obvious effects due to the demands placed upon the visual analysis of the gestures presented.

Two apraxias are seen as traditional forms. Limb-kinetic apraxia as suggested by Liepmann (as cited in Brown, 1972) refers to motoric difficulty in the use of a single limb, usually one arm but when there is no indication of weakness in the limb. It is most often seen in pantomime and during the manipulation of an object. It is no longer considered to be a true apraxia and is most commonly seen in recovering stroke patients when impairment of fine motor skills (e.g.: finger movements) can be detected after the disappearance of any weakness. Secondly, verbal apraxia is a difficulty in the articulation of words not clearly explained by aphasia or dysarthria but is diagnosed as a result of difficulties controlling the speech musculature (tongue, face, and lips) and the sequencing of muscle movements (Square, Roy, Martin, 1997). This latter form of apraxia is beyond the scope of the testing battery we use and is best left to those with specific training in speech language pathology.

There are several other disorders which at various points have been termed apraxias but are not now included as such. Briefly they include a variety of motoric deficits which do not easily adhere to the definition above. Dressing apraxia is more a deficit of visuo-spatial function relating to a faulty perception of body image. Oculomotor apraxia involves difficulty in the voluntary conjugate movement of the eyes and is most often found accompanying a variety of congenital syndromes. Gait is a highly complex, sequential motor act and apraxia of the gait is now better termed 'frontal gait disorder' and is most often seen in cases of hydrocephalus or frontal lobe lesions.

One other type of apraxia is also described in the literature but is not the focus of this research and will therefore be discussed only briefly. Constructional deficits are often termed forms of apraxia but do not strictly meet the criteria for apraxia as we have defined herein, as they are more dependent upon the assembling, building and drawing activities (Benton, 1969) and therefore most often rely on planning abilities. Constructional deficits are often measured by the drawing of a picture or completing block patterns to match a diagrammed model. While there is extensive literature on this form of apraxia including that it is often found in early in AD patients, it is also noted that constructional apraxia may not be apparent until the later stages of the disease. To date no clear explanation has been offered. While this form of apraxia may share some features (e.g.: involvement of visual- perceptual skills; Neilson, Cummings and Cotman, 1996) with the gesture based apraxia we are studying, the fact that it cannot be measured by our protocols suggests that it is beyond the scope of our research at this time.

TYPES OF APRAXIA

Traditional Apraxias:

Ideomotor
Ideational
Limb-kinetic
Verbal

Other disorders termed "apraxia":

Constructional
Dressing
Oculomotor
Gait