FROM OBJECTS TO ACTION: A NEUROPSYCHOLOGICAL ANALYSIS

by

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Abstract

This thesis is concerned with the factors that determine the performance of everyday action. Six empirical chapters are subsequently presented. First, I sought to investigate the effects of the presence of distractors and of task load on the performance of everyday life tasks, comparing a patient with ADS and controls operating with a task load (Chapter 2). The data indicate that controls and patients with ADS may suffer different demands.

The role of the task schema on ADL was examined in Chapter 3. The results showed that there is a problem in using task schema to drive action under the on-line constraints of performing the action. Relation between object recognition and action was tested in Chapters 4 and 5. I showed that 'object use' effect was maintained even when the patients showed impaired semantic access for the objects.

The final empirical study (Chapter 7), investigated the role of eye movements on performing an everyday. There were proportionately more unrelated fixations and more fixations concerned with locating objects in the ADS patient than in controls. In addition, eye movements away from objects being used were made earlier in the ADS patient, and toying errors were linked to multiple, brief fixations being made to the object involved.

In the final chapter (8), I review the evidence from across the thesis and discuss the implications of the work for understanding both normal and disordered everyday actions. The results not only point to the complexity of processes supporting such actions, but also to the critical interactions between action and attention in such tasks.

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FK (Chapter 2, 3, 4, and 5); BL (Chapter 3, 4, 5, and 7); DS (Chapter 2, 6, and 7); MP (Chapter 2); DB (Chapter 2); TT (Chapter 2); JF (Chapter 7).

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Publications

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2. Task schema and task demands in action disorganisation syndrome: K. Morady & G.W. Humphreys (expected date for submission: March 2009. This article is integrated in chapter 3)

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CHAPTER 1

1.1 Introduction

Most of our behaviour in everyday life is composed of routine activities such as grooming, dressing, eating, etc. Despite such activities being well-practised and often undertaken without creating large demands on attention, there are numerous different processes involved – from recognising the objects present, to recalling a schema for the task, to ordering the sequence of steps and keeping track of the steps are carried out. Perhaps not surprisingly, given the complex and multiple factors involved, the performance of everyday actions can break down after neurological damage. For example, patients with 'action disorganisation syndrome' (ADS; Schwarz, 1995) make abnormally large numbers of errors both in using individual objects and also in carrying out all the steps in a task in the right order. Given the central role such activities play in naturalistic human behaviour, it is important to understand how neurological disorders influence everyday action skills and how best to assess and ameliorate the impairments that may arise. In order to identify such problems and to rehabilitate them, neuropsychologists need to understand the cognitive mechanisms, which influence our everyday action.

To illustrate the factors involved consider the relatively simple everyday task of applying butter and then cheese to bread. This may involve grasping a butter knife with an appropriate grip, dipping it in butter, spreading it on the bread then using a different knife to cut the cheese and then to lay it on the bread - in each case making sure that appropriate amounts of butter and cheese are used. This requires remembering information that ensures that the actions (buttering then cutting and placing the cheese) are performed in the correct order. It necessitates that the actor recognises the differences between the knives, grasping the knives appropriately for the actions, possibly ignoring other objects that may be present. Also, if the appropriate objects for action are not available (there are no knives on the table), then it may be necessary to suspend the routine while fetching an appropriate knife from a kitchen drawer. Thus, even this simple task can be decomposed into a set of different processes, each of which could be selectively affected by brain lesion.

To understand how everyday tasks are planned and performed correctly, we have to answer some questions. For example, we need to know the extent to which the performance of everyday actions is dependent on our stored knowledge about individual objects and actions (see Humphreys & Forde, 1998, vs. Joe, Ferraro & Schwartz, 2002). We need to know how our higher-level knowledge of the task interfaces with the cognitive resources concerned with the control of visual attention, the perception of individual objects, and action to the objects. We need to know how sequences of action within individual tasks can be organised when several tasks are being conducted at once (e.g. when we make a sandwich while we are answering the phone). In terms of clinical treatments and the rehabilitation of disorders of action, we need to understand whether impairments in carrying out everyday actions are associated with particular pathologies. We also need to know how the use of familiar objects, or the instantiation of particular training procedures, can facilitate the maintenance or re-learning of everyday tasks.

1.2 Theoretical and Empirical Background

1.2.1 Hierarchical organisation in routine tasks

Everyday tasks necessitate that actions are performed in an order that leads to the task goals being attained. One classic view of how sequential actions are learned and performed is that this involves a chain of simple associative links between each action and the next (Lashley, 1951). In contrast, others argue that tasks are based on learned, hierarchically-organised schema, cued by environmental events (Cooper and Shallice, 2000; Humphreys and Forde, 1998; Norman and Shallice, 1986). On this last view, sequences of actions can be clustered within a higher-order goal, with the set of higher-order goals comprising the schema for the task.

Humphreys and Forde (1998) studied actions of daily living in both normal participants and patients with impaired everyday-life behaviour. They had normal participants list the actions they would usually carry out to realize the task, and noted that simple component actions could be grouped together into subroutines, which are themselves part of larger routines, and so forth (see Figure 1). According to this account, the processing system is arranged in layers corresponding to discrete levels of task structure, with processing at lower levels guided by input from higher ones. Humphreys and Forde argued that simple actions rather than being organized by a specific schema, involve the coordination of multiple schemas, associated with different levels of temporal structure.

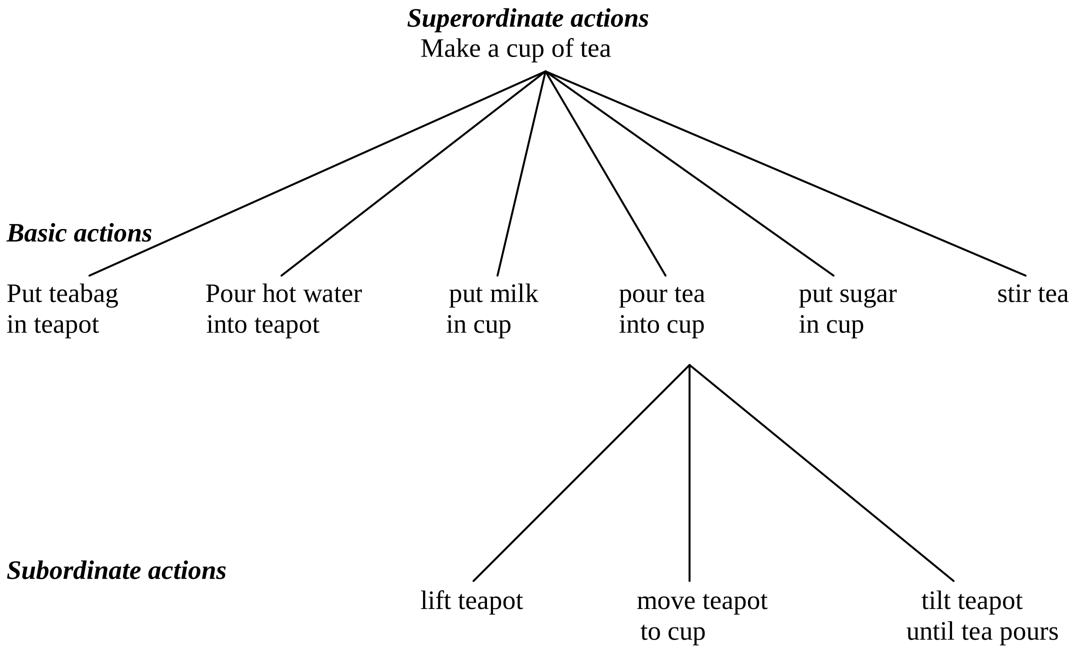

Figure 1: Hierarchical representation of routine sequential task (Adapted from Humphreys and Forde, 1998).

Cooper and Shallice (2000) incorporated the notion of action hierarchies into their model of everyday action, where they simulated action slips in normal participants (Reason, 1984) and aspects of the neuropsychological disorder of action disorganisation syndrome (see Schwartz, 2006, for a review). Figure 2 shows the processing architecture proposed by Cooper and Shallice. In this model the processing system is structured as a hierarchy of nodes or units, with units at the lowest level representing simple actions, and nodes at higher levels representing progressively larger-scale aspects of the task. The top-down flow of activation to each unit is gated until the appropriate preceding actions have been completed. Cooper and Shallice showed how a model with a hierarchical architecture could generate errors resembling those found in human participants.

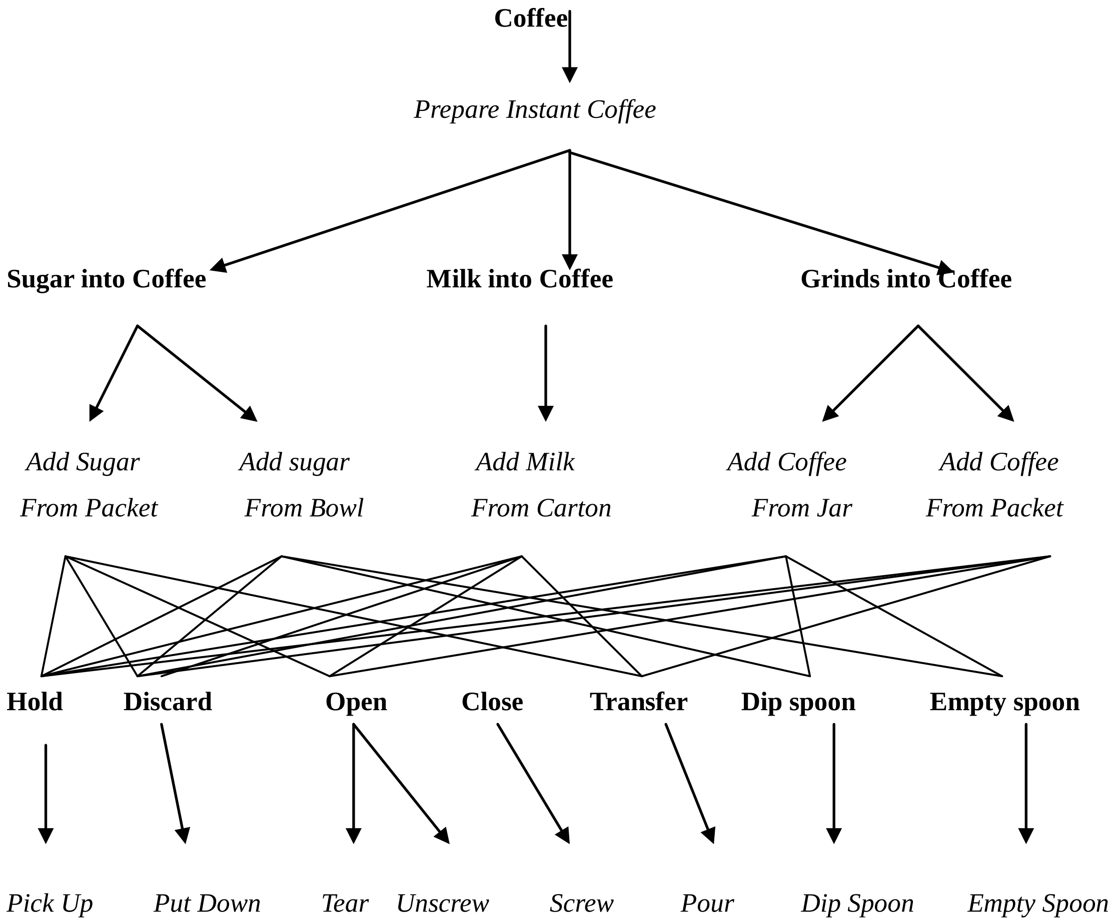

Figure 2: Schema\goal organisation in the coffee preparation domain. Schema are indicated by italic and goals by bold type (adapted from Cooper and Shallice, 2000).

These simulation results provide an existence proofs that plausible human errors arise when processing breakdown in models that use hierarchical task schema to guide the performance of everyday tasks.

1.2.2 Contention Scheduling and the supervisory attention system

The cognitive neuropsychological analysis of everyday action grew from earlier theoretical work distinguishing between automatic and controlled information processing (Posner and Synder, 1975; Shiffrin and Schneider, 1977) and the related distinction between routine and nonroutine action selection (Norman and Shallice, 1980, 1986; Shallice 1972). Norman and Shallice (1986) suggested that routine everyday tasks are controlled by a relatively automatic system, which they referred to as the Contention Scheduling System (CSS). Norman and Shallice (1986) argued that, when a triggering stimulus activates a schema above its threshold, the schema will remain active until the action goal is achieved or is actively inhibited by higher level attentional control processes. These control processes were proposed to be modulated by a Supervisory Attentional System (SAS). This Supervisory system would come into play in situations requiring attention to detail, such as when forms of troubleshooting are required, when novel actions and plans must be realised, or habitual responses need to be suppressed. The SAS controls behaviour by modulating the activation values of existing schemas or, if no relevant schemas exist, creating temporary new ones to determine action.

The localization of the CSS and SAS in the brain is still unclear. Norman and Shallice (1986) stated that the functions of the CS might be controlled by the basal ganglia. However, Rumiati, Zanini, Vorano, and Shallice (2001) suggest that task schemas (presumably part of the CSS) are localized in premotor structures. Supervisory attentional functions, in contrast, are considered to be performed by frontal structures (Shallice, 1982, 1988). Furthermore, Frith (2000) suggests that the dorsolateral pre-frontal cortex plays a critical role in the modulation of CS by the SAS.

Evidence of slips of action by normal participants (Reason, 1984) suggests that, without the recurrent intervention of the SAS, the CS is prone to error. For example, action slips are typically noted when participants are distracted and not attending fully to a task. In a similar vein, Shallice proposed that frontal lobe damage might generate dysregulation of the CS by a malfunctioning SAS or, alternatively, it may directly disrupt processes within the CS itself. The list of frontal lobe symptoms that might be explained in this way included perseveration, poor set switching, and utilisation behaviour (Shallice, 1982, 1988; Shallice et al., 1989).

The hypothesis that disorganized actions can reflect faulty modulation of the CS due to an impaired SS has not been proved completely yet. For instance, Humphreys and Forde (1998) assessed individual patients on a range of everyday tasks. The high rate of errors in two patients (FK and HG) qualified them as having a clinical problem reflecting disorganized action. A third patient (DS) was as impaired as FK and HG on frontal executive tests but made far fewer errors on the action tests. On the standard assumption that poor performance on frontal executive tests equivalent to impairment of the SAS, the evidence suggests that impaired SAS do not necessarily determine the success of naturalistic action production.

1.3 Lapses and errors in action daily living

1.3.1 The qualitative classification of errors

The complexity of the processes that control everyday activities makes performance prone to error even in normal participants. These errors ('action slips') can be informative about the processes underlying the control of routine actions. Reason (1979, 1984, and 1990) and Norman (1981) investigated slips and lapses of normal volunteers in everyday actions and developed classification systems for the errors observed. The most common errors of action included:

3. *Capture:* when action is 'captured' by familiar but unintended routine (e.g. putting on gardening boots upon entering the garage, instead of getting the car out as intended);

4. *Omission:* where some crucial action or step was left uncompleted (e.g. failing to add tea to a teapot before adding water when making a pot of tea);
5. *Anticipation:* when the action sequence is performed earlier in the sequence than it should (e.g. when filling a bucket from a tap, putting a lid on the bucket before turning off the tap);
6. *Perseveration:* where an apparently correct action is unnecessarily repeated (e.g. adding excessive tea-spoon full of sugar to coffee when distracted by an event);
7. *Substitution:* when one object or location is used in place of that which should be used (e.g. applying shaving cream instead of toothpaste to a toothbrush).

It is interesting that qualitatively similar error patterns are also found in patients, suggesting that errors from both patients and normal participants may stem from the same underlying process (e.g., noise or under-activation of the action selection system).

1.3.2 The quantitative description of action

Neuropsychologists have long used functional assessments in the study of patients with poor performance in aspects of everyday action (e.g. De Renzi and Luchelli, 1988; Liepmann, 1900, 1988, 1906/1988; Luria, 1966). Some researchers have studied single tasks such as lighting a candle or cigarette (Liempan, 1900, 1905, 1988; Luria, 1966), and the others serial behaviours using multi-objects tests (MOT) (e.g. De Renzi and Lucchelli, 1988; Humphreys and Forde, 1998; Schwartz, Fitzpatrick-De Salme, and Carew, 1995). Schwartz et al. (1991) introduced a Multi-Level Action Test (MLAT) to assess the accuracy of patient performance in accomplishing everyday tasks. The MLAT requires participants to perform a set of naturalistic tasks, such as gift-wrapping and preparing a lunch box, which had to be accomplished a number of times but without immediate repetition. The MLAT was simplified later into the Naturalistic Action Test (NAT), which includes both isolated tasks (e.g. making a sandwich) and more extended activities (e.g. preparing breakfast). Schwartz et al. (1991) developed an action coding system (ACS) for measuring performance on this and other everyday tasks, where behaviours were divided into smaller units of action (A-1). Schwartz et al. defined the basic unit of action "to be the smallest component of a behavioural sequence that achieves a concrete, functional result or transformation, describable as the movement of an object form one place to another or as a change in the state of an object" (p.384). At the next level a number of A-1s (e.g., lift the milk, open the milk, move the milk to milk bottle to the teacup, and pour the milk in tea) make an A-2 step (e.g., put milk in the cup), if the A-1's are ordered in a principled way. This A-1 to A-2 relationship reflects the different levels within a hierarchy of actions leading to the completion of the sub-goals making up complex tasks.

1.3.3 Error rates and error profile

This action coding system has been used to study a number of different patient groups including individuals with closed head injury (CHI: n = 30; Schwartz et al. 1998), left hemisphere stroke (LCVA: n = 16; Buxbaum et al., 1998), and right hemisphere stroke (RCVA: n = 30; Schwartz, et al., 1999). It has also been employed in case studies of disorganised action (e.g. Schwartz et al., 1991, 1995; Schwartz et al., 1993; Forde and Humphreys, 2000, 2002; Humphreys and Forde, 1998), as well as in patients diagnosed with degenerative dementia (Giovannetti, Libon, Buxbaum, and Schwartz, 2002) in order to measure and compare errors.

De Renzi and Lucchelli (1988) categorized patient errors on a multiple objects test into six types. The most frequent error type was the omission of a necessary step. Only one patient who was least severe on most measures in their group of 20 made no omission errors. Object misuse and action mislocation were the other common errors. There were more moderate rates of general clumsiness and low rates of anticipatory sequence errors. The MLAT studies demonstrated that errors of action are widespread in all neurological groups that were studied (CHI, RCVA, LCVA). In each of the three patient groups, omission errors were most common (LCVA: 44%; RCVA: 47%; CHI: 40%), followed by sequence errors (LCVA: 27%; RCVA: 19%; CHI: 21%). Substitution errors and action addition errors also occurred in all groups, at lower proportions than omission and sequence errors (Buxbaum et al., 1998; Schwartz et al., 1998; Schwartz et al. 1999). Humphreys and Forde (1998) obtained similar trends towards omission and sequence errors (they observed 34% omission errors and 40% sequence errors in their case studies of two patients with extensive frontal lesions). The two other main error types, object substitution and action addition errors, each accounted for approximately 10% of errors.

1.3.4 Accomplishment and its correlation with error score

Schwartz et al. (1998) scored the behaviour of patients on a single accomplishment dimension that reflected the percentage of subtasks of the ADL that each participant completed, ignoring errors along the way. Schwartz et al. found a strong negative correlation between total error score and accomplishment in their study (r = –. 918, p <. 001). Patients who make more specific errors tend also to accomplish fewer steps, suggesting that both specific errors and accomplished steps provide markers of underlying pathology.

1.3.5 Errors in relation to severity

The relation of the error profile to severity of deficit has been taken by Schwartz et al. as indicating that omissions were particularly indicative of ADS. Omissions were common to all the groups tested (RCV, LCV, CHI) and in all patient groups, low error producers tended to produce more commission errors, while high error producers tend to produce more omission errors.

1.3.6 The effect of distractor objects

Schwartz et al. (1998) and Buxbaum et al. (1998) also investigated the effect of the absence or presence of distractor objects on ADL performance. In one condition participants were required to complete an ADL task while seated at a desk with all and only those items required for the task present on the desk. In a second condition, participants were supplied with several additional items that were not needed for the task. It was found that the presence of distractor objects did not lead to inappropriate use of those objects. Schwartz et al. (1998) did, however, report an increase in omission errors when distractor objects were present. Humphreys and Forde (1998), however, reported two case studies and showed no overall effect of distractor on total error rates. From these results it is not clear whether distractor objects affect everyday action, and, if they do, how these effects come about – for example, do distractors compete for selection with targets; do they increase general effects of task load and generate errors for that reason? More detailed analysis of when and why distractor effects occur may be helpful for understanding how multi-step everyday task are performed and how they breakdown after brain lesion. Such an analysis is presented in Chapter 2, where the performance of a patient with ADS is compared with how normal participants performed the same tasks under conditions of cognitive load. One argument is that patients perform poorly with multiple-step everyday tasks because they lack sufficient cognitive resources to support the tasks (Schwartz, 1995). If that is the case, then the same qualitative pattern of errors should arise in ADS patients and in normal participants performing under conditions of cognitive load. For example, if a patient shows effects of semantic errors and of the presence of distractors on task performance, then so should controls operating under conditions of dual task load? This is tested in Chapter 2.

1.4 Neurological disorders

Everyday action may be affected by a range of specific neurological disorders. The two primary disorders of everyday action are apraxia (Luria, 1966; De Renzi and Luccelli, 1988) and action disorganization syndrome (Schwartz et al., 1991, 1995, 1998, 1999). I discuss each of these in turn, emphasising the different errors that occur in order to assess whether the problems are qualitatively similar or different.

1.4.1 Apraxia

Apraxia is defined as a deficit in the higher order control of motor function in which the resulting impaired production of skilled movements cannot be accounted for by sensory loss, weakness, tremor, dystonia, ataxia, poor comprehension, or dementia. Researchers have attempted to characterise in detail different type of apraxia (e.g. Liepmann, 1905).

Ideomotor apraxia can be defined as a disorder of temporal, sequential, and spatial organisation of action (Heilman and Rothi, 1985). It is usually diagnosed on the basis of spatio-temporal errors on transitive gesture tasks with single stimuli, where patients are required to demonstrate the pantomime linked to object use and/or on gesture imitation tasks. Many patients with ideomotor apraxia also have difficulty with intransitive gestures. Lipemann (1905) reported patients with parietal lesions who were unable to gesture to command or in some instances to imitation. Subsequently, Liepmann and Mass (1907) described a patient with a lesion of the corpus callosum who was unable to produce gestures with his left hand to verbal command. The gestures that such patients produce often contain errors in the spatial and temporal parameters of action but correctly specify the semantic content of the action. In contrast ideational apraxia is defined as incapacity to evoke mentally the action associated with an object (Heilman and Rothi, 1985). So in ideational apraxia, gestures may be well formed but unrecognisable or associated with different objects. Poeck (1983) includes in the definition of ideational apraxia patients who have problems with the sequentional organisation of multi step actions. To differentiate such patients from patients making content errors, Ochipa, Rothi, and Heilman (1992) proposed the term “conceptual apraxia” to refer to patients showing content errors on tasks requiring actions to single objects.

Liepmann’s original distinction between ideomotor and ideational/conceptual apraxia, invites a separation between “central” and “production” forms of action impairment. On this account, ideational apraxia is a disorder of the conceptual system, which contains knowledge of tool function and actions, whereas ideomotor apraxia is a disorder of the production system that includes sensorimotor action programmes concerned with the generation and control of movement. Hence, in this dissociation, a central deficit could involve a failure to recognise the object or to understand the verbal command linked to a given action, due to the central conceptual impairment. In contrast a production form of action impairment can co-occur not only in intact recognition of gesture but also intact imitation, alongside impaired gesturing to verbal command (Heilman, 1973). In chapter 4, I will examine aspects of apraxic errors with single objects in order to understand the nature of these deficits too.

1.4.2 Action Disorganisation Syndrome (ADS)

Schwartz et al. (1991, 1995, 1998) and Humphreys and Forde (1998) investigated action disorganization on everyday tasks following frontal injury. Action disorganization syndrome is a term to describe patients who make abnormally high numbers of errors on familiar multiple-step tasks, where the deficits are not due to a motor impairment or to a deficit in object recognition. Such patients make frequent errors when dressing, grooming, eating, and so on. They misuse objects, perform actions out of sequence, terminate tasks prematurely, and perseverate on the task or its components (see Schwarz, 1995). There are a few similarities between the type of errors in ADS and Apraxia. For instance, some errors in ADS patients can reflect apparent conceptual problems. Schwartz et al. (1991) studied a patient (HH) with damage to and beyond the frontal lobes. On a task requiring eating from the hospital breakfast tray, HH spooned a pat of butter into his coffee; on another occasion he poured coffee into his bowl of oatmeal. In a later study Schwartz et al. (1995) studied a CHI patient (JK), who started to spread shaving cream onto his toothbrush. When stopped by the therapist, and without specific instruction from her, he reached into his grooming kit, extracted the toothpaste tube, and proceeded to brush his teeth in the appropriate manner. These errors in ADS patients resemble ideational/conceptual apraxia.

However, all aspects of ADS cannot be accounted for in terms of ideational apraxia. There are patients who perform well with single objects but have problems in performing everyday action; for instance Forde and Humphreys (2000) studied a patient (HG) who was able to name, gesture the use, and provide definitions for almost all objects presented but he was severely impaired at using the objects in a range of relatively routine everyday tasks and the ADS problems emerge only in the context of the everyday task.

There is evidence too that actions with unusual objects can emerge only in the context of the everyday tasks; Bickerton, Humphreys, and Riddoch (2007) examined patients with subcortical and frontal damage, who were relatively good at naming or showing how the unfamiliar implements could be used outside of the task context in isolation. In contrast, errors emerged with the unfamiliar objects during multiple-object task performance. In this case, as in that noted with patient HG above, impairments in a task schema seems to add errors into performance that is not seen with individual objects.

In sum, while there may be some overlap between aspects of apraxia and ADS, many of the symptoms of ADS only emerge in the context of the multi-step everyday tasks, indicating that performance needs to be examined and measured in the context of these tasks in order to understand this disorder. This is what I will do in Chapter 2.

1.5 Cognitive neuropsychological models of action

Rothi, Ochipa, and Heilman (1991) developed a model of the praxis system to accommodate the various neuropsychological dissociations that have been described within the syndrome of apraxia including: problems in gesture imitation, gesture to command, and gesture to the sight of objects (Figure 3).

The model includes two routes to gesture production and imitation. The first is an indirect or “lexical” route which processes meaningful actions via access to semantic system (conceptual information) and stored movement representations at two loci, the input and output action lexica (route “a” in the model). The second is a direct route, which bypasses gesture engrams and action semantics and allows meaningless gestures to be imitated (route “b” in the model). When this route is intact and other routes disturbed then imitation may be preserved even when gesturing to verbal command and to visually presented objects is impaired. There are also dissociations between gesturing to verbal command and gestures prompted when objects are presented in other modalities, including both vision (De Renzi, Faglioni, and Sorgato, 1982; Pilgrim and Humphreys, 1991; Riddoch, Humphreys, and Price, 1989; Rothi et al., 1986) and touch (De Renzi et al., 1982).

The modality-specific apraxias, for vision and touch, have led to suggestions that there are direct modality-specific routes to action in addition to those for imitation, again bypassing the semantic system (routes “d” and “e” in Figure 3) (Riddoch et al., 1989; Rothi et al., 1991). I review below whether the proposal of these routes, alone, can account for these modality-specific apraxias.

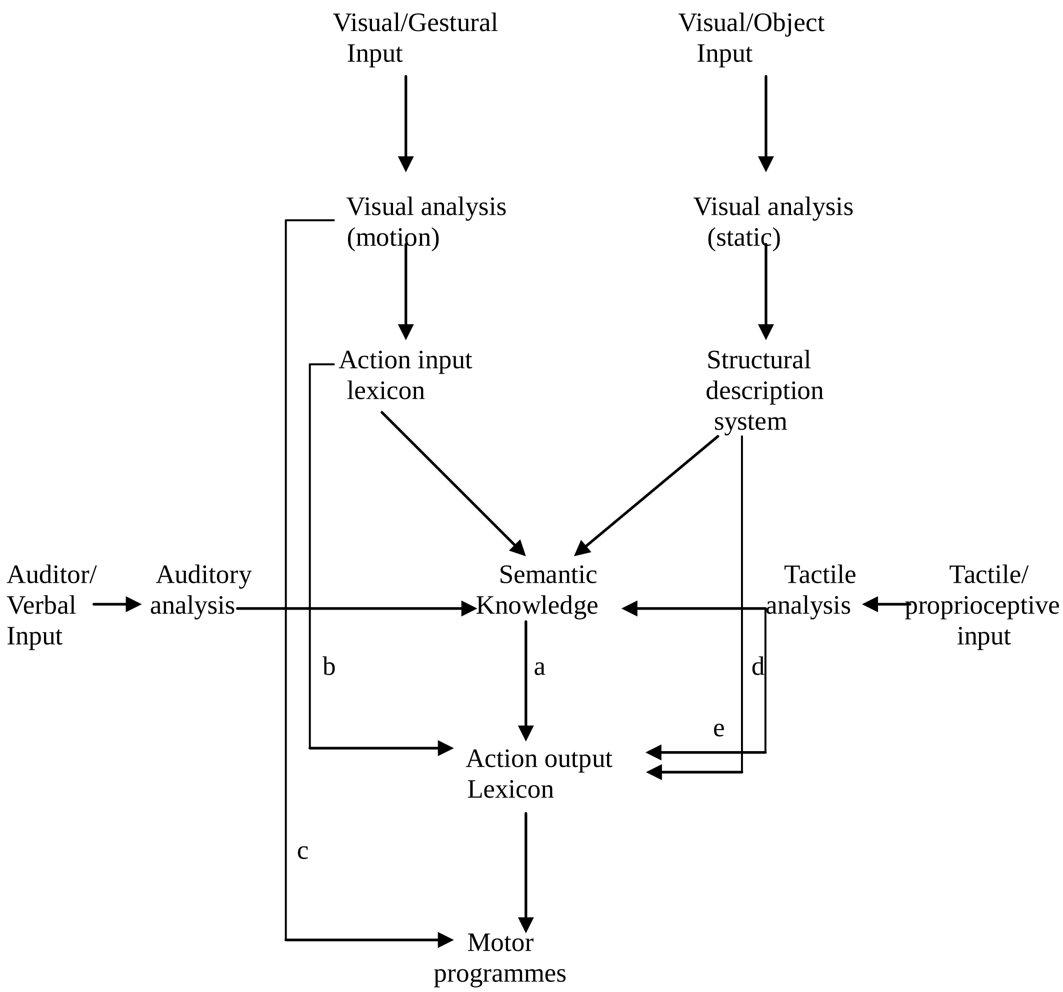

Figure 3: The multiple-route model of action (extracted from Rothi et al, 1991).

The argument for direct modality-specific routes to action are supported by other pieces of neuropsychological evidence; for example, in syndromes such as optic aphasia, patients can show a good ability to gesture along with impaired naming of visually presented objects. In addition, where tested such patients have demonstrated poor matching of objects based on inter-object associative relation. This suggests that there is a deficit in accessing semantic knowledge (e.g. Riddoch and Humphreys, 1987). The relatively presented gestures in these patients then may be attributed to a direct, non-semantic route from vision (route “d”) (Riddoch and Humphreys, 1987). An analogous argument can be made concerning naming deficits specific to the tactile modality (Route “e”) (Beauvois, Saillant, Meininger, and Lhermitte, 1978).

It is also possible that links may be established between the parts of objects and actions, which are not dependent on access to the structural description of whole objects; for example Chainay and Humphreys (2002) studied performance decrements when perceptual input is degraded. They found that the patients were impaired at gesturing to non-action parts of objects even though they could name the objects from parts.

The model of Rothi et al. (1991) is a traditional ‘boxes and arrows’ model in which information is thought to be passed discretely from one processing stage to the next. Chainay and Humphreys (2002) proposed an alternative view to this, suggesting that activation is passed continuously between processing stages, with the selection of the appropriate action for an object based on the convergence of activation from multiple systems (modality-independent semantics and modality-specific input systems). This ‘convergent activation’ model is able to account for some aspects of action selection in patients where the discrete model has difficulty. One example of this is the disorder visual apraxia, where a patient is impaired at gesturing to visually presented objects even though they are able to gesture when given the object’s name (e.g., Riddoch et al., 1989). In such cases patients are able to recognize visually presented stimuli (e.g., they pass semantic matching tasks) and they may even name visual objects correctly. For a discrete model this disorder is difficult to account for, since it is not clear why a patient with good visual object recognition and intact semantic access to action cannot gesture to a visually presented object using the intact semantic route. This disorder can be account for using the convergent route model, however, According to this idea, activation from an impaired visual route to action can add noise to activation from the spared semantic route with the system for action selection. If selection normally relies on convergent activation from the two routes, so the noisy visual route will disrupt action selection (see Yoon, Heinke & Humphreys, 2002, for an explicit simulation). The convergent route account can also explain some benefits to action selection found when patients use objects rather than more abstractly pantomiming their use. It has long been know that apraxic patients may show better use of objects than gesturing. Chainay and Humphreys (2002) showed that patients with this profile could recognise the objects they failed to gesture to, irrespective of whether they were just looking at the stimuli or held them in their hands (as in the ‘use’ condition). The ‘use’ advantage then cannot come about through object recognition improving when objects are held for use, but instead there must be some direct effect from object use on the action selection system, by-passing the semantic route to action. Again this fits with the idea that there is convergent action from touch as well as semantic and visual representations, and that these different inputs into action selection normally converge to push the system into a state where the appropriate action is selected. In Chapter 4 here I will use the convergent action model as a guide for understanding disorders at different ‘levels’ of action selection in contrasting patients.

As noted above, one reason why actions may be performed better when patients actually use objects compared with when they mime gestures is that the convergence of touch and vision (in the use condition) drives a strong, associated action directly (by-passing semantic knowledge). Another way to assess whether this direct evocation of action can occur is presented in Chapter 5 here. In Chapter 5, I present data from 2 patients with impaired semantic knowledge and consequently poor object recognition and naming. Despite this central disturbance I present evidence for the first time indicating that the patients are better at identifying objects under conditions where they are allowed to use the stimuli compared with when they merely look at them or when they are allowed to hold and touch them (but without moving the objects). I interpret these data as supporting the argument that, in the object use condition, the patients can respond to actions that are directly associated with the enriched perceptual input into the action selection system. The patients then name objects from the actions that are evoked.

1.6 Effect of therapy on everyday actions

The successful performance of most routine everyday action is dependent on a substantial number of cognitive processes. As mentioned before these cognitive processes include: an intact stored knowledge of routine actions; the ability to impose such knowledge on behaviour through working memory for action; and an intact knowledge of the actions related to individual objects (Humphreys, Forde and Riddoch, 2001). Action disorganisation syndrome, the abnormal impairment of these abilities, can reflect impairments to these different processes (see Humphreys & Forde, 1998). To be successful, rehabilitation would need to be targeted selectively at the impairments in order to facilitate performance in a given patient.

1.6.1 Previous studies in rehabilitation of everyday action

Goldenberg and Hagmann (1998) reported effects of training on patients with some degree of apraxia when asked to handle simple and familiar objects. In their procedure the therapist led the patient through sets of single-object actions, performing the action alongside the patient, and drawing the patient’s attention to the functions associated with the perceptual properties of stimuli and to critical features of actions linked to these features. Performance was improved on trained but not untrained actions.

Later Goldenberg, Daumuller, and Hagmann (2001) examined performance on four complex activities of multi-step daily living (ADL) in order to compare two methods of treatment. Here, “direct training” of the activity based on the guided performance of the whole activity improved performance of daily living activity while “exploration training” alone did not. In the “direct training”, support was given at all critical stages and was reduced only as the patient’s competence increased. For example, the therapist would take the patient’s hand and lead it through a difficult action. In the “exploration training”, the objects involved in an activity were explored, but the activity itself was not carried out. The therapist tried to direct the patient’s attention to functionally significant details of the object and compared the objects with other objects used for either the same or different purposes. For example, the serrated knife used for cutting bread was compared with a saw and a plain knife to highlight the importance of serration for cutting.

In contrast to this, Forde and Humphreys (2000, 2002) tried to investigate the implications for therapy of a “non-specific cognitive resources” account of everyday life-task performance. The “non-specific cognitive resources” hypothesis (Schwartz, 1995) predicts that decreasing the cognitive resources required for everyday tasks should consistently facilitate performance in ADS patients, if typically they lack sufficient resources to perform the tasks successfully. Forde and Humphreys (2000) reduced the role of working memory on performance by providing cues to each step on a range of everyday tasks. The patient, HG, was given a set of commands to follow. Despite the fact that HG could read the commands perfectly well, and even though he continuously referred to written commands when doing the task, his performance was no better than in a baseline condition (no instructions). They suggested that HG’s disorganized behaviour when carrying out everyday tasks was not simply due to an inability to maintain a representation of the goal in working memory, or to problems in accessing the components steps from action schema, because eliminating these requirements did not facilitate his performance.

Despite this lack of success, other investigators have shown some improvements when patients are taught to use an explicit verbalisation strategy. Donkervoort et al. (2001) examined the effects of training on a group of left hemisphere stroke patients with apraxia. The strategies involved teaching the patients to self-verbalise actions, to support their performance. The strategies were shown to improve behaviour on a set of everyday tasks, compared with standard occupational therapy, in the patients.

Pilgrim and Humphreys (1994) similarly used a self-verbalisation strategy to facilitate the retraining of action in a patient who was apraxic with single objects. In their training programme the patient received both physical assistance and verbal guidance when making actions, with the verbal instructions breaking down each action into a sequence of steps (reach the beaker, clasp the beaker, carry the beaker to my lips). Pilgrim and Humphreys found that the actions made by their patient improved for objects subject to action training, but not to control objects for which no training was given.

Bickerton, Humphreys and Riddoch (2006) investigated the use of a verbal rehabilitation strategy in a clear case of ADS (FK). In their training strategy, FK was taught a poem based on the steps involved in making a cup of tea. The results showed that, after training, the everyday action was performed more successfully than prior training but there were not training effects on new tasks or on the same task with a different key objects.

These results suggest that aspects of everyday action can be remediated and that ‘weighting’ impaired semantic and direct-visual routes to action against a more spared verbalisation process helps to impose order onto patient performance. In Chapter 6 I will present data from a patient showing aspects of limb apraxia where I attempt to alter performance by applying multiple cues to the correct action during training, and then assessing performance when the cues are withdrawn. The data point to the importance of convergent (multi-modal) inputs in re-learning motor actions in patients with action disorders.

1.7 Eye movement and action daily living

Everyday action is hard to study in the laboratory. There are the obvious practical impediments to simulating real-world conditions (e.g., at the very least the environment will probably not be familiar, where the home environment will), as well as difficulties in establishing the requisite degree of experimental control. Creative energy has gone into development of laboratory procedures that have face validity and that predict real world performance. One technique that is already available and that has been used to great advantage with non-neurological subjects is eye movement monitoring (Hayhoe, 2000; Land and Hayhoe, 2001).

Some recent data from eye movement studies of normal people completing the everyday task of tea making (Land et al., 1999) suggest that some supervisory type processes are employed to guide attention on-line during task performance. In particular, Land et al. (1999) found evidence for several different types of monitoring (locating, directing, guiding, and checking) that normal people engage in at key points during tea making. This monitoring behaviour may reflect supervisory processes that, if necessary, modulate activation flow within the CS. If so, the data of Land et al.

imply that some supervisory processes play important roles in the performance of everyday action. It would be most instructive to know how actions and eye movements are coupled in patients who do and do not make action errors.

Forde et al. (in press) provide the first analysis of eye movements in a patient with ADS. These authors report that the close coupling between eye movements and actions remained relatively preserved in the patient compared with controls (e.g., the eyes moved to an object at about the same time as controls, prior to an action being effected). This suggests that the coupling of attention to action can remain spared even when incorrect actions to objects are selected. On the other hand, the patient made frequent eye movements that were unrelated to ongoing actions when certain error types occurred (e.g., when there were perseverations). In this case the patient's actions seemed to be disconnected from attentional monitoring. Whether these characteristics hold for the eye movements of other patients with ADS will be examined here in Chapter 7, where I present data from a study where eye movements were monitored in a patient showing ADS.

1.8 The thesis

This thesis is concerned with the factors that determine the performance of everyday action, and how aspects of everyday action (such as using objects for action) influence other ongoing processes. Six empirical chapters are presented with deal with:

3. the effects of distractors and task load on the performance of everyday life tasks, comparing a patient with ADS and controls operating with a task load (Chapter 2);
4. the role of task schema and the effect of reducing task demands in

ADS (Chapter 3);

5. the differentiation between different forms of apraxia, in relation to cognitive neuropsychological models of action selection (Chapter 4);

6. the use of action information to overcome visual recognition deficits in patients with impaired semantic knowledge about objects (Chapter 5);

7. whether apraxic errors could be improved by the use of convergent, multi-model cues during learning, as predicted by accounts such as the convergent routes model of action retrieval (Chapter 6); and

8. the operation of eye movements in everyday-life tasks in a patient with ADS, and whether the coupling of action and attention can remained preserved in such cases (Chapter 7).

Altogether the data are informative about the factors that underlie the performance of everyday tasks in patients, as well as being informative about how constraints during the performance of these tasks impact on object recognition and attention, and how basic component actions in the tasks may be remediated. The results conform to the view that action retrieval is influenced by inputs from multi-modal systems which converge to determine action selection, that action information can be derived rapidly and influences both object processing and the allocation of attention, and action information can break down at different levels, giving rise to different problems in performing everyday tasks.

CHAPTER 2

Comparing Action Disorganisation Syndrome and Dual-task Load on Normal Performance of Everyday Action Tasks

Abstract

A range of everyday life tasks was used to examine the effects on a patient with action disorganisation syndrome (ADS) of having related distractors present during task performance. The presence of related distractors increased omission errors in the patient. A second experiment assessed whether this pattern of deficit was replicated when normal participants carried out the everyday tasks when a secondary task was imposed to place demands on executive processes. Secondary task load produced a general increase in errors in the controls and it reduced the number of self-correcting responses, but there were no proportional increases in omission errors. Control participants and patients with ADS may suffer from demands on different process involved in the performance of everyday actions. I discuss the implications for understanding everyday-action.

2.1 Introduction

Following brain damage patients can often have problems in carrying out even simple and daily activities that they used to perform pre-morbidly. Schwartz and colleagues introduced the term action disorganization syndrome (ADS) to describe patients who make many ‘cognitive’ errors, relative to controls, on familiar multiple-step tasks that cannot be attributed to motor incapacity (Schwartz, Reed, Montgomery, Palmer, and Mayer, 1991) (See chapter 1 for more information). These deficits can be found even in patients who show good recognition and gesturing to individual objects (Buxbaum, Schwartz & Carew, 1997; Forde & Humphreys, 2000), indicating that ADS does not necessarily reflect impairments in object recognition but rather problems in organising actions when multiple steps have to be undertaken.

2.1.1 Quality and quantity of errors

Schwartz and colleagues developed a standardized scoring system for measuring performance on everyday actions in which they classified the kinds of errors made by neuropsychological patients (Schwartz et al., 1991; Schwartz, Mayer, Fitzpatrik De Salme, and Montgomery, 1993; Schwartz, 1995, Schwartz et al., 1995). In very broad terms, they divided action errors into:

- *Errors of omission*, which are errors resulting from failures to initiate some task-essential action or sequence of actions
- *Errors of commission*, which are errors resulting from initiating an action that is in some way incorrect or inappropriate

Commission errors may be further subdivided into different sub-types including: *sequence errors* (performing component actions in the wrong sequential order), *additions* (inserting an extra component action incorrectly), *semantic errors* (using an object as another semantically related item), *perseverations* (repeating an action or action sequence once its goal has been achieved), and *quality or spatial errors* (failing to use tools or using excessive quantities of ingredients). Schwartz et al. (1998) observed that around 38% of the errors made by their patients were step omissions, with sequence errors accounting for another 20% of the errors. Humphreys and Forde (1998) found a similar tendency towards omission and sequence errors with, respectively, 34% and 40% of their patients' errors falling into these two categories (see also Buxbaum et al., 1998; Schwartz et al., 1999).

Schwartz et al. (1998) noted that, compared with commission errors, there were stronger relations between omission errors and overall measures of clinical severity in everyday tasks. In addition, patients and controls were distinguished primarily by omission errors, with the proportional distribution of commission errors being strikingly similar in the two groups. Omission errors, in particular, may be strong indicators of ADS. Schwartz et al. (1998, 1999) also found few differences between patients with selective left or right hemisphere lesions and patients with more diffuse closed head injuries. They concluded that, rather than suffering deficits in particular cognitive processes necessary for everyday action, patients could have difficulties due to a general reduction in cognitive resources, with omission errors reflecting this reduction in resources. Simulations of this pattern have been reported by Cooper, Schwartz, Yule, and Shallice (2005).

On the other hand, other authors have argued that patients manifesting ADS can have a more specific disturbance which affects their stored knowledge of the actions that should be performed in the task, along with the order with which the actions should be generated. For example, Humphreys and Forde (1998) showed that their patients were impaired at ordering descriptions of the actions that comprise different everyday tasks suggesting that, in addition to any general loss of processing resource, there can be problems in guiding performance based on knowledge about the task.

One aim of this study is to assess whether aspects of ADS can be characterised solely in terms of reduced processing resources, or whether performance needs to be accounted for in terms of damage to other cognitive components involved in the task. To do this, we examined the effects on omission errors when everyday life tasks were performed in the context of related and unrelated objects, comparing performance in a patient with ADS with that of control participants carrying out the tasks under dual task load conditions. The control participants performing under load conditions can provide a model of the deficits expected when processing resources are compromised (particularly for cases where the overall level of deficit is matched across patients and controls). If loss of processing resources is sufficient to account for ADS, then qualitatively similar patterns of deficit may be expected in the patient and the controls.

2.1.2. The effects of distraction in normal participants

Diary studies indicate that “action errors” in normal participants generally occur under conditions in which people are distracted or thinking about something else. (e.g. Norman, 1981; Reason, 1979). For example, during making a cup of tea one might unintentionally pour cold water from a kettle, instead of boiled water, into the teapot. People usually notice action errors such as these and spontaneously correct them (Cooper et al, 2005). In contrast, self-correction tends not to occur in ADS patients (Humphreys & Forde, 1998).

Differences in self-correction between normal participants and patients may reflect the differential operation of the 'Supervisory Attentional System' (SAS) in these groups. Norman and Shallice (1986) proposed a model of the control of action based around a distinction between two processes: (i) a Contention Scheduling System (CSS), which is the substrate of learned responses to stimuli, and activated during the execution of routine tasks, and (ii) the SAS, which performs error monitoring and which may need to override the activation of the CSS when novel behaviors are undertaken. In ADS patients, impairment to the SAS would disrupt their ability to monitor error, so that incorrect responses are explicitly generated. However, as noted by Schwartz and Buxbaum (1997), damage to the SAS alone may not be sufficient to account for ADS. In particular, the normal operation of the CSS should be sufficient for routine tasks to be effected. On the other hand, if the SAS were intact, then patients ought to be able to employ problem-solving strategies to accomplish tasks even without supportive lower-level knowledge (similar to when the task itself is unfamiliar). This suggests that ADS may arise out of impairments in both lower (CSS) and higher-level procedures (the SAS).

Which aspects of ADS may reflect damage to the proposed CSS, and which to the SAS, is difficult to assess, given that the systems interact to determine behaviour. However, attempts to assess the links between the SAS and everyday actions have been made by examining the performance of normal participants when they undertake everyday tasks under cognitive load (e.g., when performing an irrelevant secondary task). Humphreys, Forde and Francis (2000) tried to experimentally test the role of the SAS in performing everyday actions in control participants. They gave participants a version of Trails Test (Heaton, Grant, & Mathews, 1991) to load the SAS while simultaneously performing the everyday task; this should consequently reduce the resources from the SAS that may otherwise support performance. Normal controls showed a number of omission and toying errors in action performance and some errors in the secondary task, however, these errors were still immediately self-corrected. From this, Humphreys et al. suggested that the SAS does not only play a role in error monitoring (which appeared to continue, despite the secondary task), but it also played a role in retrieving actions in the routine task. Thus, as the load on the SAS increased, so there was less support from this mechanism for retrieving appropriate actions in the right sequence; accordingly, action errors increased. One framework for understanding this result was introduced by Humphreys and Forde (1998), who proposed that action retrieval in everyday tasks was guided by temporary activation of the task steps in working memory, which needed to be maintained for the correct actions to be retrieved in the correct order. Proposing a ‘competitive queuing’ model, they suggested that the order of actions in everyday life tasks was generated through an ‘activation profile’ in processing units representing the order of the steps in the tasks. This can be thought of as holding a temporary memory for the steps in a task (see Humphreys & Forde, 1998). Disrupting this working memory representation will affect action retrieval if there is damage to the activation gradient differentiating the steps in the tasks. This will make actions more vulnerable to noise when activation values vary. Baddeley (1986) proposed that working memory involved a number of core, co-operating systems, including an executive component like the SAS which can both hold temporary representations during a task (as suggested by Humphreys and Forde, 1998) and monitor for errors.

In the present study, we assessed whether aspects of the performance of ADS patients could be simulated in normal participants carrying out the tasks under conditions that load working memory/the SAS. In an extension of Humphreys et al. (2000) we examined the effects of having sets of objects from related and unrelated tasks as well as the effect of the difficulty of the secondary task. Performance in a set of control participants was compared to that of a patient with ADS (patient FK; see Humphreys & Forde, 1998). When objects come from related tasks (e.g., two tasks both performed in a kitchen or in an office), then there may be more competition to select the appropriate object for the task due to distractor objects having some association to each task. An analogy for this comes from work with normal participants by Moores, Laiti and Chelazzi (2003). They had normal participants search for a target object (e.g., a motorbike) and, on some trials, presented a semantically related distractor in the display (e.g., a crash helmet). Participants were slowed by the related distractor, reflecting the extra time taken to resolve the competition for selection when the related distractor was present. In the context of everyday life tasks, problems in selecting the appropriate object or action may arise when related distractor is present. This could again be due to loss of resources from working memory/SAS, if this means that the activation profile favouring task-related objects, or a particular order of actions, are disrupted. Problems in selecting the appropriate action for the task may also be exacerbated in patients if the task schema itself is impaired, and so does not differentially activate the objects to be used for the task relative to other objects found in the same context. In prior reports with FK, Humphreys and Forde (1998) showed that he had impaired task knowledge, being impaired when asked to sort task steps into the appropriate order. Hence we might expect that problems in everyday life tasks in such a patient might increase when objects from the same context are present. Experiment 1 focuses on a patient with symptoms of ADS and assesses his errors in different everyday actions performed in the context of related or unrelated distractors. Does the presence of related distractors disrupt performance, and does it do this by selectively increasing particular action errors? Experiment 2 examines the performance of normal control participants under dual task conditions, to evaluate if qualitatively similar effects emerge.

2.2 Experiment 1: Effects of related distractors on everyday action

Experiment 1 contained 3 conditions involving performance of everyday tasks when: (a) semantically related distractors objects were present; (b) unrelated distractors objects were present, and (c) no distractors were present. Related distractors may increase the competition to select the appropriate target objects for action (Moores et al., 2003). If more resources are called upon the select the target under these conditions, fewer resources will be available to support other aspects of task performance. Performance should thus deteriorate.

2.2.1 Method

Participants

There was one ‘experimental’ participant, FK, and four patient controls. FK was 37 years at the time of testing. He suffered carbon monoxide poisoning in 1989 while studying for an engineering degree, but has subsequently lived with the full support of his family. FK’s personal care is supervised by his family. A Magnetic Resonance Imaging scan revealed bilateral damage affecting both the right middle and inferior temporal gyri and left inferior temporal gyrus. Another lesion affected the right middle occipital gyrus and small lesion in the right medial orbital gyrus (see Figure 4 for MRI Scan). Previous general cognitive tests shows that FK’s full IQ score after accident was 58 (Wechsler, 1981) and his memory performance on the WMS (Wechsler, 1990) was less than 50. These scores are substantially lower than would be expected from his pre-morbid academic achievement. Assessed through the NART his pre-morbid IQ was estimated at 110. FK’s verbal short-term memory is relatively intact (digit span= 7). However, he presented with a range of clinical problems including: impaired object recognition and naming (Humphreys & Forde, 2005), dysexecutive disorders and problems in everyday action (see Humphreys & Forde, 1998 for more information). Although he had impaired visual object recognition (see Humphreys & Forde, 2005), FK was able to carry out the instructions for single actions with the objects from the everyday life tasks. FK has previously been reported in several papers focusing on ADS (e.g., Humphreys & Forde, 1998) and he was the patient who failed to respond to single written commands administered in the context of complete tasks, in the study of Forde and Humphreys (2002). His problems in everyday action were the focus of the current study.

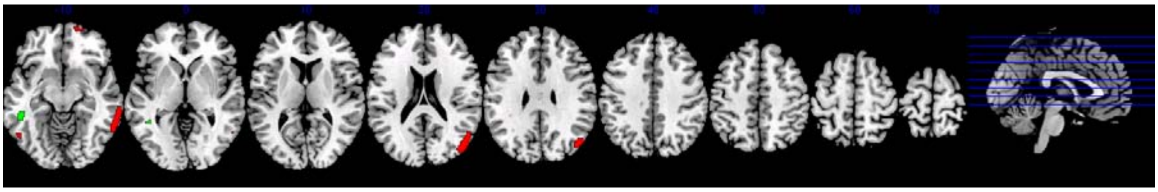

Figure 4: FK's MRI Scan

Table 1: Patient characteristic and lesion description

Patients	Sex, age	Handed ness	Aetiology	Lesion	Clinical Symptoms	NART (IQ)*	Brixton	Corsi block	Digit span
FK	M 37	R	Carbon monoxide poisoning	Right middle & inferior temporal gyri. Inferior temporal gyrus. Right middle occipital gyrus. Right middle orbital gyrus	ADS Dysexecut-ive syndrome Visual object recognition	110	38	4	7
DB	M 71	R	Stroke	Left inferior parietal, superior and middle temporal gyri	Aphasia	95	20	4	4
MP	M 59	L	Aneurysm	Right inferior frontal, inferior parietal and superior temporal	Neglect, acalculculia	105	21	3	5
DS	M 73	R	Stroke	Left inferior frontal gyrus. Left middle frontal gyrus. Left precentral gyrus. Left poscentral gyrus. Left caudate & putamen.	Aphasia	105	20	3	4
TT	M 69	R	Stroke	Right inferior and middle frontal gyrus	Elements of dysexecutive syndrome	115	21	5	5

* The Brixton test of executive function (Burgess & Shallice, 1997) provides a measure of non-verbal executive function. A raw score above 26 indicates a clinical abnormality.

The control patients (DB, MP, DS and TT) were all chronic stroke victims, with TT having had the most recent lesion (3 years prior to testing). All were older than FK (mean age 68 years), but here the general effects of ageing would act against our finding a selective deficit with FK. The control group were an attempt to control for both the effects of ageing and of generalised brain lesion All of the patients (controls and FK) would have had experience with the everyday tasks pre-morbidly, though DB and MP (and their spouses) confirmed that they rarely carried out tasks involving wrapping gifts or making sandwiches. Two patients had unilateral left hemisphere damage (DB and DS, with lesions of respectively the tempo-parietal junction and the left dorsolateral prefrontal cortex) and two had right hemisphere lesions (MP and TT, with damage respectively to the right superior temporal, inferior parietal and inferior frontal regions and to the right middle frontal gyrus) (see Table 1). None of these control patients reported evidence of having problems with everyday tasks. Other clinical deficits in the patients are noted in Table 1. The control patients only took part in the tasks with related objects present. The presence of the control patient tests for whether FK presents with ADS, when measured against the performance of other patients with brain injury.

2.2.2 Procedure

Each patient was tested individually by being placed in front of a table and asked to perform a particular task. The tasks were: (i) make a cup of tea with milk and sugar, (ii) make a cheese sandwich and put the sandwich in a sandwich bag, (iii) wrap a gift, and (iv) write a card and prepare it for the post. These tasks were chosen so that two included the preparation of food/ drink and would normally be carried out in a kitchen (making tea and making a sandwich); the other two tasks were both typically performed on a desk (wrap a gift and write a card). We considered, as semantically related, the tasks (and objects) that were normally conducted in the same context (tea + sandwich; gift + card).

In the semantically related condition, each task was performed with distractors from the related task being present in front of the patient when it was performed (e.g., the tea task was performed with the sandwich objects present). In the unrelated condition (FK only), each task was performed with distractors from an unrelated task being present (e.g., the tea task with the objects from the card task present). In no-distractor condition (FK only) the tasks were carried out without any distractors present. The objects were randomly positioned on the table at the start of each trial (see Appendix A for a full list of the tasks). Performance was videotaped for later analysis. To ensure that any problems were not due to failures to recognize the objects, a first session was carried out prior to the everyday tasks in which all of the objects were present and the patients were given the name of each object and asked to point to it. All participants were able to point to all of the objects used here, indicating that problems should not reflect failures in recognition.

The different tasks, in the contrasting presentation conditions, were carried out in a random order. FK performed one task per session to avoid immediate carry-over effects. FK also performed each set of tasks twice in order to establish the reliability of performance.

The videos were transcribed to record every action made by each patient. The action coding system (ACS) developed by Schwartz et al. (1991) was used to provide quantitative and qualitative measures of each subject's performance. FK's errors were classified into a number of different categories including:

- Omissions: When FK omitted one of the steps to accomplish the task.
- Semantic errors: When a semantically related object was used in place of the target object.
- Sequence errors: When an action was performed in a wrong order (according to norms collected in previous studies for these tasks; see Humphreys & Forde (1998) (Appendix A).
- Additions: When FK added an action that was outside the range of actions produced by normal participants.
- Quality/ Spatial errors: When FK misjudged the appropriate amount of a

stimulus to use (e.g., milk in tea) or the spatial orientation of the objects.

- Perseverations: When an action or action sequence was repeated after achieving its goal.
- Toying/ Capture: Reaching towards or lifting an object without actually using that for any purpose.

The control patients only performed the tasks with related distractors.

2.2.3 Results

Examples of the errors made by FK in the Tea and Card tasks are shown in Table 2.

Table 2: Example of errors in two tasks, generated by FK

Error type	Examples
Step omission	Failure to include milk when making the cup of tea Failure to stick the stamp on the envelope in the card task
Sequence	Adding sugar before pouring tea in the cup Writing the address before putting the card in the envelope
Addition	Drinking milk after making tea Taking the stamp off the envelope
Semantic	Using a knife to stir the tea instead of a spoon Using cello-tape to close the envelope
Perseveration	Pouring milk in the cup several times Sticking a second stamp on the envelope
Quality	Pouring too much milk in the cup Sticking the stamp in a wrong place on the envelope
Toying	Taking the milk carton and then putting it down without using it Picking up the envelope before writing card and then putting it down again

Number of errors

The data were analysed by counting the errors in each task. Table 3 shows the total number of errors in the three conditions for FK (averaged across two performance of each task in each condition), and the mean of the errors across the control patients in the related condition. There was a reliable correlation between the numbers of errors made by FK across the two performances of each task (see Appendix E for scores of two trials), not taking the different conditions into account ($r\ (12) = 0.637$, $p < 0.05$). In order to justify labeling FK as having ADS, the number of errors he made was compared with those made by the control patients in the related distractor condition using a between-subjects ANOVA (with patients as the between subject variable, and tasks treated as subjects). There was a reliable difference between the patients ($F\ (4,15) = 22.19$, $p<0.001$). FK made 9 times the mean of the number of errors made by the control patients (FK made an average of 31.5 errors across the tasks, the control patients made a mean of 3.5 (range: 2-5), SD=1.7). FK clearly performed outside the control range in the related distractor condition. However even in the unrelated and basic (no-distractor) task conditions FK's errors were around 5 and 4 times greater than the means of the control patients. This general deficit in FK's performance held also across all the tasks (see Table 3).

Comparisons between FK's performance across the task conditions used a repeated measures ANOVA with the factors being condition and time (test 1 and test 2), taking tasks as subjects. In carrying out this ANOVA it is assumed that FK's performance of the tasks was independent on the different test occasions. Note that non-independent performance ought to make the different conditions (with related, unrelated and no-distractors) more similar. FK performed worse in the related condition compared with the basic condition ($F\ (1, 3) = 33.0$, $p < 0.01$). The trend for the number of errors to increase in the related over the unrelated condition was not reliable (F (1, 3)=4.53, p=0.123). The unrelated and basic conditions did not differ (t<1.0). There were no interactions with time, indicating that the effects generalized across the two test sessions.

Table 3: Number of errors in each condition in Experiment 1

Patients	Condition	Tea	Sandwich	Gift	Card	Total
		Tasks				
FK	*Basic*	6	2	4	3	15
	Related	12	6	6.5	7	31.5
	Unrelated	3	3.5	5	5	16.5
Mean of control patients	*Related*	1.25 (±0.9)	0.75 (±0.5)	0.75 (±0.9)	0.75 (±0.9)	3.5 (±1.7)

Accomplishment

This score was based on the number of steps in each task that participants completed, ignoring errors along the way (see Appendix A). FK accomplished an average of 7.5/27 steps over the repeated performances in the related and unrelated conditions and 8.5/27 in the basic condition. There was no effect of condition on this measure of his performance (χ^2<1.0). He was worse on all conditions than the control patients (mean 25.5/27; Fisher exact probability p<0.001 for the comparison with each condition).

Type of errors

The proportions of each type of error, relative to all the errors made by FK in each condition are shown in Figure 5. The majority of FK's errors were step omissions followed by toying errors, sequence errors, perseverations and quality errors. The errors made by the control patients were much less frequent (see above) though the majority were again step omissions (43%) followed by additions (25%), sequence and quality errors (12.5%) and toying (6.3%).

The effects of the conditions on FK's performance were analyzed by comparing, for each error type, the relative number of errors in comparison with the number of steps across the tasks (averaged across the two test sessions per task). Relative to the steps in the tasks, omission errors increased in the related condition compared with both the unrelated condition (χ^2 (1) = 4.28, $p < 0.05$), and the basic condition (χ^2 (1) = 5.25, $p < 0.025$). The unrelated and basic conditions did not differ (χ^2<1.0). There was no evidence for variation in any other error type across the conditions (all χ^2<1.0).

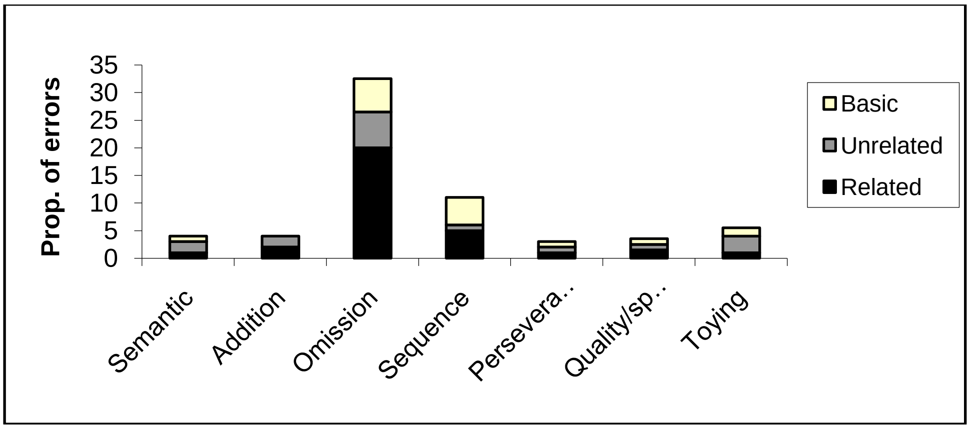

Figure 5: Proportion of each type of errors made by FK in three conditions of Experiment 1

2.2.4 Discussion

We examined the effect of having semantically related and unrelated distractors on everyday life tasks. We reasoned that the presence of semantically related distractors would increase the competition for selecting the appropriate target objects for selection (Moores et al., 2003). Under these circumstances, there may be fewer resources available to support other aspects of task performance, and performance may decline. We found that FK was worse than 4 older control patients, who did not present with clinical aspects of ADS (and even though two controls reported being relatively unpractised with two tasks). Moreover, the number of errors made overall by FK increased in the related condition compared with the basic condition, when there were no distractors present. Performance when there were unrelated distractors present fell in-between. On top of this, FK made relatively more step omissions when related distractors were present (comprising 57% of the errors in this condition, compared with 33% with unrelated distractors). This increased number of step omissions was not due to FK carrying out critical steps in the tasks using a related distractor instead of a target object – this was done on only one occasion. Rather a step tended to be completely omitted. In Experiment 2 we examined whether this result could be simulated in normal, young participants when they performed the task under the load of a secondary task. Does an increased cognitive load increase omission errors, in particular, when related objects are present?

2.3 Experiment 2: Control performance under dual-task condition

Experiment 2 assessed the role of general resource capacity in everyday actions directly by evaluating the performance of control participants when they performed the tasks under load conditions. The 'non-specific cognitive resources' account predicts that, as tasks become more difficult, the participant should make an increasing number of errors (Schwartz et al., 1998). This is consistent with action errors in everyday life being noted under conditions of distraction (see Reason 1984) and with errors in everyday life tasks increasing when secondary tasks are introduced (Humphreys et al., 2000). However, how secondary task effects interact with the 'load' introduced by adding semantically related distractors to the tasks has not been examined. This was tested here. In order to load working memory two groups of controls carried out everyday actions with two types of secondary task (easy and hard). The hard task was a form of the Trails test (Heaton et al., 1991) in which participants were given a pair of numbers (e.g. "2-45") at the start of each trial and then prompted at regular intervals to shift the sequence by increasing the first number and decreasing the second (e.g. "2-45→3-44→4-43→5-42, etc.). In the easy task the participants had to say the word 'the' each time they were prompted. While some errors may emerge with the easy secondary task, errors should increase when the secondary task is hard. If this mimics the data from FK, then errors should increase differentially in the hard conditions when semantically related distractors are present, and this should be particularly the case for omission errors.

2.3.1 Method

Participants

In order not to repeat the tasks across participants, the conditions were manipulated between-subjects. Sixteen participants (age mean = 45; 5 male and 11 female) undertook the hard secondary task (adapted Trails test) with related distractors present; 15 participants (age mean = 36; 8 male and 7 female) the hard secondary task with unrelated distractors present; 9 participants (age mean = 35; 3 male and 6 female) the easy secondary task with related distractors and 8 participants (age mean

= 49; 4 male and 4 female) the easy secondary task with unrelated distractors. All the participants had an education level of at least 12 years. The controls were volunteers who agreed to help provide background data for neuropsychological studies of the effects of stroke on cognition. All were in current employment with jobs ranging from cleaners and secretaries through to teachers and office workers.

2.3.2 Procedure

Participants performed the tea, sandwich, gift and card tasks, with the tasks administered in a random order to each participant within a single session. As they performed the task, the experimenter tapped the table every 3 seconds and the participant then had to make an utterance out loud, which was noted. All actions were videotaped for later scoring. In the hard secondary task condition (the adapted trails test), participants were given a pair of numbers (e.g. “2-45”) at the start of each trial and they had to shift the numbers in each pair in opposite directions in sequence (e.g. “3-44”→ “4-43”→ “5-42”, etc.). In the easy secondary task condition, they had to utter the word ‘the’ at each prompt.

Error scores

Action errors were scored using the action coding system (ACS) developed by Schwartz et al. (1991). In the hard secondary task condition, number errors were scored according to the first error that occurred. However, if on the next trial the subject carried on with the incorrect sequence but this was ‘locally’ correct (e.g. if the sequence was 8- 44 → 7- 43 → 6- 44 → 5-45, etc.) then only the first response (7-43) was taken as an error.

2.3.4 Results

Number of action errors

The number of action errors was analyzed in a two-factor independent measure ANOVA with the factors being distractor relatedness and difficulty of the secondary task. There was a reliable effect of secondary task difficulty ($F(1,44)=15.51$, $p<0.001$); more errors were made when the secondary task was more difficult. There was no effect of relatedness ($F(1,44)=1.05$, $p=0.314$, and no interaction ($F<1.0$). The mean numbers of errors summed across the tasks are shown in Figure 6.

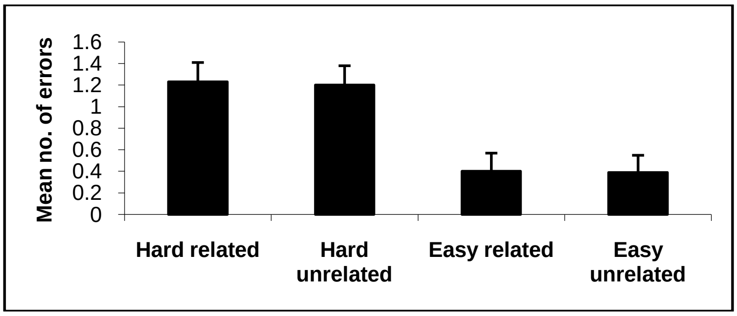

Figure 6: The mean number of action errors made by the controls in Experiment 2

Errors on the secondary tasks were also analyzed. For the difficult secondary task there was no effect of relatedness ($t<1.0$). The mean of errors in counting numbers in the difficult secondary task was 1.4 ± 0.8 in the related condition and 1.5 ± 0.9 in the unrelated condition. There was a significant positive correlation between the number of errors when performing the tasks and the number of errors in the secondary task; rho = 0.236, N = 124, p = 0.008, two-tailed. There were too few errors in the easy secondary task for the data to be analyzed.

More errors tended to occur in the tea task (mean 5.69 errors across participants, summed across the conditions), followed by the card task (mean 2.61), the sandwich (mean 2.15) and the gift task (1.18).

Error analyses

There were too few data for both the difficult and easy versions of the secondary task for the different error types to be analysed by participants (see Figure 6). Instead the data were analysed using Log Linear analyses summing the different error types across participants. Of primary interest in these analyses is whether there was an interaction between the main conditions (ease of secondary task, presence of related distractors) and the relative proportions of a given error type (e.g., omission errors) relative to the total errors. Such an interaction would indicate that the proportion of one type of error, relative to the total error rate, changed across the conditions.

For omission errors there was no interaction between the proportion of omission to all errors as a function of either the effect of secondary task difficulty or relatedness. Omissions accounted for 24% of the errors when related distractors were present relative to 32% when unrelated distractors were present. There was a non-significant trend for omissions errors to increase when the secondary task was more difficult (29% of the errors with a difficult secondary task vs. 20% with an easy secondary task). For sequence errors, however, the best fitting model included an interaction between secondary task difficulty and error type (number of sequence to other errors) (χ^2 (3)=1.22, p=0.748, for the best fitting model). There were proportionately more sequence errors when the secondary task was easy than when it was difficult (68% of the errors with an easy secondary task vs. 30.4% with a difficult secondary task). There were too few other types of error for meaningful analysis.

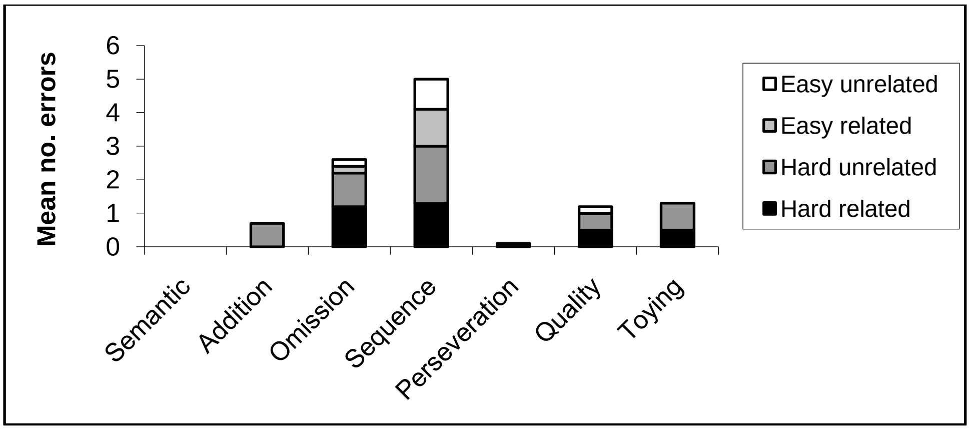

Figure 7: Number of each type of error for control participants in the different task conditions.

As well as evaluating the different error types, we also assessed the number of 'self-correction' responses, generated when participants moved towards or touched an object that was inappropriate to the required action. The best fitting model here included an interaction between the difficulty of the secondary task and the number of self-corrected responses relative to the total errors made (χ^2 (3)=8.61, p=0.07). There were proportionately more self-correction responses when the secondary task was easy relative to when it was difficult (19% self-correct responses to errors with a difficult secondary task vs. 56% self-correct responses to errors in the easy secondary task). There was no effect of relatedness (21% self-corrected responses to errors with related distractors vs. 29% with unrelated distractors)

2.4 General Discussion

We examined the effects of having related distractors present on the performance of everyday actions by a patient with clinically defined ADS (Experiment 1) and control participants operating under conditions of task load (Experiment 2). The ADS patient, FK, tended to make more errors overall when related distractors were present, and, in particular, there were increases in the proportions of omission errors. The relatively high numbers of omission errors made by FK fits with prior data on everyday actions in brain lesioned patients (Schwartz et al., 1998), a result that has been interpreted in terms of patients lacking sufficient cognitive resources to support task performance. For example, without sufficient resources, patients may be unable to keep activated all of the sub-steps in a complex task, so that occasionally some steps ‘drop out’ of the sequence of actions. When related distractors are present, the attentional demands on selecting the appropriate target are increased (Moores et al., 2003). The data suggest that FK was vulnerable to this increased competition, and was less able to maintain/activate all of the steps for the tasks when targets had to be selected amongst related distractors. The result was that omission errors, in particular, increased.

These proposals were explored further in Experiment 2 where we examined the effects of secondary task difficulty on everyday task performance by normal participants. There were clear effects of the difficulty of the secondary task, with the more difficult secondary task increasing the overall error rate, however they did not produce a similar error rate to FK. Also, unlike the results with FK, dual-tasks did not selectively increase the proportion of omission errors. Though it is possible that a higher proportion of omission errors might have been seen if the error rate had been higher, the data suggest that there may be a qualitative shift in performance, with the controls showing no effects of distractor relatedness on performance even under the difficult dual-task conditions. There were decreases in the number of self-correcting actions made, though, when the secondary task was more difficult.

The present results indicate a contrast between, on the one hand, the particular effects of relatedness on omission errors in FK, and, on the other, the lack of relatedness effects and the across-the-board effects of secondary task load on controls.

This contrast may be explained if FK's brain lesion affects particular aspects of task performance more than others (rather than there being an across-the-board decrease in function). Previous results suggest that FK has abnormal difficulty in selecting between semantically related stimuli (see Humphreys & Forde, 2005), and this might make the task of selecting between target objects and related distractors particularly demanding in his case (even though FK could point to and name all the objects we presented). In addition to this, FK has difficulty in activating/ maintaining all of the steps required for a given task (Forde & Humphreys, 2002; Forde, Humphreys & Remoundou, 2004) a deficit, which may more generally characterize patients with ADS. The consequences of these two particular problems are that, when extra resources are required by FK to select targets (amongst related distractors), there is an increase in omission errors because there is reduced activation of all the steps required to complete the task.

In contrast to FK, normal participants suffered fewer demands when required to select between targets and related distractors. Furthermore, normal participants may have sufficient resources to activate all the steps in everyday tasks, but, under high load conditions, there is reduced allocation of resources to all processes involved in the tasks. The consequence is a general increase in errors, rather than a particular increase in omissions. The only evidence for a selective effect of load with controls was that self-correcting responses reduced as the load increased. This suggests that conditions of high load may disrupt the ability to monitor actions and to respond to conflict between different goals for action. Error monitoring, along with responding to conflicting information, has been associated with frontal lobe activity in studies of functional brain imaging (e.g., Botvinick, 2007). The more difficult secondary task in this study placed a demand on 'executive' processes also associated with frontal lobe function, including maintaining information while other processing was ongoing and shifting the task rules (from addition to subtraction and vice versa). The reduction in self-correction responses may reflect the common demand for frontal structures from error monitoring and executive-demanding secondary task processes. Even so, the present results indicate that any ‘general’ effects of task load, or any specific effects on some executive processes (error monitoring and responding to response conflict), are not sufficient to mimic some specific deficits in ADS patients. In patients such as FK there are specific deficits that generate problems in carrying out all the steps in tasks (leading to omission errors); these deficits can increase under load conditions (here, when related distractors are present), but the load effects apparent in such patients differ from the load effects generated through imposing demanding executive tasks on control participants. This points to at least some ADS patients having a deficit in which there is a differential effect of load on a process that is relatively undemanding in normal participants (e.g., maintaining the identity and order of steps in an everyday life task).

CHAPTER 3

Task schema and task demands in Action Disorganisation Syndrome

Abstract

The role of task schema and context on the performance of everyday life tasks was examined in two patients with Action Disorganisation Syndrome (ADS). In Experiment 1 the patients had either to carry out 4 everyday life tasks or they had to instruct the examiner how to perform the tasks. Omission and sequence errors decreased when the patients instructed the examiner. In Experiment 2 the requirement to use a task schema was lessened by giving verbal instructions for the task steps, and in Experiment 3 the demands on error monitoring were reduced by both instructing the actions and giving the patients feedback when errors occurred. In Experiment 4 the patients were given instructions to perform the same actions as before, but out of the task context. The data indicate that ADS patients can maintain a schema for everyday life tasks, but fail to implement their schema when having to perform actions in the context of monitoring for errors and over-ruling prior actions from the same task. The implications for understanding ADS are discussed.

3.1 Introduction

The performance of everyday tasks depends on a range of cognitive processes including the retrieval of stored knowledge about the task steps and their order, the ability to maintain completed and future steps in memory, the ability to over-rule already activated actions, and the ability to execute the correct actions, once selected (see Cooper, 2002; Humphreys & Forde, 1998). Following brain lesion patients may have difficulties in performing everyday tasks for a number of reasons including: loss of specific knowledge about the tasks, an inability to maintain and/or over-rule actions for already completed steps, poor error monitoring or an inability to order the steps in sequence (See Chapter 1 for more information) When this group of problems leads to performance that is outside the boundaries of that normally found the patients may be classed as having ‘action disorganisation syndrome’ (ADS; Schwartz, 1995).

According to one prominent account of the disorder, ADS is associated with general decreases in cognitive resources, which result in patients not being able to draw upon and maintain all of the information required for adequate task performance (Schwartz, 1995). According to this ‘non-specific cognitive resource’ hypothesis, the performance of the patients should be facilitated by decreasing the cognitive resources required for the tasks. Forde and Humphreys (2002) investigated the effect of reducing the resources required for task performance by providing different cues as the actions were performed. This included giving written commands for each step the patient had to follow and having the patients copy steps in the task. They reported contrasting results in two patients. One patient showed improved performance when written cues were presented one at a time, suggesting that reducing the burden of retrieving each action alleviated performance. However, this approach was not successful in a second case, who continued to make errors indicating that, in this instance, alleviating poor retrieval of stored knowledge about the task steps was insufficient to generate correct performance. This in turn suggests additional aspects of task performance can play a critical role in ADS, such as inhibiting already completed actions. In terms of models of everyday action, these additional deficits can be characterised as problems not only in patients' having sufficient resources to activate stored schema for actions (Humphreys & Forde, 1998) or to activate the 'Contention Scheduling System' in models such as Norman and Shallice (1986), but also in executive processes required to hold task steps and to monitor both when actions are completed and when errors might be arising (e.g., a deficit in the Supervisory Attentional System, in Norman and Shallice's, 1986, terms). In such cases, additional rehabilitation procedures may need to be overcome the deficit. However, in Forde and Humphreys's study it is not clear how much the patients comprehended the steps being read (performance given each step alone was not tested), and it is not clear how much attention was given to each task step by each patient.

The aim of the present study was to take these results further by examining whether (i) ADS patients have at least partial knowledge of task schema, assessed by having them instruct another person how to perform everyday tasks, and (ii) whether the demands of retrieving the schema, having to monitor for errors and having to over-rule actions in the task context all contribute to the patients' deficits. Four experiments were conducted. Experiment 1 was carried out to test if the patients did have intact knowledge of the steps making up everyday-life tasks, even when they did not have to perform the actions themselves (the task was to instruct the experimenter how to carry out the task). In this experiment, the patients do not have to monitor for errors (since the experimenter did not make errors in executing the instruction) and, in addition, the need to inhibit their prior action is minimised (since the patients do not perform the actions). Performance when instructing the experimenter was tested against a ‘standard’ condition, where the patients were simply asked to perform the tasks. This standard condition provides a baseline for diagnosing the patients as having ADS. Does relieving the patients of the need to monitor errors and to inhibit prior actions improve performance, when actions remain dependent on retrieval of the stored knowledge of the task? In Experiments 2-4, the requirement to retrieve the task schema was reduced by giving the patients instructions to the actions required for successful task performance. In Experiment 2, the patients were given consecutive verbal instructions for each task step. In Experiment 3 they were given the same instructions, but this time they were given feedback on whether they made an error. The idea here was to reduce the need for the patients to monitor their own performance while completing the tasks. Did reducing the load on error monitoring improve task performance? Experiment 4 was a control study in which the patients were given the same verbal instructions as before, but the instructions for each of 4 tasks were given in a pseudo-random order so that consecutive instructions did not come from the same task. This assessed whether the patients were able to recognise the objects and to carry out each task step when they did not have such strong demands to inhibit the prior step (which would still be related to the ongoing task when the steps were carried out consecutively, in Experiments 2 and 3, but not in Experiment 4). The results highlight the impact of different task demands on ADS. In the General Discussion we highlight the implications for understanding the disorder.

3.2 Patients and Controls

Performance was assessed in two patients (FK and BL). BL was 80 years old at the time of testing. She was a former General Practitioner who suffered a stroke in 1998, which affected her right middle occipital gyrus, extending in to inferior occipital gyrus (see Figure 8). She presented with a number of neuropsychological deficits including alexia (18/26 even on identifying single letters; 0 reading of 20 HF concrete, short words) and object recognition. (see Table 6 for more information). On other neuropsychological tests BL had some problems with executive function tasks, having an error score of 21 on the Brixton test of non-verbal executive function (finding a rule and rule shifting; a score of 26 indicates a clinical impairments; Burgess & Shallice, 1997). She had a Corsi block span of 3 and a digit span of 4 (forwards). Background neuropsychological data on FK were reported in Chapter 2.

Although both patients had impaired visual object recognition it is unlikely that this was critical here given that Experiment 4 demonstrated that the patients were able to carry out the instructions for single actions with the objects from the everyday life tasks. FK has previously been reported in several papers focusing on ADS (e.g., Humphreys & Forde, 1998).

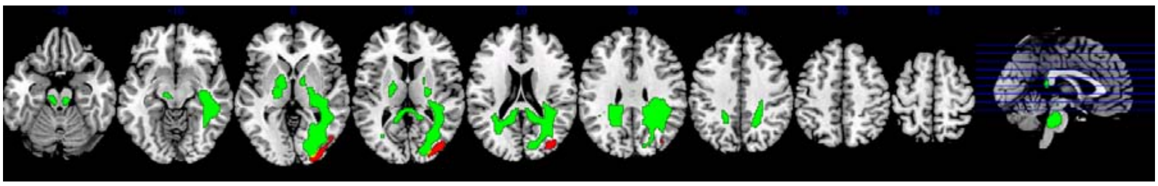

Figure 8: BL's MRI Scan

The procedure of the standard condition for both patients was the same as Experiment 1 in Chapter 2. The tasks were: (i) make a cup of tea with two sugars and milk (the Tea task); (ii) make a cheese sandwich and put it in a sandwich bag (the, Sandwich task); (iii) wrap a present (the Gift task), and (iv) prepare a postcard for the post (the Card task). The patients' performance was compared with two sets of control data – using results from 4 'control' patients, all of whom had brain lesions but did not show signs of ADS (see Table 1, Chapter 2 for details of the patient controls), and a group of 16 non-brain lesioned young control participants. The tasks for the ADS patients were conducted under easier conditions than those used for the control participants. The control patients carried out the tasks with the objects from two related tasks being on the table together (tea + sandwich and gift + card). The controls non-lesioned carried out the tasks while performing a difficult secondary task comprising a form of the Trails test (Heaton et al., 1991). Participants were given a pair of numbers (e.g. "2-45") at the start of each trial and then prompted at regular intervals to shift the sequence by increasing the first number and decreasing the second (e.g. "2-45→3-44→4-43→5-42, etc.). They did this while completing the steps for the secondary tasks. Impaired performance by FK and BL here, relative to each set of control data collected under less optimal conditions, would indicate the clinical impairment apparent in the ADS patients.

3.3 Experiment 1: Instructing the examiner

3.3.1 Method

The examiner sat in front of the patient, next to a table with all objects, which were required for performing the specific task (see Appendix A for a list of all the objects and the steps required for the tasks). There were 4 tasks: making a cup of tea with milk and two sugars; make a cheese sandwich and place it in a sandwich bag; wrap a gift, and prepare a postcard for the post. Each patient was asked to give step-by-step commands for the examiner to complete the task. The examiner completed each instruction correctly. Performance was videotaped and scored according to the action coding system (ACS) developed by Schwartz et al. (1991). The steps to complete the task were taken as the common set produced by the non-lesioned control participants (these same steps in the same order for 80% + of the controls). On a subsequent test occasion, the patients were given the same arrays of objects and asked to carry out the everyday tasks.

3.3.2 Results

Number of errors

The numbers of errors made by FK and BL are given in Table 4. The data were analyzed in a mixed design ANOVA with condition (standard action vs. instruction) as a within-subjects factor and patient as a between-subject factor (with tasks treated as subjects[1]). The difference between the conditions was not reliable, $F(1, 6) = 2.78$, $p = 0.15$. There was no overall difference between the patients and no interaction of condition and patient (both $F<1.0$).

The control patients made on average 3.5 errors (SD 0.15) and the non-lesioned controls made on average 1.2 errors (SD 0.15). The errors made by FK and BL in the standard tasks were more than 2SDs greater than the errors made by each set of controls, confirming the diagnosis of ADS. The errors generated by FK and BL even when just giving the task instructions remained more than 2SDs from the errors produced by the controls carrying out the tasks under more taxing conditions.

[1] I should note that violation of the assumption of subjects as independent data source might lead to Type 1 errors (that is to say; repeating different tasks with the same person is not the same as a set of independent observations on different subjects).

Table 4: Number of errors made by the patients

Patients	Conditions in order	Tasks				
		Tea	Sandwich	Gift	Card	Total
FK	*Standard (Expt. 1)*	6	2	4	3	15
	Command (Expt.1)	2	1	0	5	8
	Cue (Expt. 2)	3	0	3	1	7
	Cue+feedback (Expt. 3)	2	3	1	1	7
	Cue, random order (Expt. 4)	1	0	0	2	3
BL	*Standard (Expt. 1)*	8	1	2	3	14
	Command(Expt. 1)	1	0	3	2	6
	Cue (Expt. 2)	2	2	1	2	7
	Cue+feedback (Expt. 3)	1	0	1	0	2
	Cue, random order (Expt. 4)	1	0	0	1	2

Accomplishment

Accomplishment scores were based on whether a given step in the task was accomplished, irrespective of the order of the steps. FK correctly generated 8/27 steps in the standard condition and 10/27 steps when he gave instructions; BL accomplished 11/27 in the standard action condition and 15/27 steps when she gave instructions. The mean steps accomplished by the lesioned controls was 25 (SD 1) and by the non-lesioned controls 27 (SD 2.2). Both FK and BL were clearly impaired relative to the controls, in both conditions. The differences between the steps accomplished in the standard conditions and the instruction conditions were not reliable ($\chi 2<1.0$).

Type of errors

Table 5 documents the types of errors made by the patients. In the standard condition, the majority of errors made by both patients were omission and sequence errors, though BL also made some quality/spatial errors (e.g., cutting up too small a piece of paper when wrapping the gift). When the patients instructed the examiner to perform the tasks, omission and sequence errors decreased. The data were analyzed using a 3 factor Log Linear analysis with the factors being patient (FK vs. BL), condition (standard vs. command) and accuracy (number correct vs. number errors). The best fitting model ($\chi 2$ (4)=1.92, p=0.75) was based on a single interaction between condition and accuracy ($\chi 2(1)=4.99$, $p<0.025$). There was a relative decrease in omission and sequence errors when the patients instructed the examiner.

Table 5: The number of each type of errors across the different conditions

	% Type of error	Standard (Expt. 1)	Command (Expt. 1)	Cue (Expt. 2)	Cue +Feedback (Expt. 3)	Cue, random order (Expt. 4)	**Total / type**
	Semantic	0	0	1	1	0	2
	Addition	0	1	0	0	0	1
	Omission	7	2	2	3	0	14
FK	*Sequence*	5	1	0	2	0	8
	Perseveration	1	0	1	1	0	3
	Quality/Spatial	1	2	3	0	2	8
	Toying	1	1	1	0	1	4
	Total / condition	15	7	8	7	3	40
	Semantic	0	0	0	0	0	0
	Addition	0	1	0	1	1	3
	Omission	7	2	2	2	0	13
	Sequence	1	1	2	0	0	4
BL	*Perseveration*	1	1	2	0	0	4
	Quality/Spatial	5	0	1	0	1	7
	Toying	0	0	0	0	0	0
	Total / condition	14	5	7	3	2	31

3.3.3 Discussion

Both patients made more errors and accomplished fewer steps than did control participants, even though FK and BL here carried out the tasks under ‘standard’ conditions (with just the objects for the tasks present and with no dual task load) while the controls performed the tasks under less optimal circumstances (with distractor objects present and with a dual task load). These data indicate that FK and BL can both be classed as having ADS. Interestingly the patients performed relatively well when asked to instruct the examiner to carry out the tasks, and, in this command condition, there was a reliable decrease in the proportion of omission and sequential errors. These results indicate that loss of the schema for the everyday actions may not be a major component behind the patients failing to perform the actions correctly – rather the patients may be detrimentally affected by ancillary factors that become critical when they have to perform the tasks themselves. For example, the requirement to carry out the actions may demand resources, and there may also be demands due to having to inhibit actions within the tasks that have just been completed or to monitoring for errors when performing the actions. The net result of these increased demands may be that the task schema no longer remains so strongly activated, and omission and sequence errors result.

Humphreys and Forde (1998) also presented some evidence consistent with aspects of the schema for tasks still be present for patient FK. They instructed FK to carry out simple actions that contravened the standard action that might be involved in an everyday task (e.g., put the saucer on the cup, rather than put the cup on the saucer). They found that FK made many errors by carrying out the standard action (putting the cup on the saucer), even though he was typically able to repeat back the instruction. In such cases, performance seemed to be driven by activation of the standard actions. In addition, Bickerton, Humphreys and Riddoch (2007) found that ADS patients were likely to omit actions with unusual exemplars of objects, but only when the actions were conducted within the context of the everyday tasks. When instructed to perform single actions, the patients used the unusual objects successfully. Here the schema for the everyday task seemed to ‘drive’ the patients to use standard/prototypical objects, suggesting that the schema still had some influence on task performance. The present study provides more direct evidence for task schema still being present in such patients, though they seem impaired in using it when they have to implement everyday tasks. The reasons why the patients are impaired were examined further in Experiments 2-4. Experiment 2 reduced the need to retrieve the task schema by giving the patients one instruction at a time, while Experiment 3 did this while also reducing the requirement for error monitoring by giving the patients immediate feedback when they made errors. Experiment 4 tested whether having the patients perform single actions outside the context of the task (randomising the order of instructions across tasks) improved performance.

3.4. Experiment 2: Verbal cues to action

Experiment 2 tested if patients could successfully complete everyday tasks when they did not have to depend on their stored knowledge of the component actions or their knowledge of the temporal order of the actions, but when all the steps were nevertheless required and all the objects present before the patients. Verbal cues to action may bypass the requirements to access stored knowledge of schema and could consequently facilitate performance on the everyday tasks, if use of the schema is problematic. Some evidence for verbal cueing has been reported by Bickerton, Humphreys, and Riddoch (2006), who also worked with patient FK. Bickerton et al. taught FK a verbal ‘poem’, which included the instructions for an everyday task. FK’s performance improved under conditions where he could remember the poem and used the poem to verbally cue his actions. We evaluated whether external instructions, given by the examiner, might also be effective here.

3.4.1 Method

The Method was the same as for the standard condition examined in Experiment 1, with the sole difference being that the examiner read out to each patient each consecutive instruction. The patient was then asked to perform the instruction.

3.4.2 Results

Number of errors

The numbers of errors produced by each patient when they performed the tasks are shown in Table 4. The data were analyzed using a mixed-design ANOVA. Patients were included as a between-subject factor, conditions as a within-subject factor and the tasks as subjects. Performance in the verbal cue condition was compared with that in the standard condition (Experiment 1). There tended to be fewer errors overall after the patients received a cue, compared with the standard condition, $F(1,6) = 5.87$, $p = .052$. There was no overall difference between the patients and no interaction between patient and cue ($F < 1$).

Accomplishment score

FK accomplished 14/27 steps of tasks in the verbal cue condition. FK tended to accomplish more steps following a verbal cue (χ^2 (1)= 2.20, p=0.14). BL completed 18/27 steps of the tasks under both the instruction and the standard conditions.

Type of errors

Table 5 gives the number of each type of error made by FK and BL in each condition. The data were analyzed by treating the different error types separately.

Conditions was treated as a within subject factor and patients as a between subject factor, with each task treated as a separate subject. Omission errors significantly decreased in the verbal cue condition ($F(1, 6) = 21.43$, $p= .004$); there was no effect of patient ($F <1$). The effect of the verbal cue on other error types was not reliable, for either patient.

3.4.4 Discussion

Giving the patients a verbal instruction for each task step tended to improve their performance, compared with when the tasks were performed in the basic condition, without instruction. Overall the patients made fewer errors and FK accomplished a greater number of steps. Omission errors decreased across both patients. The data are consistent with the patients encountering problems in everyday life tasks when they depend on using a self-generated schema for task accomplishment, so that they improve when task schema are provided externally (by giving instruction). However, even when the task instructions were provided, the patients still made more errors than is apparent when controls perform the same tasks (see Experiment 1). In addition, while the verbal cue tended to reduce omission errors, it did not affect some of the other types of error that characterize the patients' performance (e.g., perseverations). These additional errors may reflect a tendency by the patients to be driven in a bottom-up manner to the objects present in front of them, when the task schema is partially activated and/or when an earlier action is activated – in which case they may carry out a step that is highly activated but which either repeats an earlier action (generating a perseverative error) or which occurs out of sequence (generating a sequence error). Such errors may arise due to poor modulation of task performance by executive/supervisory attentional processes (cf. Norman & Shallice, 1986), which fail to modulate activation driven by the task context. In Experiment 3 an attempt was made to reduce the load on executive processes specifically by providing direct feedback to patients when they performed the actions for everyday tasks, so that the requirement for error monitoring decreased. Does this additionally improve performance by reducing the sequence and perseverative errors apparent even when task instructions are given (in Experiment 2)?

3.5 Experiment 3: Effects of error feedback

In addition to any problem relating to schema knowledge, ADS patients may have problems in the internal monitoring of their performance through executive control processes/the supervisory attentional system (Humphreys & Forde, 1998; Miltner, Braun, & Coles, 1997; Norman & Shallice, 1986). At least one demand on attentional processes during the performance of everyday tasks is the requirement to monitor for errors. In a study of the effects of secondary tasks on the performance of normal participants, Humphreys, Francis and Forde (2002) noted that control participants increased the number of mis-selection errors – where they made an action towards an object that was inappropriate for the given stage of the task – but then self-corrected their behaviour, stopping before implementing the action. In such cases, potential action errors may be activated, but a monitoring process limits their effect on performance. In patients with ADS, though, action errors are typically carried out and the patients may show little awareness of the error occurring. Thus patient BL here made errors by omitting the tea in the tea-making task, but showed no sign of disappointment when the ‘tea’ she produced was white. In Experiment 3 we sought to reduce the requirement of self-monitoring by giving feedback (as a external monitoring source) after each action. As in Experiment 2 each action was instructed, however if the action was performed correctly or if an error occurred then the patient was told this immediately. Thus, in this task we reduced not only the need to use stored knowledge of the actions and their order, but also the need for supervisory attention system in monitoring the actions to minimize errors.

3.5.1 Method

Patients were given positive and negative feedback of their actions additionally, step-by-step verbal commands. For example, in a wrong order action or in performing incorrectly, they were told that the action performance was not correct and they were given the command one more time. If patients after this still made the same error, they were allowed to carry on the task. In the correct action they were given positive feedback such as “that’s excellent”. In all other respects the method matched that in Experiment 2.

3.5.2 Results

Number of errors

A repeated measures ANOVA design was used to analyze data. We considered patients a between subject-factor, conditions as the within subject factor and tasks as subjects. The results showed a reliable main effect of condition; $F(1, 6) = 7.89$, $p = .031$, but no significant difference in error numbers between patients and no interaction (both $F<1$).

Accomplishment

Relative to the standard condition, both patients significantly improved their accomplishment score. FK now accomplished 21/27 steps and BL 27/27 ($\chi2$ (1) =12.59 and Fisher exact probability p=0.0001 respectively).

Type of error

The majority of FK's error types were step omissions, although he made some sequence, perseveration, and semantic errors. BL only produced two errors (one omission and one addition). The data were analyzed in a mixed design ANOVA, with patients as the between-subject factor, condition (standard vs. Experiment 3) as the within-subject factor, and tasks as subjects. There was a significant decrease in the number of omission errors in the cue + feedback condition compared with the standard condition ($F(1, 6) = 81$, $p < 0.001$) and also in the number of quality/spatial errors ($F(1, 6) = 7.71$, $p < .032$). In each case the two patients did not differ and there were no interactions with patient (all $F<1.0$). The number of sequence errors did not change across the conditions ($F<1$).

3.5.3. Discussion

Giving the patients instructions for each task along also with feedback about performance reduced the number of errors and increased the accomplishment of the actions. Under the conditions used in Experiment 3, BL improved to the level found in the control groups (see Experiment 1). FK, however, continued to perform worse than the controls, The data suggest that, when the demand of having to use self-generated schema are reduced, along with the need for error monitoring, then the performance of ADS patients can improve. In the final experiment, we gave the patients the same instructions as in Experiments 2 and 3, but this time we used a pseudo-random presentation order so that we never asked a patient to perform two separate actions from the tasks. Would performance of the same actions be improved in this case, when actions were carried out outside the context of the tasks?

3.6 Experiment 4: Single actions outside the task context

3.6.1 Method

In Experiment 4 the patients were given the same verbal instructions as before, but the instructions for each of 4 tasks were given in a pseudo-random order so that consecutive instructions did not come from the same task.

3.6.2 Results

Number of errors: The number of errors is shown in Table 4. The data were compared with those from Experiment 2 (same instructions, but given consecutively from the task) using a mixed design ANOVA with patient as a between-subjects factor and condition as a within-subjects factor. There was a borderline difference between the conditions ($F(1,6)=5.65$, $p=0.055$).

Accomplishment: FK accomplished 20/27 and BL 24/27 steps. The data were compared with the results from Experiment 2 in a Log Linear analysis with the factors being patient, condition (Experiment 4 vs. Experiment 2) and accuracy (number of correct or error responses). This generated a best fitting model ($\chi2(4)=3.24$, $p=0.518$) with an interaction between condition and accuracy ($\chi2(1)=6.52$, $p<0.025$). There were more steps accomplished here than in Experiment 2, and this held across patients.

Type of errors: Unlike previously, neither patient made omission or sequence errors, though some quality/spatial errors remained. This result is striking given that the patients made more omissions than any other type of error, when the tasks were performed under standard conditions. The results suggest that one source of omission and sequence errors is the fact that, in normal task performance, actions are undertaken in the context of a recently completed action with the same objects present, and this can disrupt performance.

3.7 Discussion

Data have been presented from 4 experiments documenting the performance of 2 ADS patients on everyday life tasks under different conditions. Experiment 1 compared the ability of the patients to instruct the examiner to perform the task compared with when the patients carried out the tasks themselves. The patients were better able to instruct the examiner to carry out the tasks than they were able to perform the tasks themselves, and there was a reduction in omission and sequence errors in the ‘command’ (examiner instruction) condition. This indicates that the patients retained some ability to retrieve appropriate task schema, and could use the schema when they were not themselves engaged in the everyday life tasks. In

Experiments 2 and 3, we reduced the need to rely on a self-generated task schema by giving the patients sequential verbal instructions to each action in the tasks. Experiment 2 presented the patients with the instructions alone, while in Experiment 3 the patients were also given feedback about the performance of each action. Again these conditions improved performance, highlighting that the load of having to retrieve and maintain a task schema could impair the performance of the patients. Though it is possible that repeating the tasks may cause learning, and the differences between the present conditions, this is unlikely. Both FK and BL had stable deficits in carrying out everyday tasks, and had been tested on all of the tasks used here on several occasions without showing any evidence of learning. Finally, in Experiment 4 the patients were given the same instructions as before, but now consecutive instructions did not come from the same tasks. Interestingly there was a further improvement in this condition compared to when the same instructions were given but consecutively from each task. This last result indicates that there is a further disruption to the patients when consecutive actions come from the same tasks. This suggests that, when consecutive actions come from the same task, there is stronger competition for selection of the appropriate action. This might come about because the patients need to inhibit previously activated actions, or because there is stronger competition for action selection due to object-action links perhaps being activated on the immediately prior trial. In studies of visual search, Moores, Laiti and Chelazzi (2003) (see also Belke et al., 2008) have shown that normal participants can be affected by the presence of stimuli that are semantically related to a target that is being searched for. For example, search for a target ‘motorbike’ will be slowed by the presence of a ‘crash-helmet’. In work with patient FK (Morady & Humphreys, 2009) it has also been shown that the presence of related distractors disrupts task performance (see also Chapter 2 here). When consecutive actions are cued from the same task, it can be proposed that not only are related objects present before the participants, but those objects (and any associated actions) will also be in an activated state (having recently been cued), and this may create more 'noise' in selecting the appropriate object and action to take place.

One framework for the performance of everyday action tasks was put forward by Humphreys and Forde (1998), who suggested that actions may be controlled through a 'competitive queuing' mechanism. In this framework, representations of individual actions are activated in a top-down manner by a task schema, with activation levels capturing the order in which actions must be output. Following the production of one action the action representation is temporarily inhibited, enabling the next action representation to be selected and the action articulated. Within this scheme, ADS may result from either weak top-down activation of the task schema, or from noise in the representations so that some actions are output in the wrong order, others suppressed (and omitted) and so forth. The present data suggest that patient can maintain some knowledge about task schema (enough to instruct the examiner to perform the actions, in Experiment 1). This does not mean that the schema is correctly maintained within the competitive queuing system, however, if there is noise at that level. The data from Experiments 2-4 further indicate that reducing the need to rely on a task schema, reducing the requirement for error monitoring, and reducing the noise from recently activated actions in the same task, all also have a positive effect on performance. In each case, it can be suggested that the competition to select actions will reduce when (i) only one action is strongly activated by the task instruction (Experiment 2), (ii) more resources are available to sustain any differential activation of action representations (e.g., by reducing the need for error monitoring, Experiment

3), and (iii) there is less competition from objects and object-action associations that have been activated in the same context (Experiment 4). The results point to the important roles that these extra factors may play in ADS, over and above poor retrieval of task schema.

The present data also have implications for the rehabilitation of ADS. The results indicate that taking measures to reduce the demands on processing while the patients perform the tasks will be useful in ensuring that the patients complete the tasks correctly. This fits with the work of Bickerton et al. (2006) who, as already noted, demonstrated that verbal cueing in the form of a poem helped patient FK reduce his errors in everyday tasks. The improved performance when the patients performed the actions out of context (Experiment 4) also suggests that it might be useful to start from this condition and then to gradually increase the number of actions from the same task, so the patients gradually re-constructs a portfolio of actions that comprise the task. The bottom-up chaining of actions may then help to support any top-down activation from task schema which may be weak and noisy.

CHAPTER 4

Convergent Route Model for Action

Abstract

In this Chapter, I present evidence indicating that patients with impaired semantic knowledge, who show a consistent deficit with particular items, nevertheless are better in actually using objects than in pantomiming action. There is also no additional effect of object use on stimuli the patients can retrieve semantics for, compare with objects they fail to retrieve semantics for. The data are interpreted in terms of the patients benefitting from convergent activation from multiple modalities when using objects, which by-passes their impaired semantic knowledge.

4.1 Introduction

Deficits in object recognition can occur at a variety of levels. For example, some patients can have perceptual impairments that are specific to one input modality, often due to a selective, modality-specific deficit in perception (see Humphreys & Riddoch, 1987). In contrast, other patients can present with impaired recognition despite spared perceptual processing – up to and including access to stored knowledge about the structural properties of objects (e.g., as reflected in spared object decision when semantic matching is deficient; Hillis & Caramazza, 1995; Fery et al., 2003; Riddoch & Humphreys, 1987a; see Humphreys & Riddoch, 2006, for a review). In such cases, there can be a disturbance in stored semantic knowledge about objects, which affects recognition across different input modalities (Riddoch et al., 1988). This central semantic disturbance can also be characterised by the patients having a consistent deficit across items over different test occasions (e.g., Humphreys & Forde, 2005; see Warringrton & Shallice, 1979), suggesting that semantic representations for particular items have been lost.

Patients with perceptual impairments in object recognition very often fail to show how objects might be used, when they fail at identification (Riddoch & Humphreys, 1987b). This is consistent with the patients failing to derive sufficient perceptual information to enable appropriate gestures to be generated. With patients with semantic loss, however, the case is less clear. For example, patients with poor access to semantic information about objects can nevertheless show some ability to gesture to the objects (Hillis & Caramazza, 1995; Riddoch & Humphreeys, 1987a), a result which has been interpreted as indicating that there can be direct access to action representations that by-passes any impairment in accessing semantic knowledge. In such 'direct route' accounts of action, it is supposed that either perceptual properties of objects are derived by the patients, or there is access to stored perceptual representations for objects, which in turn activate action routines, so that appropriate actions are made (e.g., Riddoch, Humphreys & Price, 1989; Yoon, Heinke & Humphreys, 2002).

Although there is evidence for direct access to action in such patients, the factors that determine whether or not actions are correctly carried out have not been clearly specified. In the field of apraxia, one standard finding is that patients show better use of objects when they are allowed to hold the stimuli when acting, compared with when the patients are asked to pantomime the action (see Chainay & Humphreys, 2002; Chainay and Humphreys, 2002) examined why this was the case. They noted that one possible reason for better use than pantomime is that the patients may better recognize the objects when they are held, when there is joint input from touch as well as vision. However, the 'use advantage' remained for objects that were identified, so that the improvement could not be due to better access to semantics, since semantic access was achieved in such cases. Chainay and Humphreys consequently proposed that the 'use advantage' arose because of direct activation of action representations from the multiple modalities, based on what they termed a 'convergent activation' model. According to this model, the direct perceptual input converges on action representations to 'push' those representations into a state that supports retrieval of the correct action. This can enable patients to overcome a deficit in activating action representations from semantic knowledge. An alternative proposal is that pantomiming might be more difficult than 'object use' because action gesturing makes more cognitive demands compared to actual tool-use. Any decrease in performance with extra cognitive demand might exacerbate a deficit even if the objects can be identified.

Chainay and Humphreys (2002) examined the ‘use advantage’ for stimuli that could be identified. The present study examined the converse case, namely whether there is a ‘use advantage’ for items that cannot be identified due to patients having impaired semantic representations for stimuli. To assess this, object use was compared with pantomimed actions for two patients with impaired object recognition due to semantic loss. If there is semantic loss, found across multiple modalities, then the object use effect should not stem from improved recognition (indeed, see Chapter 5 here for evidence that recognition may be driven by the action stimulated from the extra perceptual input, in such cases). Instead, the use advantage may follow from multiple perceptual inputs constraining action retrieval.

4.2 Method

Case reports: Two participants were tested: FK (see Chapter 2 for more details) and BL (see Chapter 3 for full details). Table 6 provides scores on a range of standardised tests of object processing. Perceptual processing from both vision and touch was relatively spared (e.g., judged from his ability to match objects across different views), however FK showed impaired semantic access, his performance fell well outside the control range when performance depended on access to semantic knowledge to enable judgments to be made. Prior testing demonstrated item-specific consistency (confirmed in the present data-set too). This is indicative of a central deficit in semantic knowledge (Humphreys and Forde, 2005).

In BL– Similarly to FK– there appeared to be relatively good perceptual processing from both vision and touch, along with impaired access to semantic knowledge.

Table 6: Performance of standardized tests of object processing (impaired scores in bold)

Neuropsychological test	**FK**	**BL**	Controls – mean (SD)
Copying simple shapes from (BORB)	Spared	Spared	N/A
Foreshortened matches (BORB)	22/25	22/25	21.6(2.6)
Minimal-feature matches (BORB)	24/25	22/25	23.3 (2.0)
Associative matches (BORB)	**20**	**17**	27.5 (2.4)
Pyramids & Palm Trees (Pictures)	**36/52**	**34/52**	50/52
Pyramids & Palm Trees (Auditory words)	**37/52**	**40/52**	50/52
PALPA picture-auditory word match (test 39)	**29/40**	**29/40**	39.24 (.07)
PALPA auditory synonym matches (test 49)	**32/60**	**33/60**	60

BORB = Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993)
Pyramids & Palm Trees (Howard & Patterson, 1992)
PALPA= Psycholinguistic Assessment of Language |Processing in Aphasia (Kay, Lesser & Coltheart, 1992)

4.2.1 Tests of apraxia

To examine the ability of both patients to act appropriately to objects they performed the following actions:

1. Object use: the patients had to use the objects. For this the patients were allowed to both hold and see the objects
2. Pantomime actions: the task was to pantomime transitive gestures to stimuli. The stimuli were presented in the following modalities: (i) vision (either as objects or pictures), (ii) touch, and (iii) written verbal
3. Pantomime intransitive gestures to verbal prompts
4. Copying both transitive and intransitive gestures

4.2.2 Tests of semantic processing

The ability to access semantic information about the stimuli used in the action tests was evaluated. For this, each patient was presented with triplets of objects which the patients could both see and feel. 25 of the objects from the action task were designated as targets (e.g., hammer). On each trial one target was presented along with one extra item that was strongly associated to the target (nail) and another (the distractor) that belonged to the same general semantic category as the target but was less strongly associated to it (saw) (see Appendix C). The task was to decide which two stimuli were used together or were related to one another.

Stimuli

Forty-seven commonly used objects were used. A full list is provided in Appendix B.

Procedure

Each object was presented to the patients, one at a time, in different conditions. First the Use task condition was presented to patients and then they performed the pantomime tasks.

4.2.3 Transitive actions

Use task (Task a)

In the real use condition, patients were told: “Pick up the object and show me how you would use it”.

Pantomime task (Task b)

The orders of four conditions were: visual (object presented), visual (picture presented), verbal and tactile. In the visual condition with real objects, the stimuli were presented on the table in front of the patients who were told: “Show me how you would use the object placed in front of you”. In this condition the patient was not allowed to touch or handle the object. For the mime with pictures, the picture of each stimulus was presented on a paper on the table in front of the patients where it remained there till the action was finished. The instruction was to “Show me how you would use the object that you are seeing in this picture”. In the verbal condition the name of stimuli were presented on a paper on the table in front of the patients and the examiner said: “Show me how you would use a (name of object). In the tactile condition, patients were blindfolded, and the objects were placed in their hand and were told: “Show me how you would use the object in your hand”. Patients were allowed to handle the object for about a few seconds before giving it back to the examiner. Then, patients were asked to pantomime the related action.

Scores

Each patient’s response was videotaped and scored subsequently as correct or incorrect (correct was defined as a recognisable and accurate gesture).

In order to analyze the consistency of participants’ actions, all the conditions were repeated in a separate session. To provide a measure of validity of the scores, two independent judges scored each patient’s performance, randomly.

Control subjects

Three control participants (1 Male and 2 Females) took part in the study, 2 age-matched to BL and 1 to FK. The controls scored at the ceiling in all tests.

4.3 Results

Accuracy

Table 7 presents the frequency of accurate gestures made by FK and BL when performing the tasks in the different conditions. Differences between the conditions for each patient were analysed using sign tests. The consistency of each patient's actions, across the two tests in each condition, was evaluated by comparing performance relative to the scores expected by chance, given the level of performance in each session (see Appendix E for scores of first and second assessment)

Table 7: Frequency of correct scores in the patients

Task	FK	BL
Object Use (Task a)	56/94 (60%)***	52/94 (55%)***
Pantomime (Task b)		
Transitive gestures		
Visual (object)	29/94 (31%)***	30/94 (32%)***
Visual (picture)	20/94 (21%)***	21/94 (22%)***
Tactile	37/94 (39%)***	15/94 (16%)***
Verbal	19/94 (20%)***	26/94 (28%)***

The Chi square tests are for the comparison between patient and control subjects
*p<.05, **p<.001, ***p<.0001

Table 7 presents the results in the different condition for each patient. The controls performed at ceiling. It is clear that both patients were impaired relative to the controls. Both patients also showed an 'object use advantage', when performance in the 'use' condition was compared with that in the single modality, visual and tactile action conditions. For FK the 'use' condition was better than when he was asked to pantomime to visually presented objects ($p = .006$), to pictures ($p < .0001$), to tactilely presented objects ($p = .004$) and to verbally presented names ($p < .0001$). Similarly for BL there was an advantage for 'object use' compared with the same conditions: pantomime to visual objects ($p = .01$), to pictures ($p = .001$), to tactilely presented objects ($p < .001$) and to verbally presented names ($p = 0.01$)[2].

There were also some differences between the patients in the pattern of performance across the conditions where pantomimes were required. FK's pantomimed gestures were more correct in the tactile condition than in the verbal and picture conditions (p= .014 and .007 respectively). In contrast to this, BL performed better in the visual object condition than in the tactile condition (p=0.17).

Semantic matching and the 'use advantage'

FK scored 13/25 and BL scored 11/25 on the semantic matching test. Neither patient performed above chance (all χ^2<1.0).

To assess whether the object use advantage arose irrespective of whether the objects were successfully recognised, the use advantage was examined for objects where semantic matching was correct and for objects where semantic matching was incorrect. The results are presented in Table 8.

Table 8: Number of correct and incorrect semantic matches (visual condition), with the different action conditions broken down as a function of whether semantic matches was correct (a) or incorrect (b)

(a) Correct semantic matches

Action condition:	Patient	Correct actions	Incorrect actions	χ^2 analyses vs. object use	Probability of difference occurring by chance
Object use	FK BL	12 9	1 2		
Object pantomime	FK BL	8 5	5 6	5.2 5.86	.025 .025
Picture pantomime	FK BL	4 4	9 7	23.11 9.82	.001 .01
Touch pantomime	FK BL	10 3	3 8	1.73 16.5	n.s. .001
Verbal pantomime	FK BL	3 5	10 6	35.1 5.86	.001 .025

[2] All tests 2-tailed

(b) Incorrect semantic matches

Action condition:	Patient	Correct actions	Incorrect actions	χ^2 analyses vs. object use	Probability of difference occurring by chance
Object use	FK BL	8 7	4 7		
Object pantomime	FK BL	1 4	11 10	53.44 3.51	.001 .08
Picture pantomime	FK BL	1 2	11 12	53.44 14.58	.001 .01
Touch pantomime	FK BL	1 2	11 12	53.44 14.58	.001 .01
Verbal pantomime	FK BL	1 1	11 13	53.44 38.76	.001 .01

For all but two comparisons, both, FK and BL showed an 'object use advantage', and this held irrespective of whether the patients were able to make correct semantic matches to the particular stimuli. The data suggest that the use advantage held irrespective of whether semantic access for the objects was achieved.

Action consistency

Table 9 gives the tests of consistency carried out on the action data for each patient, examined the observed performance against that expected from chance consistency.

Table 9: Consistency of action

	FK		BL	
	χ^2 analyses vs. chance	Probability of difference occurring by chance	χ^2 analyses vs. chance	Probability of difference occurring by chance
Object use	14.1	.01	6.01	.05
Object pantomime	17.87	.001	4.01	.13
Picture pantomime	12.5	.01	48.16	.001
Tactile Pantomime	12.8	.01	13.23	.01
Verbal pantomime	19.6	.001	18.11	.001

With one exception (object pantomime, for BL), both patients showed item-specific consistency which was reliably greater than could be expected by chance.

This pattern is consistent with the actions being limited by a central representational deficit. Despite this, performance improved in the use compared with the pantomime conditions.

4.4. Discussion

The results show that there is better use of objects than action gesturing in FK and BL. This pattern of performance has been observed on numerous occasions in patients showing aspects of apraxia (e.g., Chainay & Humphreys, 2002). Chainay and Humphreys accounted for the result in terms of direct sensory representations (visual and tactile, when objects are used), helping to constrain action performance. An alternative is that there may simply be higher cognitive demands on the action system when actions must be pantomimed compared with when objects are directly used. Whichever the case, the interesting aspect of the present data is that both FK and BL have impaired object recognition, and in particular poor access to semantic knowledge, and this occurs across different modalities of presentation. The results from the semantic matching tests suggest that the patients have a central semantic deficit. Despite this, ‘object use advantage’ occurred both for objects that were matched correctly and for objects which were matched incorrectly. Given that the semantic matching task could use both vision and touch, it cannot be argued that the ‘use advantage’ came about because there was improved recognition when both modalities were present. Instead, the results consistent with a ‘direct route’ proposal that input from the two modalities converges at a stage of selecting and programming an action to the stimulus, by-passing the recognition deficit (Chainay & Humphreys, 2002). It is also consistent with any reduced cognitive demand on action programming, in the use condition, influencing performance irrespective of the semantic impairment in the patients.

It is also of interest that both FK and BL by and large showed item-consistency in their action performance – they were consistently correct at using certain objects and unable to use others. In the neuropsychological literature item-specific consistency has been associated with patients having impaired representations of stimuli, which results in the representations not being accessible across different test occasions (Warrington & Shallice, 1979; Shallice, 1985). It is as if the representations have simply been lost from memory and cannot be retrieved – the degraded store account. However, if this was the case, then how could actions be performed correctly when the perceptual input increased, in the object use condition? At least two possibilities can be suggested – one of which maintains the 'degraded store' account of consistent deficits, while the other takes a different approach to explaining item-specific deficits.

According to the degraded store account, the patients show item-specific consistency because of their semantic impairment. It may be that the semantic route to action is dominant, especially when perceptual input into the action system is limited. As a consequence the patients are impaired at acting to stimuli which have degraded semantic representations. Consistent with this proposal, both FK and BL were better at acting to stimuli that they could match correctly at a semantic level, compared to stimuli that were matched incorrectly (with objects matched correctly FK made 37 correct to 75 incorrect actions; with objects matched incorrectly he made 12 correct to 48 incorrect actions, summing across the different actions conditions; χ^2 (1) =4.73, $p<0.05$. With objects matched correctly BL made 26 correct and 29 incorrect actions, while with objects matched incorrectly she made 16 correct actions and 54 incorrect actions; χ^2 (1)=8.23, $p<.01$). However, a direct route, driven by convergent activation from different perceptual modalities, could enable action representations to be accessed even if these same representations could not be accessed semantically (due to impoverished semantic input).

The alternative view is that item-consistency could occur not because representations are lost, but because they are fragile or easily placed into a below-threshold state. Such ‘vulnerable’ representations may mean that actions are not easily accessed across two different occasions. However, if there is increased perceptual input, then the representations may be raised above threshold, enabling actions to be made correctly (see Forde & Humphreys, 1997 for similar arguments). According to this proposal, the patients may have impaired action representations, in addition to any impairment at a semantic level. These action representations may be raised above threshold by increased perceptual input, in the ‘use’ conditions.

A final point to note is that there were some contrasting results between BL and FK in terms of their performance when stimuli were presented in different modalities. BL was particularly poor with tactile input while FK was poorest with verbal stimuli and pictures. In FK’s case, it could be argued that his performance decreased when the perceptual input was impoverished (with pictures and words compared with objects). In BL’s case the tactile condition could be poor if she failed to explore the object correctly, again generating impoverished perceptual input. Both patients were encouraged to explore objects fully in the tactile condition, but it was difficult to ensure that this was done consistently across the patients. Irrespective of this, the similarity of the ‘use advantage’ across the patients, combined with their similar semantic impairments, points to the use of perceptual information directly for action.

CHAPTER 5

Real object use facilitates object recognition in semantic agnosia

Abstract

In the present chapter I show that, in patients with poor semantic representations, the naming of real objects can improve when naming takes place after patients have been asked to use the objects, compared with when they name the objects either from vision or from touch alone, or together. In addition, the patients were strongly affected by action when required to name objects that were used correctly or incorrectly by the examiner. The data suggest that actions can be cued directly from sensory-motor associations, and that patients can then name on the basis of the evoked action.

5.1 Introduction

Agnosic patients show impaired object recognition that cannot be attributed to elementary sensory defects, mental deterioration, attentional disturbances, aphasia misnaming, or unfamiliarity with sensorially presented stimuli (Bauer, 1993). A variety of different forms of agnosia have been described, varying from patients with early disturbances in contrasting forms of early perceptual processing (e.g., Riddoch et al., 2008) through to patients with deficits in accessing semantic representations following access to stored perceptual representations of objects (Hillis & Caramazza, 1995; Riddoch & Humphreys, 1987; see Humphreys & Riddoch, 2006, for a review). The term 'semantic agnosia' proposed to describe patient who appear to have a central deficit in accessing semantic information. For example, the patients perform poorly on tasks requiring matching between objects based on their conceptual or associative relationships. In cases where semantic knowledge itself is disturbed this may present as a multimodal deficit, where matching is disrupted irrespective of the modality of the stimuli (Riddoch, Humphreys, Coltheart & Funnell, 1988). In some cases of patients with semantic agnosia it has been reported that the patients can make relatively preserved gestures to objects even when they fail to name them (Hillis & Caramazza, 1995; Riddoch & Humphreys, 1987), and, when the naming impairment is most pronounced from vision, the pattern of better gesturing than naming has also been labeled as optic aphasia (Ferreira, Giusiano, Ceccaldi & Poncet, 1997; Freund, 1889). However, more detailed testing of such patients has also indicated that modality-specific deficits link to poor access to precise semantic knowledge about objects, rather than reflecting a deficit in modality-specific naming (Hillis & Caramazza, 1995; Riddoch & Humphreys, 1987). In such cases, the relatively preserved ability to gesture to objects appears to be based on patients using the perceptual properties of the stimuli to direct the gestures (see Yoon, Heinke & Humphreys, 2002, for a simulation of this result).

The likelihood that agnosic patients successes in object recognition can depend on how objects are presented. For example, patients are typically better at the visual identification of real objects than of photographic images or line drawings of the same stimuli (e.g., Farah, 1990), at least in part because the patients are able to use additional cues with real objects (e.g., motion parallax and binocular depth cues) to facilitate object encoding (see Chainay and Humphreys, 2001). There are also some studies with normal observers demonstrating that correctly coloured objects may be named faster than line drawing, at least when the colour is informative about the object and the object is drawn from a class with perceptually similar neighbours (Price and Humphreys, 1989; Tanaka and Pressnell, 1999). However, colour seems unlikely to be contributory factor for patients who, along with being agnosic, are also achromatopsic (Riddoch and Humphreys, 1987; Chainay and Humphreys, 2001).

There are also some suggestions that patients may use the visual properties of objects to directly access information about object use (see above), and they may infer the object's identity from its function. For example, Sirigu et al. (1991) reported that their agnosic patient often named objects by describing how the object might be used and then identifying it from the functional properties being described. Wolk, Coslett and Glosser (2005) similarly reported a patient who was better able to identify objects that were rated as having strong 'manipulative' associations compared with objects that were rated as being low in manipulability. They suggest that the activation of manipulative associations can help patients retrieve information about object identities. Riddoch and Humphreys (1987) further documented a patient, JB, who was often able to gesture to visual presented objects despite having impaired access to semantic knowledge about the stimuli when formally tested. In many cases, JB then named the object from the gesture he produced. To account for their results, Riddoch and Humphreys proposed that visually presented objects could activate associated action-related knowledge independently of any access to associative semantic knowledge, with identification being mediated by action-related knowledge even when semantic access was impaired (see also Pülvermuller, 1999, for a similar proposal). This proposal, for an action-based mode of object identification operating in parallel with semantic-based naming has been simulated by Yoon et al. (2002) in their convergent route model of object naming and action retrieval. In this model gestures can be activated by associations between the perceptual properties of objects and action representations (e.g., the perceptual properties of a cup being associated with a drinking action) and this can operate independently of the activation of action representations from conceptual/semantic knowledge. If a patient generates an action through this 'direct' route between vision and action, then this may provide a new form of motion-based input into the perceptual recognition system, leading to better object recognition than that provided by the static image of the object. Ferreira et al. (1997) also showed that their patient was better able to name objects that were used in pantomime actions by the experimenter, which would fit with the idea of object gestures providing a distinct form of input into the recognition system (see Rothi, Ochipa & Heilman, 1997, for an explicit account).

In prior studies the ability to name through gesturing to objects has been reported in patients with a modality-specific deficit in naming and recognition (Ferreira et al., 1997; Riddoch & Humphreys, 1987). In the present study I report data on whether patients with an apparent central semantic impairment can also show evidence of naming objects through action, compared with, when they just view or touch the same objects or to when they both view and touch the objects. We examined two patients with impaired semantic knowledge when tested across different modalities. Two experiments were conducted. In Experiment 1 I assessed the ability of the patients to name objects after they were asked to use the stimuli compared to conditions in which the patients saw but could not touch the objects (vision only), held but could not see the objects (touch only) or both held and touched the objects but did not use them (combined vision + touch). Is there any advantage for naming objects after using them compared with when the tasks stress naming only, and can this emerge even if the patients are impaired at access semantic knowledge about the objects? Note that this could come about if, under conditions where action was stressed, the patients were able to use direct information from touch and vision to activate an action, and then named the objects via the actions. In Experiment 2 I evaluated the relations between object use and naming further. In this case, the examiner used the object with either the correct action (as in Ferreira et al., 1997) or with an incorrect action (e.g., using a toothbrush as a hairbrush) and had patients name the objects. Were the patients affected by the incorrect actions even when they were irrelevant to the naming task? Yoon and Humphreys (2005) reported that the times taken by normal participants to name objects were affected by the gestures being made with them, even when the gestures were irrelevant. Would the same emerge here on naming accuracy? To foreshadow the results, we show that, despite the patients having a semantic impairment in object recognition, their ability to name objects improved when they were asked to use the stimuli. Given the semantic impairment apparent in the patients, this ability to use the objects, and then name from the action, suggests that the actions were generated non-semantically. In addition, the patients were strongly affected by how the experimenter used the objects and misnamed objects in terms of the inappropriate action. We discuss the implications for understanding action retrieval and object naming.

5.2 Experiment 1: Naming from use, vision, and touch

5.2.1 Method

Case reports

There were two participants, FK and BL. See the case report in Chapters 2 and 3.

Design and Procedure

We assessed FK and BL's ability to name objects under a variety of conditions in two sessions per condition which were conducted with at least one-week-gap between them:

1. the objects were presented one at a time to each patient who was asked to show how the object was used and then to name it;
2. the patients viewed each object from a distance of about 50 cm without touching it and were asked to name it;
3. the patients were asked to pick up and feel each object without using it while they were blindfolded; then they had to name it;
4. the patients were asked to both look and touch each object without using it and then to name it.

There were 47 objects presented one at a time in each session of each condition, and conditions repeated twice in separate sessions (see Appendix C for list of objects). The order of the conditions (each conditions and its repeat) was randomized for each patient.

As well as the conditions testing object naming, we examined the patients' perceptual processing of the same objects from vision and their access to semantic knowledge about the objects from vision and from the object names (there is an overlap between the procedure and data of this experiment and the experiments reported in Chapter 4). Perceptual processing was tested by presenting each object for 30s, then covering it and showing it in a new orientation alongside another similar object. The orientation shift was at least 90 degrees. The task was to point to which of the two re-presented objects was the same as the one just seen (visual matching across viewpoint).

Semantic access was assessed by presenting each patient with triplets of objects (or object names, presented auditorally): one was a target object from the naming task (hammer), one was strongly associated to the target (nail) and the other (the distractor) was from the same general semantic category as the target but was not strongly associated to it (saw) (see Appendix C). The patient was asked to decide which two stimuli were used together or were related to one another. For the naming, perceptual matching and semantic matching tasks, control performance (2 participants (M/42 and F/78), 1 age-matched to each patient) was at ceiling and they did not produce any errors in the different conditions).

5.2.2 Results

Object naming

The naming data were analysed using a Log Linear analysis with the factors being Patient, Condition, Test (first vs. second session) and Accuracy (number correct, number wrong)[3]. A first comparison between the conditions of naming from object use (condition i) and naming from vision (condition ii) revealed a final model in which there were reliable interactions between Patient and Accuracy (χ^2 (1) = 25.13, p<0.001) and also between Condition and Accuracy (χ^2 (1) = 6.81, p<0.01) (χ^2 (10)=0.746, p=1.0 for the best fitting model). FK named more objects than BL, giving rise to the Patient x Accuracy interaction, but, across both patients and both test sessions for each condition, naming in the object use condition (i) was better than in the vision only condition (ii) (generating the Condition x Accuracy interaction) (see Table 10).

A similar comparison was conducted between the naming from use (i) and naming from touch (iii) conditions. Here the final model again gave reliable interactions between Patient and Accuracy (χ^2 (1)=43.11, p<0.001) and between Condition and Accuracy (χ^2 (1) =9.27, p<0.01) (χ^2 (10)=4.25, p=0.936 for the best fitting model). FK again named more objects than BL and naming overall was better in the object use condition (i) than when the objects were felt (condition iii). The advantage for the object use condition held across patients and test sessions.

For the comparison between object use (i) and combined vision and touch (iv), the final model generated reliable interactions between Patient and Accuracy (χ^2 (1) = 41.97, p<0.001) and between Condition and Accuracy (χ^2 (1) =8.72, p<0.01)(χ^2 (10)=4.73, p=0.909 for the final model). FK was more accurate overall than BL, and performance was better in the object use (i) condition than the combined vision and touch condition (iv). The improvement for the object use condition over the combined condition held across patients and test sessions.

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[3] By including Accuracy as a factor in this Log linear analysis, we test whether the relative number of correct to incorrect responses changed across the different conditions. This would be revealed by an interaction between the factor of Accuracy and the conditions of interest.

The conditions of naming from vision only (ii), touch only (iii) and combined touch and vision (iv) were examined in a Log Linear analysis with the factors being Patient, Condition (vision only, touch only, vision + touch), Time (sessions 1 and 2) and Accuracy. The final model (χ^2 (16) =5.87, p=0.989) revealed only an interaction between Patient and Accuracy (χ^2 (1) = 64.39, p<0.001). FK named objects more accurately than BL but there were no differences across the conditions or test sessions.

Across all the presentation conditions the patients tended to make errors by either (i) failing to respond (60% of errors), (ii) making a semantic error (ladle → soup; 20% of errors), (iii) describing a part of the object (scissors → a blade), and (iv) perseverations. There were no occasions on which the patients produced a verb name (e.g., brushing) when trying to name an object (e.g., hairbrush).

Consistency of naming

We analysed the consistency of the patients' performance across the repeated trials of the Object use (i), Visual (ii), Tactile (iii) and Combined (Vision + Touch) conditions (iv) (see Appendix E for the mean scores of first and second trials) by comparing the differences in the number of occasions when both items were named accurately, one item was named accurately, or neither item was named accurately, relative to the probabilities of these responses if there was chance consistency (probability of correct or error on test 1 x probability on test 2 x number of trials). FK generated a level of consistency above chance, in all conditions: Object use (χ^2 (3) = 13.47, p <0.01), Visual naming (χ^2 (3) = 12.51, p<0.01), Tactile naming (χ^2 (3) = 11.25, p = .01) and Combined (Vision + Touch; χ^2 (3)=11.25, p=0.01). In contrast, BL did not show any consistency above chance (Object use, χ^2 (3) = 2.39, p = .496; Visual naming, χ^2 (3) =

1.95, $p = .583$; Tactile naming, χ^2 (3) = 3.45, $p = .06$; Combined (Vision + Touch), χ^2 (3)=3.45, $p=0.327$).

Object use

We assessed the number of correct action responses made by the patients. FK made 68/94 (72%) correct actions while BL made 52/94 (55%) correct actions. (See Chapter 4 for more information). For FK the trend for more correct actions than correct name responses (when names were given immediately following each action) was not reliable ($\chi^2(1) = 2.0$, $p>0.05$; McNemar test of change). BL, however, made significantly more correct gestures than correct name responses (χ^2 (1) = 23.06, $p<0.05$; McNemar test of change).

Consistency of naming and action

The consistency between the action and immediate naming responses of the patients was also examined, comparing the observed number of trials where both the action and the name were correct, both incorrect, or one correct and the other incorrect, against the numbers expected by chance given the probability of a correct or error response being made for the action or naming task. Both FK and BL showed greater consistency between correct action use and naming than would be expected by chance (χ^2 (3)= 19.54, $p<0.001$, for FK; χ^2 (1) =8.07, $p<0.045$, for BL). FL had responded either both correctly or both incorrectly with the action and name on 81% (76/94) of the trials; BL had both correct or both incorrect on 64% (60/94) of the trials.

Table 10: Frequency of correct scores in the patients compared to the controls

	FK	BL
Object Naming		
Object use	50/94***	24/94***
Visual	35/94***	16/94***
Tactile	40/94***	8/94***
Visual and Tactile	40/94***	9/94***
Perceptual matching	19/22	20/22
Semantic matching		
Name	12/25***	10/25***
Object	13/25***	11/25***

The Chi square tests are for the comparison between patient and control subjects
*p<.05, **p<.001, ***p<.0001

Perceptual matching

The comparison between the patients' performance and that of controls failed to show any reliable differences (FK, χ^2 (1) = 3.22, p = .073; BL, χ^2 (1) = 2.09, p = .148).

Semantic matching

Name presentation: When we presented the name of objects to be matched, FK made a correct match on 48% of the trials, while BL only matched objects correctly on 40% of the trials. Both patients performed significantly poorer than controls (FK, χ^2 (1) = 17.5, p< .001; BL, χ^2 (1) = 21.4, p< .001), and neither was above chance.

Object presentation: When required to carry out semantic matching with objects, FK scored 52% correct and BL in 44% correct. Again both patients generated considerably more errors than controls (FK, χ^2 (1) = 15.7, p < .0001; BL, χ^2 (1) = 19.4, p < .0001) (see Table 10), and neither was above chance.

5.2.3 Discussion

Both FK and BL showed clear evidence of impaired semantic knowledge about objects, both when their performance on standardized tests was assessed (Table 10) and when their semantic matching performance was evaluated with the objects used in the naming tasks here (Table 10). This deficit was present both when stimuli were visually presented and when they were auditorally presented. In contrast, their perceptual matching of objects was relatively good. Based on the consistency of his performance it can be argued that FK has impaired semantic knowledge about objects (see also Humphreys & Forde, 2005, for additional evidence), in contrast BL was quite inconsistent on which items she named correctly across different test occasions – a pattern that suggests that there is impaired semantic access (cf. Warrington & Shallice, 1970). In previous cases where patients have been reported as having a multi-modal deficit that is inconsistent across items over time (as with BL here) it has been suggested that the brain lesion leads to central semantic representations entering a refractory state after initially being activated (perhaps due to loss of re-current excitatory links within the semantic system; Forde & Humphreys, 1995, 1997). Irrespective of this, both patients were better able to name objects that they were allowed to use relative to when the patients merely looked at or felt the objects (naming in the vision (ii) and touch only (iii) conditions) and relative to when the patients were able both to see and touch (but not move) the objects (iv). To the best of our knowledge, this is the first formal report that patients with selectively impaired access to semantic knowledge show facilitated naming after they have been asked to use an object themselves, relative to the other naming conditions examined here. As noted in the Introduction, Ferreira et al. (1997) reported data from one patient who was better at naming an action pantomimed by the experimenter than at naming static objects, though the patient's naming through his own actions was not examined. This patient was also better at retrieving verbs associated with objects than the names of the objects themselves, a pattern of performance observed too by Yoon, Humphreys and Riddoch (2005). Interestingly, the patient described by Yoon et al. (2005) was impaired at retrieving the associated verb when stimuli were presented verbally. Yoon et al. (2005) accounted for this result in terms of the convergent route model of action retrieval and naming. They proposed that the patient had a semantic deficit which disrupted verb retrieval when he was presented with object names, but, when objects were presented visually verbs could be retrieved non-semantically through the visual activation of action knowledge. The same account (based on direct access to action knowledge from vision) can be put forward to explain the superior naming of verbs when Ferreira et al.'s patient was presented with objects.

In addition to being better at naming objects after being required to use them, both patients also showed item-specific consistency in using and then naming objects. This result is most striking with patient BL, who failed to demonstrate item-specific consistency for any tests of naming across two occasions. The consistency generated from using and then naming the object is consistent with name retrieval being affected by the activation of action-based knowledge.

The novel result here is that the patients' ability to use the objects and to name the objects after use was coincident with them having a multi-modal semantic deficit. How then can this 'object use' effect come about? One possibility is that the perceptual input is in some way 'richer' in the use condition compared with the other conditions here. For instance, one referee suggested that, in the object use condition, information was available through modalities – from vision, touch and from seeing the object being used. However, this proposal takes no account of how the objects came to be used correctly rather than incorrectly in the first place, from input then coming from two modalities – vision and touch. The 'third' modality (seeing the object being used) would only present appropriate information when the action was generated correctly. Neither of the patients made arbitrary/toying gestures to the objects and then guessed from these what the object might be, but rather they used the objects from the start after being asked to use them. Hence we must ask how the actions came to be generated correctly in the first place. The benefit seems to be unlikely to be due to the quality of the information coming from each of the critical input modalities in this 'joint' modality condition, compared to when only one modality was used. Note that the patients could freely look at the objects from different angles in the vision only condition, and note also that the patients were able to match objects across different viewpoints. This argues against the recognition deficit, which generalized across modalities, reflecting a failure to derive sufficient visual information in the vision only case. Note also that, in the touch only condition (iii), the patients could pick up and feel the object, and so had available to them the same tactile information as they had in the object use condition. Another possibility is that the combination of vision and tactile information (in the object use condition (i)) may help the patients to access semantic information easier. This possibility was tested in visual and tactile condition (iv), when the perceptual input allowed information to be combined across the modalities the patients still performed poorly, however. As a final test of the idea that the patients benefitted from the presence of multi-modal associations that the objects may have, I examined whether the patients were better able to identify items that had object-specific associations with visual, touch and also sound (e.g., hammer, whistle, telephone) compared to objects that did not (e.g., salt-shaker, paintbrush). There was no evidence for objects with more cross-modal associations being named more accurately than objects without these associations (summing across the visual and tactile presentation conditions, 8/14 for the multi-modal objects vs. 31/80 for testing at time 1 with FK; 4/14 vs. 10/80 for BL; χ^2 (1) = 1.66 and 2.43 respectively, both $p>0.05$).

The above data indicate that, unless the patients were cued to directly act with the object, they were unable to use perceptual input to access names through semantic knowledge, even when the input was derived across input coming simultaneously from vision and touch, and even when objects had multi-modal associations. We suggest that, when cued to respond using action, the combined sensory information was able to 'drive' the correct action in a direct, non-semantic manner, which then helped the patients to name the objects. One final point to note is that neither of the present patients made errors by naming the verb associated with the objects (e.g., scissors → cutting). In at least one prior report it has been noted that there was relatively good naming of verbs associated with visually presented objects even when object names were poorly produced (Yoon et al., 2005). I saw no evidence for this. Indeed, I also assessed whether there was better naming of objects whose names were at least partially related to a verb associated with object use (e.g., hammer) compared to object without associations to a verb name (e.g., ashtray). For BL there was no difference between these two classes of object (4/40 for objects whose named were partially associated with verbs; 10/54 for objects whose names had no such associations; χ^2 (1) = 1.32, $p>0.05$, summing across visual and tactile modalities at test time 1). FK actually named more objects whose names were unassociated with verbs than objects whose names were associated with verbs (9/40 vs. 30/54, χ^2 (1) = 10.43, $p<0.001$). It should be noted that these comparisons are post-hoc and the objects entered into them were not matched in any way. Hence we should not make strong conclusions from the data. The point to note is that there was no evidence for naming mediated by retrieval of verb names, as opposed to the action itself being evoked by the objects.

5.3 Experiment 2: Effects of correct and incorrect object use on naming

I have used the results of Experiment 1 to suggest that the patients were influenced by a direct route to action from the visual properties of objects, when the task emphasized object use prior to naming. They may also have named the objects on occasions from the actions they produced. However, given the preponderance of failures to respond on naming trials, this last possibility was difficult to assess. Experiment 2 sought to provide a more direct test of the idea that there is naming from action by examining directly the effects of object use on the ability of the patients to name objects.

FK and BL were presented with a sub-set of 20 of the objects from Experiment 1. These objects were then either used correctly or incorrectly the examiner and the patients were asked to name what the object was. In studies with normal participants Yoon and Humphreys (2005) have shown that object identification is slowed when objects are used incorrectly compared with when they are used correctly, suggesting that it is difficult to ignore information about object use even when it is irrelevant to the task. Here we test if the patients show an abnormal effect of action by making errors when the action information is incongruent with the object.

5.3.1 Method

The patients were presented with a sub-set of the objects used in Experiment 1. On each trial the patient sat opposite the examiner, who grasped a target object and either used it appropriately or inappropriately. Inappropriate actions took the form of an action appropriate for another object (using a toothbrush as a hairbrush). The objects and conditions were presented in a random order for each patient. The task was to name the object on each trial.

5.3.2 Results

FK named 14/20 of the objects correctly when they were used appropriately and 6/20 when they were used inappropriately. BL scored 11/20 and 2/20 correct in the same conditions. In both cases object naming was strongly affected by object use (McNemar test of change, p=0.008 and 0.004 respectively). In the incorrect action condition FK misidentified 6 objects by naming them in terms of the object that would have matched the gesture (toothbrush used as hairbrush → comb); BL made 5 equivalent errors in the incorrect use condition.

5.3.3 Discussion

The results show that both patients were affected by how the objects were used, and they were better at naming objects in the correct use condition than in the incorrect use condition. Also, on incorrect use trials they sometimes misnamed objects in terms of the action that was performed. The results are consistent with the proposal that the patients tended to name objects from action. Note however, that even when all the actions were correctly carried out, the patients were still far from perfect. This indicates that the patients had some problem in recognizing actions, which may reflect their central semantic impairment. This would limit object-naming performance, even if the ability to retrieve actions non-semantically from objects were perfect.

5.4 General Discussion

We have presented two experiments on two patients with a multi-modal semantic impairment. In Experiment 1 we found that the patients were better able to name objects after being requested to use them, compared with when the same objects were shown visually, through touch or through both vision and touch (without object use). The sensory input in this last condition matches that in the object use condition at least up to the enactment of the action. Thus the object use advantage cannot be attributed simply to more input being present – since the sensory input would need to access the information about object use before any enactment took place. It is difficult to see how this could operate semantically, given that both patients had a semantic impairment. Instead we suggest that the patients were able to use direct associations between the sensory input and actions, and these enabled the actions to be elicited when the ‘action route’ was emphasized by the task. Objects were then named through the action information that was retrieved. Consistent with this last proposal, we found that both patients showed greater item-specific consistency when using and then naming objects than expected by chance, even though one patient (BL) showed highly inconsistent performance in her naming of objects across different occasions.

In Experiment 2 we provided further evidence for the patients naming through the direct activation of action knowledge. In this experiment we presented the patients with objects that were used either correctly or incorrectly. Object naming was better under conditions of correct action, and, when objects were used incorrectly the patients sometimes misnamed objects in terms of the actions.

It might be argued that the gains generated by naming objects through associated actions were relatively modest (e.g., in Experiment 1 FK showed a 16% gain in the object use condition compared with the vision-only condition, and BL showed only a 9% benefit). However, the patients both had impairments in identifying actions and were far from perfect even when shown objects that were being used correctly (Experiment 2). When action knowledge is retrieved, this information still needs to be used for naming, and this likely involves accessing conceptual knowledge to link an action to a name. Both patients had conceptual impairments, which would disrupt this process. However, despite this the gains that we did observe, which held across patients and test sessions, are consistent with extra information signalled by action, and with the action information being retrieved non-semantically, by direct visuo-motor association in Experiment 1. In the present cases, naming from action appeared to overcome a residual deficit in accessing semantic information, enabling objects to be named more accurately. The same direct visuo-motor associations may also underlay the better gesturing than visual naming performance in patients classed as optic aphasic (see Riddoch & Humphreys, 1987).

CHAPTER 6

Rehabilitation of Apraxia

Abstract

Studies on the re-mediation of apraxia have focused on re-training gesture production. In this part of the study, I sought to see the influence of re-learning transitive and intransitive gestures in a case of both aphasia and apraxia (DS). The treatment consisted of presenting multiple cues to using a given tool. The results showed an improvement at making transitive gestures for the trained objects. There was no generalization of training in apraxia which fits with prior studies on rehabilitation of apraxia

6.1 Introduction

One of the cognitive impairments following stroke that can have a major impact on independence in activities of daily living is apraxia. Limb apraxia is generally understood as covering all those disorders of purposive movements resulting from neurological dysfunction which cannot be explained by intellectual deterioration, lack of cooperation, sensory disturbances, agnosia, disrupted body schema, visio-spatial disturbances or aphasia (Maher and Ochipa, 1997). The relative frequency of limb apraxia in patients with stroke is 51.3 % after left hemisphere lesions and 6.0 % after right hemisphere lesion (Zwinkles, Geusgens, Van de Sande, and Van Heugten (2004). One general distinction between patients with apraxia is based (essentially) on whether a patient cannot access information about what they are to do with an object (e.g., because the plan of action is disrupted) or whether the patient knows what to do but not how to do (De Renzi, 1989) – a distinction between so-called ideational and ideomotor forms of the disorder. The deficits can involve both single and series of movements and can be found (depending on the patient) in multiple modalities – in gesturing to verbal command, in gesturing to visual and/or tactile presentations of objects, or in imitating objects.

Studies on the remediation of apraxia have focused on re-training gesture production (Maher, Rothi and Greenwald, 1991; Pilgrim and Humphreys, 1994) (see Chapter 1 for more information about previous studies in rehabilitation of ADL disorder). This ability to re-learn gesture production may be particularly important for patients dependent on gesture as a primary method for communication, as is the case for individuals with both aphasia and apraxia (such as patient DS, who was studied here).

There are some studies on training of communicative gestures, as well. Code and

Gaunti (1986) studied a case of limb apraxia with sever Broca's aphasia and disrupted communicative hand signs following CVA. Code and Gaunti formed a six-stage hierarchical program involving imitation, fading and reinforcement focused on pairing the word and sign in response to various commands for 1 session in a week in 8 months. The results showed improvement in production of gestures to word and word to gesture on post-test. Moreover, in 1991, Cubelli, Trentini, and Montagna trained a woman with global aphasia and limb apraxia to pantomime to visually presented objects and actions by drawing attention to distinctive features of objects and perceptual characteristics and presenting possible pantomime for each picture to be imitated. Cubelli et al. saw improvement in performing pantomime after 2 months training (2 sessions in a week), and interestingly they found generalization to untrained gestures without improvement in apraxia post assessment. Hence, Cubelli et al. concluded that limb apraxia does not affect acquisition of communicative signs and gestures.

The data on rehabilitation suggest that patients are able to re-acquire gestures and to re-learn how to perform functional tasks, though the factors underlying any improvements (and whether improvements generalise across items) are not well understood (see Table 10). Some prior results have shown poor generalisation of gesture training in apraxia (e.g., Ochipa et al., 1991; Pilgrim & Humphreys, 1994), but other reports have noted some generalisation (Maher et al., 1991; Smania et al., 2000). The question here is whether this because there is generalization when an ideational/comprehension problem is involved whereas purely ideomotor patients only improve with trained items. Could this be separated here by testing effects of training on a patient who shows good comprehension for some types of gestures (e.g. transitive, object gestures) but not others (intransitive, symbolic gestures)? Answering this question formed the motivation for this study.

Table 11: Summary of studies on the rehabilitation of non-communicative gestures in apraxia

Study & Design	Subjects	Training Used	Results
Maher, Rothi and Greenwald (1991)	55-year-old man with a 22 m. history of IMA with presented gesture recognition	***Goal***: Successful gesture to visual presentation of tool ***Intervention***: Multiple cue provision (tool, object, visual model, feedback) with gradual fading ***Feedback***: Knowledge of results and error correction through modeling and physical limb manipulation ***Frequency***: 1hr/day for 2wks	Immediately post-treatment: improved verbal pantomime error performance on both trained and untrained gestures but no improvement on A probe measure of 10 meaningless gesture sequences. Two weeks post-treatment: both treated and untreated gestures performance diminished with the former having some retained gains.
Ochipa, Maher and Rothi (1995)	Two participants with 3 and 4yr. history of ideomotor apraxia (IMA) with presented gesture recognition and Aphasia	***Goal***: Decrease errors in movement ***Intervention***: Treatment geared toward their specific IMA error Profile (need another sentence to describe treatment)	Errors did not decrease until targeted in treatment. At post-treatment and two-week follow-up both subjects demonstrated treatment gains on treated but not untreated gestures, as measured by verbal pantomime error scoring and Florida Apraxia Screening Test(FAST).
Pilgrim and Humphreys (1994)	Head injured participant with left-sided IMA 23 m. post-injury	***Goal***: Appropriate gestures during object use ***Intervention***: Modified conductive education coupled with diminishing amounts of physical assistance ***Frequency***: 1/day for 3 wks+ 15 min/day practice with spouse	Differences between pre- and post-tests measuring ability to gesture to verbal, visual, and visual and tactile command demonstrated changes in trained but not untrained gestures. The conductive education strategy was not carried out spontaneously post-treatment
Smania, Girardi, Domenicali, Lara and Aglioti (2000)	13 left CVA participants with apraxia lasting greater than 2m. Random assignment to apraxia treatment or conventional treatment group	***Goal***: Improve gesture production on wide range of test ***Intervention***: Training occurred in 3 parts for transitive, intransitive-symbolic and intransitive non-symbolic gestures. Training in each segment graded from multiple to minimal contextual cueing conditions and assistance was provided verbally, visually or manually. ***Frequency***: 35 session maximum (50min, 3/wk).	The treated group of participants showed significant improvement in post-tests of IMA and ideational apraxia (IA), along with a significant error reduction in IMA and IA Tests. There was also a trend toward improved gesture comprehension following treatment

Source: adapted from Hebert and Roy 2002.

6.2 Case report

DS was 74 year old when tested. He suffered a stroke in 1995 and he used to be a train inspector pre-morbidly. DS lives at home with his wife but functioned in a relatively self-sufficient manner. His MRI report revealed a large lesion to the left inferior; middle and superior frontal gyrus, left pre-central gyrus, and left post-central gyrus (see Figure 9). He presented with hemiplegia and aphasia. There was poor function of his right hand and DS made all responses in our study using his left hand, which had good motor function. His full IQ score on WAIS was 72. His Wechsler memory score was 56 verbal and 79 visual, with the verbal score perhaps being depressed to some degree by his language impairment. Digit span was 4 forward and 2 backwards. Visual and tactile perceptions were intact. He scored 0 on the clinical version of the Stroop test and also failed to progress beyond the first colour category on the Wisconsin Card task. He did not show major symptoms of everyday action dysfunction on tests of ADL (data reported in Forde & Humphreys, 1998). However earlier work had pointed to DS being particularly poor at forming the appropriate grip when ask to gesture how to use objects (Chainay & Humphreys, 2002). He made just a few conceptual errors (e.g., making a gesture to an item related but not identical to the stimulus he was cued to). He was also better at showing how to use an object when he was holding it than he was at gesturing to verbal command or following visual presentation of the object. These prior results suggest a form of ideomotor apraxia reflecting poor planning and execution of actions, along with relatively spared recognition of actions (see Chapter 4 for similar results in other patients).

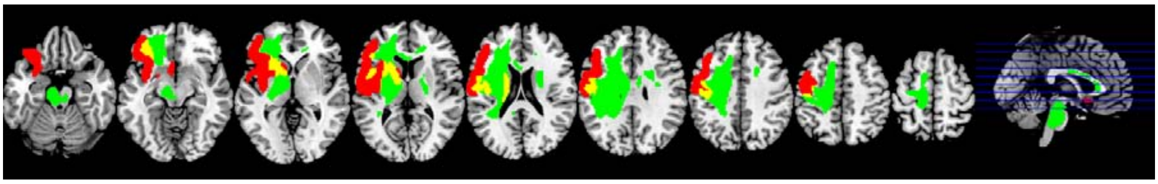

Figure 9: DS' MRI Scan

6.3 Method

The data in the present study were collected across three different assessment sessions:

- Baseline section including two sessions with one week gap between;
- Immediate post treatment sections, started two weeks after baseline; and
- Follow up section (eight weeks after baseline)

Limb praxic function was evaluated by requiring DS to perform transitive and intransitive symbolic gestures. The test is based on the work of De Renzi (1989) and consists of 40 transitive items (e.g. hammer, toothbrush) and 14 symbolic-intransitive gestures (e.g. Salute like a soldier). All items were randomly classified to a study or control group.

Before and after the treatment (immediate post-treatment and follow-up) DS underwent a series of standardized neuropsychological tests to provide independent assessments of performance in a multiple-baseline design. These standardised tests included:

- Object naming from BORB (Riddoch and Humphreys, 1993)
- Object recognition by action (Naming objects based on their action)
- Rule shift card from Behavioural Assessment of the Dysexecutive Syndrome (BADS) (Wilson, Alderman, Burgess, Emslie, and Evans, 1996)
- Brixton Test (rule attainment and rule detection task)

6.3.1 Intervention

The intervention consisted of presenting DS with multiple cues to using a given tool (a picture, a real object, a visual model, copying and feedback) and asking him to demonstrate the use of the target. The length of training depended on the number of contextual cues used in different sections and it was performed in weekly sessions in the University (where he given feedback to indicate the correct actions) and daily homework gesture-production exercises. For both training in the University and at home, DS received both transitive and intransitive-symbolic gesture training.

6.3.2 Transitive gesture training

First DS was given the name of a common tool and he was required to show the experimenter how to use that object (gesture to verbal command). If there were errors then a picture of the target object was shown and DS was required to produce the corresponding gestural pantomime (gesture to picture). If an error was still made, DS was presented with the real tool and asked to pantomime the use of that object. Finally, DS was asked to copy the examiner's action (articulated step by step) and, subsequently, to reproduce the gesture. Any errors in all sections were corrected and DS was given verbal feedback of his performance. Once DS was able to correctly perform the correct relevant gesture, another object was presented. This type of training program was given weekly within the University. At home DS undertook daily exercises to real objects and their pictures and names. In this case he was asked to try to make a gesture first to word and then to picture and then, finally, he was requested to try and show how the objects was used when he held it in his hand. These tasks were performed without feedback. Note that previous work shows that apraxic patients are typically better at gesturing when asked to use the actual objects relative to when they gesture to pictures or to verbal command without holding the objects (e.g. Grailet, Seron, Bruyer, Coyette, and Frederix, 1990) (see also Chapter 4).

6.3.3 Intransitive-symbolic gesture training

DS was asked to produce a correct, symbolic gesture to a verbal command (e.g. salute like a soldier). If there was any type of error DS was given feedback and he was asked to copy the examiner's actions, step by step. The criterion for passing from one task to another was the same as for the transitive gestures.

For both types of gesture DS was credited 1 point if he performed flawlessly on his first attempt; if his performance was unsatisfactory (e.g., due to making the wrong conceptual gesture or a gesture inaccurate in execution), he was credited 0 points. The transitive test included 20 experimental items (score 0 – 20) and the symbolic intransitive test 7 trials (score 0 – 7) (the other items were 'controls', and did not appear during the training sessions). All DS's responses were video-recorded and scored by two raters – one experiment (KM) and one independent judge. There was good agreement between the judges (90%+ concurrence rate); only the scores of KM are analysed below.

5.4 Results

DS's performance was compared between the initial baseline sessions and the last training session (week 7) and the follow-up session (week 9), using sign tests for both the experimental and control stimuli. The scores for the experimental and control items are presented in Figure 10 Transitive gestures to experimental objects improved reliably from pre- to last post training section shows significant improvement in his performance; $p < .0001$. In addition he performed well on follow-up testing; for the comparison with the original baseline, Exact sign (2-tailed) = .004. In contrast to this DS's performance in gesturing to control objects did not differ between pre- and post-training; p = .727, or between pre-training and follow-up; p = 1.

With symbolic gestures DS's performance showed no significant improvement, either for the experimental items (p = .125 for pre- vs. post-training) or control stimuli (p= .577 for pre- vs. post-tests).

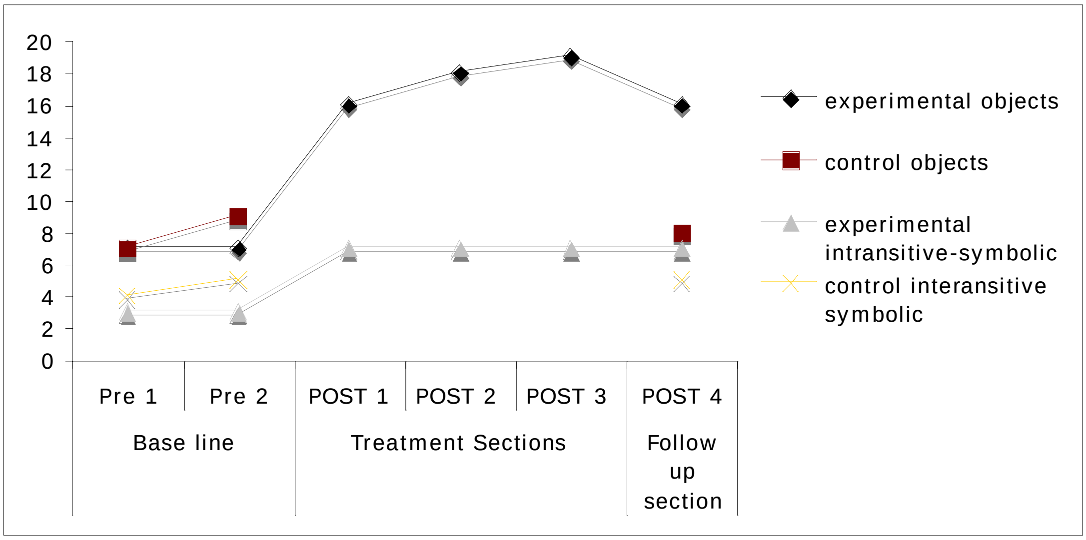

Figure 10: Comparing all tasks across different sections

6.4.2 Neuropsychological tests

The results of other cognitive tests are presented in Table 12.

Table 12: Scores for control cognitive tests

Control Cognitive Tests	*Pre*	*Post*	*Follow-up*
Object naming	66/91	75/91	71/91
Object recognition	13/23	15/23	16/23
Rule Shift Cards	9/20	11/20	11/20
BRIXTON	38/55	39/55	32/55

Comparing pre and post data of control cognitive tests indicate that there is no improvement over time in the neuropsychological tests. A McNemar test was used to compare the difference between pre and post in object naming task and the difference was considered to be not quite statistically significant (two-tailed P value = 0.073). In addition, comparing the data in the Chi square tests showed that there were no improvement in object recognition (χ^2 (1) = 1.84, p = .174), rule shift cards (χ^2 (1) = 0.808, p = .368), and BRIXTON test (χ^2 (1) = 2.68, p = 0.1).

6.5 Discussion

The results showed that DS improved at making transitive gestures for the objects he was trained on, but there was no improvement at making transitive gestures in general (e.g., for control stimuli) and no improvement at making intransitive, symbolic gestures. There was also no indication of any generalised improvement over time, in other neuropsychological tests unrelated to the training. The data suggest that there is a specific training effect, which can be maintained over the longer-term, but which is specific to the items trained.

These data match some prior results, which have again shown poor generalisation of gesture training in apraxia (e.g., Ochipa et al., 1991; Pilgrim & Humphreys, 1994), but they differ from other reports that some generalisation has been noted (Maher et al., 1991; Smania et al., 2000). What are the critical factors that may predict whether generalisation across items does and does not take place? In studies where there is a lack of generalisation, treatment has been targeted at patients with ideomotor apraxia (e.g., Ochipa et al., 1991; Pilgrim & Humphreys, 1994). This is less clearly the case in papers where generalisation has been shown (Maher et al., 1991; Smania et al., 2000), where patients have shown evidence of ideational as well as ideomotor deficits (Smania et al., 2000). In the present study DS showed better comprehension of transitive gestures to objects than intransitive, symbolic gestures; there was learning only of transitive gestures but this did not generalise. These data suggest that DS's learning here operated at a level of motor planning and/or articulation, and that, after training, he was better able to instantiate motor programmes for trained items. It appears that these motor programmes failed to generalise, however. This fits with the view that the programmes were represented not in terms of their specific component movements but rather in terms of an integrated movement pattern, which held for the treated items but then did not generalise. Recently, Graziano (2006) has presented evidence from single cell recordings for motor programmes based on whole movement patterns, while components movements making up the whole patterns were not represented independently. Our data are consistent with training helping to build-up specific, whole movement representations, but these then fail to generalise to new stimuli. It is possible that similar effects held for other training studies with patients with ideomotor deficits (Ochipa et al., 1991; Pilgrim & Humphreys, 1994).

Our training regime had little impact on stimuli for which DS had impaired comprehension (instransitive symbolic gestures, some transitive gestures). This might be because the training did not emphasise conceptual information about the stimuli and it did not distinguish between the trained stimuli and other, conceptually similar stimuli. We speculate that, in other cases where generalisation has been shown, then (i) training has targeted conceptual as well as motor programming operations, and (ii) the effect of this training is either to help distinguish the conceptual representation of one stimulus from that of another or to build up the concept of the motor action in a patient. If this conceptual representation is based on distributed coding, then it may support generalisation to other items (e.g., from one tool to another).

A final point to note is that the improved gesturing to stimuli was very unlikely to be due to generalised spontaneous recovery. For example, there was no improvement for intransitive, symbolic gestures, and in addition there was no evidence of spontaneous improvement in the other (non-action related) cognitive tests. This again points to there being a specific training effect, confined to the re-learning of whole-movement representations of gestures to objects.

CHAPTER 7

Eye movements in action disorganisation syndrome: A single case analysis

Abstract

This study examines eye movements made by a patient with action disorganisation syndrome (ADS) as everyday tasks are performed. Relative to both normal participants and control patients, the ADS patient showed normal time-locking of attention to the subsequent use of objects. However, there were proportionately more unrelated fixations and more fixations concerned with locating objects than found in the control participants. In addition, eye movements away from objects being used were made earlier in the ADS patient, and toying errors were linked to multiple, brief fixations being made to the object involved. The data highlight that eye movement analyses can be used to study the deficits contributing to ADS, with in this case, the changes in eye movements being linked to impaired top-down guidance of task performance and to action being disconnected from error monitoring operations.

7.1 Introduction

There is a long history of attempts to use eye movements to infer cognitive processes (Hayhoe, 2004). The behaviour of the oculomotor system has been studied across a range of tasks including reading text (O'Regan 1990; Rayner 1995), music reading (Land and Furneaux 1997), and steering a car (Land and Lee 1994). In many cases the results indicate that the eyes sample regions of field that maximise the useful input for the task. Studies of eye movements performed while people undertake repetitive tasks (such as copying a block pattern; Ballard et al. 1992; Hayhoe et al. 1998) have further suggested that eye movements can be quite tightly coupled to the motor actions of the participant. Of particular relevance to the current study, Land et al. (1999) examined the patterns of fixation during the performance of a well-learned everyday task (making a cup of tea), classifying the eye movements taking place in relation to task performance. Land et al. found that objects were fixated because of their relevance to ongoing related acts (ORA; Land et al., 1999) or 'A1 units of action' (Schwartz et al., 1991, 1995), not because the objects were big, bright, or distinctive in other ways. As a consequence they concluded that eye movements during familiar purposeful actions were driven by principally the memory or 'script' for the activity, not simply because of its 'visual salience'.

In order to accomplish many everyday tasks successfully we must recognize the objects involved, recall the component actions and their sequence, and, as the component actions are being carried out, we must maintain a record of our current position and not repeat steps already completed. One initial operation involves retrieving a stored memory for the tasks that details both the component behaviors and their sequence, described as 'schema' for particular tasks (Grafman, 1989). In addition, Land et al. (1999) suggested that even automated routine activities require a surprising level of continuous monitoring, revealed by fixations typically falling close to the objects being manipulated and very few fixations being irrelevant to the task. Land et al. conclude that, although the actions in a familiar task such as making tea are ‘automated’ (Norman and Shallice, 1986), and may proceed with little conscious involvement the eyes closely monitor each step in the process.

Land and Hayhoe (2001) examined the relations between eye and hand movements in extended food preparation tasks, tea-making and making peanut butter and jelly sandwiches. They found that participants typically gazed at the next object in the sequence before any sign of manipulative action, indicating that eye movements play a part in the planning of actions to objects. Land and Hayhoe also reported that the eyes usually fixated the same object throughout the action that was performed upon it, although saccades could be made to the next object in the sequence before completion of the preceding action. Thus there may be a process in which a fixation on an object is made to provide high resolution information to guide a hand action, and this remains as the hand action is programmed, but after this, the eyes may move on to the next most relevant object for the task. Eye movements are thus in the vanguard of each action plan, and are not simply responses to environmental circumstances (see also Land, Mennie and Rusted 1999; Land, Furneaux and Gilchrist 2002). In addition to this, regressive eye movements can occur, suggesting a re-checking process taking place on some occasions.

The role that eye movements may play in the behaviour of patients with acquired problems in everyday action has been relatively little studied. Forde et al. (sub.) examined eye movements in a patient with the neuropsychological syndrome of ‘action disorganisation syndrome’ (ADS), whose ability to carry out everyday tasks was highly disturbed (patient FK). Prior evidence has suggested that FK has impaired stored knowledge about everyday tasks (Forde & Humphreys, 1998). Interestingly, many aspects of FK's eye movements were relatively normal (e.g., the timing relations between his fixations on objects and his use of the objects), though some abnormalities were observed. For example, unlike normal participants, FK made no advance glances to objects that were about to be used, and he made increased numbers of fixations to irrelevant objects during the task. Both results are consistent with FK lacking stored knowledge about the tasks. There were also differences in the eye movements made when correct actions were performed and eye movements when perseverative actions occurred. During perseverations FK made proportionately fewer fixations to other objects in the environment and relatively more (but briefer) to the object being used (compared with when the action was correct). On these occasions FK seemed to be monitoring the action through the eye movement, but without linking any incoming information back to the goals of his behaviour (e.g., to detect the error). The data suggest that there may be relatively preserved 'local coupling' between eye movements and behaviour in a patient with apparent loss of the overall schema for the task, but that the patterns of eye movements can still be revealing of the underlying disturbance in such patients.

The present study extended previous work by examining the relations between eye movements and everyday action in another patient who presented with ADS – BL. As described below, BL made many of the errors characteristics of patients with ADS including omissions, sequence errors, and quality/spatial errors (see Schwarz, 2006, for an overview of errors in ADS). She was also particularly affected when distractor objects were present during task performance (even when the distractors were unrelated to the task), and semantic errors also emerged in this condition. Neuropsychological testing indicated that BL had a central disturbance in her semantic knowledge about objects, along with also impaired knowledge of the ordering of steps in everyday life tasks. Given this, it was of interest to assess whether her eye movements would provide evidence of increased distractibility, due to not having top-down knowledge to guide eye movements to objects linked to up-coming actions.

7.2 Background data

The clinical case. BL was 80 years old when she was tested. She was formerly a General Practitioner who suffered a stroke in 1998, affecting her left occipito-temporal cortex. Subsequent to this she presented with a number of neuropsychological deficits including alexia (18/26 on identifying single letters; 0 reading of 20 HF concrete, short words), and object recognition. Her scores on standardized tests of object recognition are shown in Table 6. There was evidence of relatively preserved perceptual processing from both vision and touch, along with impaired access to semantic knowledge. On other neuropsychological tests BL had some problems with executive function tasks, having an error score of 21 on the Brixton test of non-verbal executive function (finding a rule and rule shifting; a score of 26 indicates a clinical impairments; Burgess & Shallice, 1997). She had a Corsi block span of 3 and a digit span of 4 (forwards).

7.4 Defining ADS

BL's performance on everyday life tasks was examined in 4 tasks requiring her to: (i) make a cup of tea with milk and sugar; (ii) make a cheese sandwich; (iii) wrap a gift, and (iv) write a birthday card and prepare it for the post. BL's success on these tasks was compared with that of 4 brain-lesioned 'control' patients (two with unilateral frontal lesions (1 left, 1 right) and two with lesions of the temporo-parietal junction (1 left, 1 right). BL performed the tasks twice, once when there were no distractors present in the task, and once with unrelated distractors present. The control patients only performed the tasks when unrelated distractors were present. Performance was videotaped for later analysis. The videos were transcribed to record every action made by each patient. The action coding system (ACS) developed by Schwartz et al. (1991) was used to provide quantitative and qualitative measures of each subject's performance. Each patient's errors were classified into a number of different categories including:

- Omission: When a patient omitted one of the steps to accomplish the task.
- Semantic: When a semantically related object was used in place of the target object.
- Sequence: When an action was performed in a wrong order (according to norms collected in previous studies for these tasks, (e.g. see Humphreys & Forde, 1998).
- Addition: When the patient added an action that was outside the range of actions produced by normal group participants.
- Quality/ Spatial: When the patient misjudged the appropriate amount of something or the spatial orientation of the objects.
- Perseveration: When an action or action sequence was repeated after achieving its goal.
- Toying/ Capture: Reaching towards or lifting an object without actually using that for any purpose.

BL made 14 errors when carrying out the basic versions of the tasks (no distractors) and 23 when unrelated distractors were present. For comparison, the ADS patient FK (Humphreys & Forde, 1998) made 15 and 21 errors under matching conditions. The 4 control patients made an average of 4.75 errors (SD 1.25). Thus the numbers of errors made by BL in the basic version of the tasks were 6 times greater than the standard deviation added to the mean of the control patients (in the distractor condition) and her performance when unrelated distractors were present was over 14 times greater than the standard deviation added to the mean. BL was clearly worse than the control patients. She made a relatively large proportion of step omissions (33% of her errors) but in addition made quality/spatial errors (23 toying errors (14%) and added inappropriate actions such as writing address on the gift (12% of all her errors).

These results provide confirmation that BL presented with a pattern of ADS, which may be exacerbated by having a central semantic impairment for objects. (See chapter 1 for more definition of ADS). To assess BL's knowledge of everyday tasks, she was given sequences of photographs indicating key steps in 4 tasks (tea, gift, sandwich, writing a letter) and asked to sort them into an appropriate order for the tasks. She failed to order the steps correctly for any task and made only 15 correct local orderings of consecutive steps out of the 27 correct steps possible. This suggests either that BL has fragmentary stored knowledge about the order of the steps in everyday tasks or she had difficulty sorting the actions due to her problems in object recognition. To try and circumvent the recognition problem, the action in each photograph was read out to BL and, having gone through twice each action within each task, she was asked to put them in the right order for the task. She was told to ask if she was unsure of what the action was. Even under this circumstance BL made only 17 correct local orderings. The control patients generated a mean correct ordering of 25/27 with a standard deviation of 1.63. BL’s score fell more than 3 standard deviations below the mean of the controls. This last finding is consistent with BL having problems in reconstructing the correct order of the steps in everyday tasks, over and above any problem in visual recognition.

7.5 The current study

BL’s eye movements and hand actions were recorded when she carried out two familiar everyday life tasks: making a cup of tea (with milk and sugar) and making a cheese sandwich. Her performance was compared with that of two normal age-matched control participants and with two control patients, DS and JF, both of whom were matched to BL in terms of general executive function (Brixton test scores of 20 and 24, for patients DS and JF). DS was also used as a control patient in the analysis of everyday action reported by Humphreys and Forde (1998). Eye movements were scored following the procedures used by Land et al. (1999). Land et al. classified patterns of fixation into four categories including: *locating* (looking at objects that would subsequently be used in the task in order to establish the location of objects, even though there is no associated motor activity at the time of the fixation); *directing* (fixation on the hand or object in the hand during moving to new location); *guiding* (fixation in approaching one object to another that two or more objects have to be guided relative to each other); and *checking* (looking at objects to check the appropriate state). Hayhoe (2000) found that the same analysis fitted equally well in making a peanut butter and jelly sandwich task.

7.6 Method

One experimental patient, BL, two control patients (DS and JF), and two normal participants (Female, aged 65 and 52), were studied in two simple everyday tasks; making a cup of tea with milk and sugar and making a cheese sandwich and putting it in a sandwich bag. The two control patients were DS (Male, aged 73) and JF (Male, aged 68). DS had lesions of left inferior, middle and superior frontal gyrus and major clinical symptoms of right hemiplegia and aphasia. JF presented with progressive aphasia and cortical atrophy primarily confined to posterior parietal cortex. None of control patients had a major disorder in actions of daily living. DS had a Corsi block span of 3 and a forwards digit span of 4 (matched to BL). JF had a Corsi block span of 4 and a forwards digit span of 4 too.

The direction of fixation was recorded using a head-mounted video camera system (see also Forti et al. 2005). This is a non-intrusive device that allows normal head and body movement during tracking, and was used to monitor the eye movement of subjects. Eye movements were measured from the right eye using a SensoMotoric Instrument (GmbH) HED corneal reflection based eye tracker. This system consists of a head-mounted device with a scene camera that captures the participant's field of view and an eye camera that records an image of the eye. After calibration the system produces a video image of the scene with a superimposed cursor that represents the position that the participant is fixating. Because the relationship between the scene camera and eye camera is fixated, the participant is free to move their head. The video output was digitized at 25 frames/s for subsequent offline frame-by-frame analysis using a software based DVD player. Gaze direction was determined to an accuracy of approximately 1°. The subjects were precisely calibrated at the beginning of each recording session by asking participant to fixate each of five markers placed on the table surface (at the centre and towards the four corners). Each subject wore the eye tracker and was placed individually in front of a table and asked to perform a particular task. All the objects for the task were located on the table (7 objects for the tea task; 5 objects for the sandwich task) BL was instructed to use all of the objects present before her action. Actions were monitored also from an external viewpoint for further analyses.

7.7 Results

7.7.1 Execution of the task

Based on the action coding system (ACS) (see Schwartz et al. 1991 for more information), BL made 3 errors when making a cup of tea: one Omission error (she did not boil the water), one Sequence error (she failed to put the teabag in the teapot but put it in cup), and one Spatial error (pouring sugar outside instead of inside the cup). BL performed the sandwich task with 2 errors: one Toying error (took the sandwich bag and put it back without using) and one Omission (she made the sandwich with one slice of bread instead of two). The control patients and normal participants completed the task without error.

7.7.2 Number of fixation and relatedness

Despite the fact that BL omitted the longest sequence of action in Tea task (boiling water), she completed the task in 2 min 24 s, which was similar to DS (2 min 5 s), JF (2 min 21 s), and the control participants (1min 50 s). The overall time to complete the sandwich task was 3 min 40 s for BL, 1 min 57s for JF, 3 min 28 s for DS, and 1 min 18s for normal controls. DS's speed of action was hampered by his hemiplegia, which was not the case for any of the other participants.

Overall BL took a mean of 182 sec to complete the tasks while the normal controls took 94 sec and the patient controls took 137.75 sec. BL made 211 eye movements, with the average duration of fixation being 143 ms. The normal control participants made a mean of 78.5 fixations which on average lasted 115 ms each. The control patients made 87 fixations lasting on average 125 ms.

We analysed the ratio of number of fixations to time on task, comparing BL to the 4 controls in order to test if she made abnormally large or small numbers of fixations, given the length of time she took on the task. The comparison showed that BL made significantly more fixations during the task relative to the time taken; $t(3) = 5.08$, $p < .05$ .The ratio of the number of fixations to the time on task did not differ between the two types of controls; $p=0.25$. Although BL showed increased numbers of fixations, the durations of the fixations did not differ from those of the controls ($p>.14$).

We assessed BL's eye movements in relation to her errors. For the Sequence error in the tea task, BL made two fixations on the teabag before starting to pour water into teapot (without putting the teabag in the pot). In the Sandwich task BL made one toying error with the sandwich bag. In this case she made 7 fixations on the bag (average duration 407 ms) prior to the toying error occurring – these precursor eye movements occurred while BL spread cheese on one slice of bread and cut it in half. Subsequently she wrongly touched the sandwich bag and omitted using a second slice of bread to make the sandwich. The errors here seemed to reflect BL's attention being attracted to the sandwich bag, so that she came back to re-fixate the bag even after looking away from it. We compared the time of unrelated fixations on the sandwich bag prior to her toying with the other fixations made in the sandwich task. This showed that BL's fixations on the sandwich bag were shorter than her other fixations in the task (mean =1769 ms; $p = .026$).

7.7.3 Task-based and predictive eye movements

We assessed whether BL's eye movements were linked to the ongoing action, and whether she made eye movements that were predictive of the next upcoming action (see Figure 11). BL made 108 fixations during the tea task, 90 of which were related to either the task at hand or to the next sequence of action; 18 were unrelated to ongoing or future actions. DS made 110 fixations (107 related and 3 unrelated) and JF made 112 fixations (105 related and 7 unrelated to action). Normal controls on average made 114 fixations in the tea task and there were only 2 fixations made by one control that were unrelated to the ongoing action. In the sandwich task BL fixated 103 times (85 fixations related to ongoing or immediately following actions, and 18 unrelated fixations). DS made 74 fixations with only 5 unrelated fixations, and JF made 51 task-related fixations and 1 unrelated fixation. The normal controls made on average 43 fixations during the sandwich task and there was just one task-unrelated fixation. The number of fixations that were related to ongoing or immediately up-coming actions, or that were unrelated to ongoing actions, are presented in Figure 11.

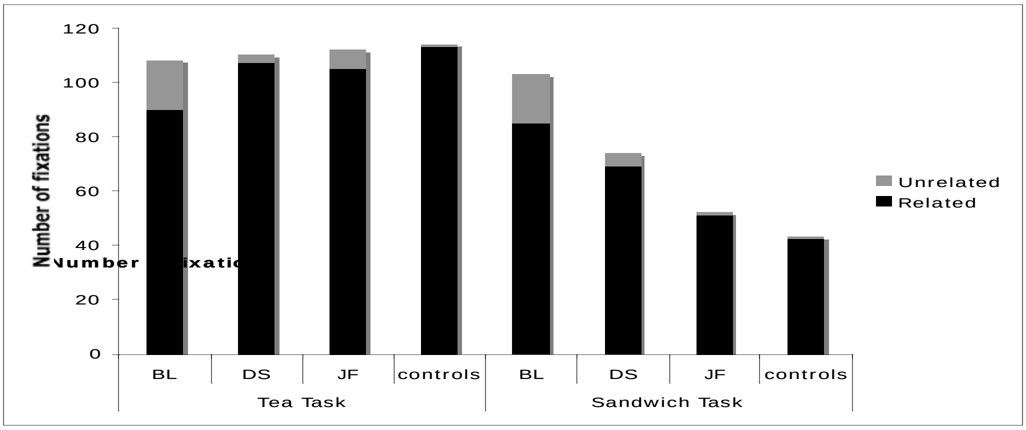

Figure 11: Frequency of related and unrelated fixation to the next step of the tasks

The number of relevant compared to irrelevant fixations made by BL and the control patients were assessed in a chi square test (using the mean data across each set of controls). BL made proportionately more unrelated fixations than the patient controls, both for the tea task (χ^2 (2)=14.7, p= .001) and the sandwich task (χ^2 (2)= 10.5, p= .005). Similarly she made proportionately more unrelated fixations compared to the normal participants; tea task: χ^2 (2) = 24.9, p< .0001; sandwich task: χ^2 (2) = 13.7, p < .0001. There were no differences between control patients and normal controls (tea task, p= .187, and sandwich task, p= .063).

As an example of unrelated fixations to the next sequence of action, in the sequence of adding milk to a cup of tea BL fixated on the kettle, teabag, spoon, milk, sugar, milk, and milk top prior to move her hand to reach the milk. During the same step in the task, all control participants fixated directly on milk. This suggests that the controls were better able to plan ahead their actions than BL.

Careful inspection of irrelevant fixations shows that BL often performed some unrelated fixations between two sequences of the task, when she finished a sequence and went through to the next step. Fifteen out of 36 unrelated fixations occurred at these junctions. It seems that BL either was thinking about the next step trying to identify objects that would be appropriate or she looked to find the relation between objects to remind the role of an object in the task to retrieve the next step. Given the evidence for BL having impaired knowledge about the order of steps in everyday tasks (Background tests), we propose that the latter strategy was the more likely.

7.7.4 Type of fixation

We classified the type of fixations into the categories, Locating, Directing, Guiding, and Checking according to Land et al.'s criteria (1999) for categorising the functions of different fixations. Table 13 shows the percentage of each type of fixations, relative to all the fixations made, for each participant in the specific task. Some of fixations could not be classified into any of the main fixation types; there were listed as "other" fixations that presented no obvious function.

Table 13: Percentage of the number of each type of fixation

	Fixation type	Locating	Directing	Guiding	Checking	Other
BL	Tea	39	24	14	9	15
	Sandwich	19	45	7	5	24
DS	Tea	28	38	12	9	13
	Sandwich	15	51	17	9	7
JF	Tea	23	46	13	8	10
	Sandwich	17	52	19	10	2
Normal controls	Tea	22	49	10	11	8 4

We analysed the proportions of the number of each type of fixation for BL and each control group, relative to the total numbers of fixations made, averaging across the two tasks and averaging performance across the two controls in each group. BL tended to make higher proportions of locating fixations, relative to the total fixations, compared to the control patients (χ^2 (1) = 5.48, $p < 0.05$) and to normal control participants (χ^2 (1) = 8.13, $p = 0.004$). These increased proportions of locating fixations suggest that BL had difficulty maintaining information about the locations of objects during the task, and so needed to make relative high numbers of fixations where objects appeared to be re-located. Alternatively BL's maintenance of semantic representations may have been poor, with semantic information decaying rapidly. Morady and Humphreys (2009b) reported that BL showed inconsistent recognition of objects across trials which is consistent with her having refractory semantic knowledge (Warrington & McCarthy, 1983, 1987), where semantic representations may fail to maintain an excitatory state after being activated. Due to this, BL may need to make re-locating fixations more than is normally the case. Similarly analysis for "other" type of fixation shows that BL significantly performed more "other" fixations than control patients (χ^2 (1) =16.9, $p< .0001$) and normal controls (χ^2 (1) =

16.3, p< .0001). The patient and control groups did not differ on any of the fixation types.

7.7.5 The timing of fixations to object-related actions (ORAs)

Figure 12 gives the overall pattern of ORAs for the two tasks, for BL and the controls. The pattern for the control patients DS and JF, as well as for the normal control participants, is very similar to that described in Land et al. (1999). Land et al. noted that actions are typically preceded about 0.5s earlier by an eye movement and, at the end of each ORA, the gaze typically moves on to the next object between 0 and 1s before the motor act has been completed. BL, similarly to the controls, made a saccade to an object on average 0.48s before acting upon. The time between the saccade and the first signs of a movement to contact the objects did not differ between BL and the control patients (F<1, treating each ORA as an independent observation). In contrast, BL's eye movements to the next object in a sequence were made earlier than the controls; BL left the object 1.64s (± 1.04s) before completing an action, compared with 0.67s (± 0.08s) before the action in control patients, and 0.53 (± 0.08) in normal controls. The two control groups did not show any differences in the time when fixations left a target object (F<1). When compared with the combined data across the control groups, BL reliably made saccades to the next object earlier than the controls ($F(1, 19) = 7.92$, $p < 0.05$).

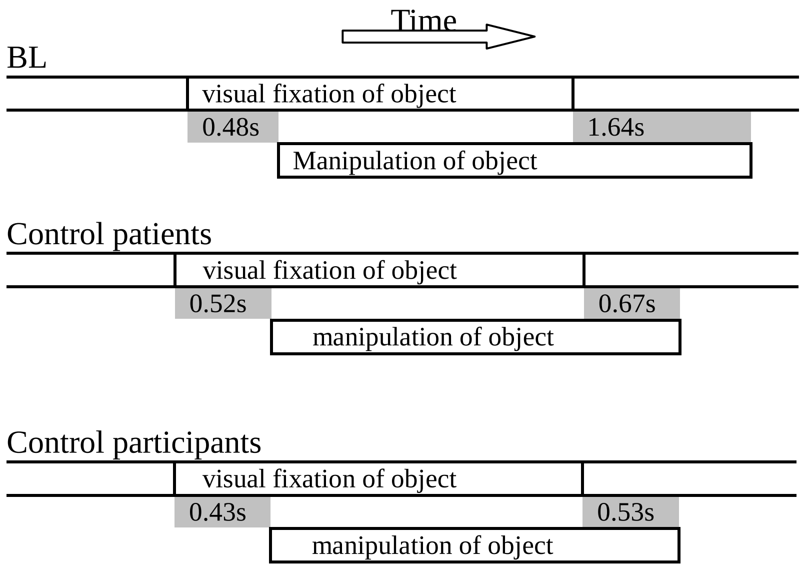

Figure 12: Illustration of the average timing of gaze movement to objects prior to action and movements of gaze off the objects prior to completion of the action for BL and the controls (patients and normals)

7.8 Discussion

The analysis of eye movements made by the ADS patient –BL– during everyday tasks showed patterns of behaviour that matched and that departed from the behaviours found in both normal control participants and non-ADS patients. Like control participants, BL made eye movements to objects prior to using them (ORAs), and the timing of these fixations did not differ from controls. BL also made proportionately similar numbers of directing, guiding and checking eye movements (following the terminology of Land et al., 1999). However, she made proportionately more ‘locating’ eye movements, more of her eye movements were unrelated to ongoing or immediately upcoming actions, and her eyes tended to move off from objects at an earlier time than normal, relative to when the action was completed. In addition to this, on the small number of trials where BL made toying errors she made multiple fixations to the object being ‘toyed with’, with her eyes sometimes returning to the object even after a saccade had been made to another stimulus.

These eye movements are informative about the underlying problems BL has in performing everyday life tasks. The eye movements that were unrelated to the ongoing or immediately upcoming task can be linked to BL scanning the objects in order to invoke the next action step for the task. The screening of BL indicated that she has impaired knowledge about the order of steps in everyday life tasks, which may result in task performance becoming driven more strongly than normal by bottom-up information. We propose that the unrelated eye movements, across the different objects present, reflect attempts to activate task schema in a bottom-up fashion.

On top of this, BL appeared to have problems in maintaining information about the locations of objects, so she makes increased proportions of ‘locating’ eye movements (where she looked at objects that would subsequently be used in the task in order to establish the location of objects without associated motor activity at the time of the fixation). We link these locating eye movements to BL either losing location information about the objects or to any semantic representations of the objects decaying, which leads to confusions in memory about where different objects are. BL had a reduced Corsi block span compared with normal (5), so it is possible that she would lose representations of the locations of the objects during task performance. On the other hand, her Corsi block span did not differ from that of the control patient DS, so it is not clear that loss of location information per se would be critical. Prior work with BL has indicated that she has inconsistent access to semantic information (Morady & Humphreys, 2009b, Chapter 5 here), which may reflect semantic representations entering a refractory state (Warrington & McCarthy, 1983, 1987). If this is the case, then the semantic representations of objects may be inaccessible after initially being activated, causing her to mislocate a target object amongst other objects related to a common task. The ‘locating’ fixations may reflect an attempt to overcome this problem.

The eye movements BL made before using an object were time-locked to the action in a quite normal way (when ORAs occurred). This is interesting in that it suggests a local-driven relationship between visual attention and action – with an action being triggered to an object following an immediately preceding fixation. This local relationship appears to be spared, despite BL’s problems with stored knowledge about the higher-order structure of the tasks. However, although the initiation of actions to objects were tied to eye movements in a relatively normal way, BL made earlier eye movements away from the objects than the control participants. This may be linked to an error-monitoring process. It may be that, in normal participants, the eyes linger sufficiently on an object that is being used in order to ensure that the action is being correctly executed. In BL this monitoring process may be deficient, so that actions are not then held upon the objects being used. It is possible that this ‘holding’ of attention may be triggered in a top-down manner, perhaps by brain regions involved in error monitoring such as the anterior cingulate cortex (Blasi et al., 2006; Carter et al., 1998). In BL the occipito-temporal lesion may disconnect earlier regions from this top-down input, disrupting the monitoring process.

Additional evidence for impaired monitoring comes through the analysis of eye movements when toying responses were made. Toying responses were linked to BL making multiple, short fixations on objects. We suggest that these errors arise on occasions when a given object attracts attention (perhaps due to its position in the field or other bottom-up factors). The re-occurrence of the fixations, and the toying actions, indicates in turn that the actions (and eye movements) are disconnected from error monitoring processes on such occasions. These proposals match the data reported by Forde et al. (2009) in their analysis of patient FK's eye movements when perseveration errors occurred, with multiple, brief eye movements again occurring. We speculate that these fleeting re-fixations reflect bottom-up driving of attention to a particular object in the absence of top-down monitoring of action. It will be interesting if future research confirms that such fixation patterns are characteristic of task-disconnected errors in such patients.

Summary

In sum, the present results indicate that eye movement patterns in ADS patients can be revealing about the nature of the underlying problems patients' experience. There can be changes in both task-driven guidance of eye movements (e.g., in unrelated and locating fixations) and in the control of fixations through error monitoring, and in the latter case, poor task-control leads to overly-strong bottom up cueing of saccades.

CHAPTER 8

8.1 Conclusion

Over the past two decades or so there has been an increasing volume of research investigating the generation and control of actions in naturalistic, everyday tasks, such as making a cup of tea. Despite such activities being routine, there are numerous different process involved– from recognising the objects, to retrieving the task schema and ordering the sequence of steps of each task. This thesis has spanned the cognitive demands of simple everyday action and the influence of aspects of everyday action (such as using objects) on the process of both recognizing objects and performing actions.

The first empirical chapter sought to assess the influence of increasing and decreasing the cognitive resources needed for successful action in a patient with apparent action disorganization syndrome, FK. Performance was assessed in the context of when the tasks were performed with related or unrelated distractors present amongst the objects required for the task. The number of errors made overall by FK increased in the related condition compared with the basic condition, when there were no distractors present. Performance when there were unrelated distractors present fell in-between. Moreover, FK made relatively more step omissions when related distractors were present. A subsequent comparison was made between FK's data and those of controls in a dual-task load condition (Experiment 2 of Chapter 2). While the increasing the cognitive demands of the tasks influence overall numbers of errors in the controls, there were no relative increases in omission errors. This points to a difference between the ADS patient and controls performing under load conditions, with omission errors particular to the patient. To account for these data I suggested that the patient, FK, had relatively greater difficulty than controls in selecting the appropriate object to use when related distractors were present. This selective increase in demand led to FK making more omission errors. In contrast, the dual task might introduce more noise for the controls, but this is not selective to when related objects are present. The net result was a selective increase in omissions for FK. The chapter illustrates that ADS patients may suffer from particular demands on particular processes (the selection of target objects), not found in control participants even under load conditions.

The role of task schema in ADS was examined in Chapter 3. The chapter examined whether ADS patients have at least partial knowledge of task schema by having the patients instruct another person how to perform everyday tasks. The patients were better able to instruct the examiner to do the task compared to when they did the tasks themselves. This shows that patients can retrieve appropriate task schema when they are not involved in doing the task. The demands due to retrieving task schema as tasks are performed, and the demands due to having to monitor errors while the tasks are performed, was subsequently tested. The requirement to retrieve task schema was reduced by giving verbal cues for the task steps in one part, while the demands on error monitoring were reduced by both instructing the actions and giving the patients feedback when errors occurred. These conditions improved the patients' performance, suggesting that the demand on retrieving schema while the task is performed and the demands on error monitoring, can both generate errors. In addition, errors when instructions were given reduced when the instructions were drawn randomly from tasks rather than the actions being performed in a consecutive order. This indicates that, under conditions of the correct order, there may be failures to inhibit activated actions along also with increased activation of upcoming actions. A failure to inhibit, along with the extra competition from activated upcoming actions, can lead to patients making increased action errors.

Two of the basic requirements of carrying out everyday tasks are to recognize the objects present and to enact the action correctly. The interactions between perception and action were examined in Chapters 4 and 5. Chapter 4 analysed one common finding in the literature on disorders of action (apraxia) – that patients can typically use objects more accurately than they can pantomime them. Chapter 4 focused on two patients, FK and BL, both of whom had problems in object recognition in addition to any problems in making single actions to objects. The 'use advantage' was demonstrated both for objects the patients could recognize and for objects that they were impaired at recognizing. The data are consistent with object use being cued by direct sensory inputs to action knowledge, by-passing impaired semantics in the patients. This fits with a dual-route account of action retrieval, in which convergent sensory and perceptual inputs combine with semantic inputs to ensure the correct action is selected (Chainay & Humphreys, 2002; Riddoch et al., 1989; Yoon et al., 2002).

Chapter 5 examined the converse case, which is where object recognition appeared to be affected by object use. In this instance, the ADS patients were better able to name objects after they had used them, compared with they simply saw, touched or touched and saw the objects (but did not use them). To account for these data, I argued that the patients used the objects directly, without accessing semantic knowledge, and then accessed semantic knowledge on the basis of the action being performed. Object identification can benefit from object use.

Apraxia is a cognitive impairment following stroke that can have major impact on independence in activities of daily living. As mentioned in Chapter 1, studies of rehabilitation of apraxia have focused on re-training gesture production (e.g. Maher, Rothi, and Greenwald, 1991). The previous researches suggest that patients are able to re-acquire gestures and re-learn how to perform a task. In Chapter 6 of this thesis, I sought to see the influence of re-learning transitive and intransitive gestures in a patient with both aphasia and apraxia (DS). The treatment consisted of presenting DS with multiple cues to using a given tool (a picture, a real object, a visual model, copying and feedback) and asking him to demonstrate the use of the target. The results showed an improvement at making transitive gestures for the trained objects. However, there was no generalization of training in apraxia which fits with prior studies on rehabilitation of apraxia (e.g. Ochipa et al., 1991). These data suggest that practised actions may be represented by a whole motor programme not easily broken down into constituent parts, and so practising this action does not easily generalize to other actions.

In Chapter 7, eye movements were measured while a patient with ADS carried out everyday tasks. Eye movement patterns in the ADS patient matched in some respects, but departed in others, from those found in both normal control participants and non-ADS patients. However, the ADS patient made proportionately more "locating" eye movements (following the terminology of Land et al., 1999), and proportionately more of their eye movements were unrelated to ongoing or immediately upcoming actions. The results showed that there can be changes in both task-driven guidance of eye movements and in the control of fixations through error monitoring; for example, ‘locating’ fixations in the ADS patient occurred more frequently than in the controls, while there were more fixations that were unrelated to the ongoing task. Such ‘unrelated’ fixation may arise due to poor top-down activation of schema, resulting in a lack of top-down guidance to the appropriate objects for action.

Taken together the results conform to the view that action retrieval is influenced by inputs from multi-modal systems which converge to determine action selection, that action information can be derived rapidly and influences both object processing and the allocation of attention, and that action information can break down at different levels, giving rise to different problems in performing everyday tasks.

8.2 Relevance to theories

(i) Direct routes to action

The results presented in Chapters 4 and 5, dealing with the relations between perception and action, fit with ‘dual route’ accounts of action retrieval. Traditional models of action retrieval suppose that this is mediated by access to semantic knowledge about the objects, when they are usually encountered and what they co-occur with (Roy & Square, 1985). However, I showed that there was an advantage for using objects, compared to when actions were pantomimed, even for objects that could not be recognised. In such cases the ‘use advantage’ does not come through semantic knowledge, but rather through direct perceptual activation of the action schema. I also showed that objects could be named more accurately after a patient had used them, compared with when equivalent perceptual input was present but the objects were not used. To account for this I proposed that the directly activated actions were identified, and from this the patients identified the objects.

(ii) Interactions of attention and stored action knowledge

The data reported in the thesis also point to the importance of attentional interactions with stored knowledge when patients carry out everyday life tasks. In Chapter 2 evidence was presented that a patient with ADS, FK, faced particular difficulty in selecting target objects from related distractors, and the increased demands on selection led to FK making more omissions than was the case for control participants. Here the demands on visual selection seemed to reduce the resources for other aspects of task performance, such as error monitoring.

In Chapter 3 two ADS patients were shown to have reasonably intact spared schema for tasks, since they were often able to instruct controls to carry out the tasks. Despite this, the demands of having to retrieve the task schema, while carrying out the tasks themselves, induced errors in the patients. The patients also made more errors when instructed to carry out actions in the standard sequence for a task, compared with when the instructions were drawn at random from different tasks. To account for this I proposed that actions coming from a single task activate upcoming actions more strongly than randomly sampled actions, and there are also increased demands on inhibiting actions that have been performed. The net result is that instructions following the course of a task can disrupt performance.

The most explicit account of the relations between task schema and attention is provided by the SAS-CSS model proposed by Norman and Shallice (1986). The first part of their model, the Contention Scheduling System (CSS), was designed to explain how we might execute routine tasks. The CSS contains hierarchically-organized schema for action which are activated by stimuli in the environment. They suggested that we store schemas for routine tasks and, when a triggering stimulus activates a schema above its threshold, that schema would remain active until the goal is attained or the schema is actively inhibited by competing schemas. Thus, CSS regulates activation so that the correct actions are made in the correct order. They proposed a second system, the Supervisory Attentional System (SAS) concerned with non-routine, intentional or willed action that would require higher order cognitive control. The SAS would be required monitor for errors, while the CSS would operate the running of routine behaviours. The data reported in Chapter 3, that errors decreased in ADS patients when the need to monitor for errors decreased, is consistent with these patients having a problem in the SAS, and with this problem being by-passed under the appropriate presentation conditions (e.g., giving task instructions with feedback). However, the fact that errors decreased further when actions are not performed in the set order for the task suggests that there are attentional demands within the running of the routine behaviour itself that the CSS is not immune from. For example, activation from previously performed actions, or from upcoming actions, may need to be resolved when actions are carried out in the standard consecutive order. The data presented here indicate that ADS patients can have problems in over-ruling such activations, and consequently make errors under the consecutive action conditions. This in turn indicates either that they have problem in recruiting attentional resources to modulate the CSS or that there are impairments within the CSS that disrupt the normal ‘automatic’ processes that resolves competition between representations. The fact that normal participants do make errors in everyday tasks when under dual task load, however, suggests that the CSS is sensitive to attentional modulation. The attentional modulation of the CSS may be something that is impaired in ADS.

(iii) The nature of action representations

Chapter 6 presented data on the retraining of ideomotor apraxia. As in prior studies on this topic (Maher, Rothi and Greenwald, 1991; Pilgrim and Humphreys, 1994; Ochipa et al., 1991), there was evidence for re-learning of actions to objects, but this did not generalize away from the training set. The result is of interest for theories of motor programming. One approach to motor programming has been to assume that complex programs are assembled from components of individual actions, based on components of action such as the joint angle, movement of particular muscles or the direction or velocity of the effector is coded (e.g., Scott & Kalasks, 1997; Cabel, Cisek & Scott, 2001; Reina, Moran & Schwartz, 2001). More recently, however, Graziano and colleagues (Graziano, Taylor and Moore (2002) have reported evidence that micro-stimulastion of primary motor cortex generates not component movements but whole complex actions (e.g., based on the movement of an arm through a particular spatial trajectory). These data suggest a change in the way we think about motor programs, suggesting that programs might be stored as complex whole representations rather than being constructed out of individual components. The results presented here, on item-specific learning of actions that do not generalise, are consistent with this proposal. It appears that patients can re-learn a whole action to a given object, but since the action to another object will differ from this (and even if some of the components overlap) then the re-learning does not generalise.

8.3 Limits and merits of the approach

The approach taken in this thesis has been to examine, in some detail, a small number of patients selected on the basis of their clinical symptoms (ADS, apraxia, agnosia). The merit of this approach is that it facilitates the detailed analysis of the factors that might ‘drive’ performance in everyday-life tasks. By analysing the patients in detail here, I have shown (e.g.,) that there is an increased role of semantic distractors in ADS patients compared with controls operating under dual-task load (Chapter 2), that there can be a breakdown due to actions being conducted in a standard order (Chapter 3) and that patterns of eye movements in ADS patients can be subtly different compared with controls (Chapter 7). Once these critical factors have been identified through detailed case studies, their more general impact can be assessed in larger group studies.

Although having several merits, the approach also has several limitations. At a practical level, considerable care needs to be taken to ensure that differences across task conditions are not due to general factors such as practice, as opposed to the specific variables being manipulated in the tasks. There are also constraints on the way the data can be analysed. Throughout the thesis, the data have been analysed where possible using ANOVAs, even for single cases, with task being included as ‘subject’. This capitalises on the power of ANOVAs (e.g., to assess for interactions), but it does make assumptions about the data being independent on different test occasions, and it could increase the likelihood of a Type I error. On the other hand, non-independence of the data (e.g., due to priming from one condition to another) would be more likely to reduce rather than increase differences between the conditions, while analysing the data over tasks (e.g.) does ensure that any statistical inferences generalise.

8.4 Conclusions

The present results highlight the complexity of performing everyday tasks. The detailed single case analyses have indicated that performance can break down in a number of ways reflecting factors such as the increased competition for selection (effects of semantic relatedness in Chapter 2) and the inappropriate spread of activation when the steps in tasks are performed in a habitual order (Chapter 3). I have also shown ways that patient performance can be facilitated (Chapters 4 and 5). This work provides the basis for additional group-based studies, where the generality of the findings across different classes of patient can be explored.

References

- Baddeley, A. D. (1986). *Working memory*. Oxford: Oxford University Press.
- Ballard, D. H., Hayhoe, M. M., Li, F., & Whitehead, S.D. (1992). Hand–eye coordination during sequential tasks. *Philosophical Transactions of the Royal Society of London.* Series B, 337, 331–339.
- Bauer R. M. (1993). Agnosia. In K. M. Heilman & E. Valenstein (Eds), *Clinical Neuropsychology.* New York: Oxford University Press.
- Beauvois, M.F., Saillant, B., Meininger, V., & Lhermitte, F. (1978). Bilateral tactile aphasia: A tacto-verbal dysfunction. *Brain, 101,* 381– 401.
- Belke, E., Humphreys, G. W., Watson, D. G., Meyer, A. S. & Telling, A. L. (in press). Effects of top-down semantic knowledge in visual search are modulated by cognitive but not perceptual load. *Perception & Psychophysics.*
- Bickerton, W., Humphreys, G. W., and Riddoch, M. J. (2006). The use of memorised verbal scripts in the rehabilitation of action disorganisation syndrome. *Neuropsychological Rehabilitation, 16,* 155 – 177.
- Bickerton, W., Humphreys, G. W., & Riddoch, M. J. (2007). The case of the unfamiliar implement: Schema-based over-riding of semantic knowledge from objects in everyday action. *Journal of the International Neuropsychological society, 13,* 1035– 1046.
- Blasi, G., Goldberg, T. E., Weickert, T., Das, S., Kohn, P., & Zoltick, B., et al. (2006). Brain regions underlying response inhibition and interference monitoring and suppression. *European Journal of Neuroscience, 23*(6), 1658-1664.
- Botvinick, M. A. (2007). Onflict monitoring and decision making: Reconciling

two perspectives on anterior cingulate function. *Cognitive, Affective and Behavioral Neuroscience, 7,* 356-366.

- Brandstater, M. E. (1990). An overview of stroke rehabilitation. *Stroke, 21* (suppl II), 40– 42.
- Burgess, P. W. & Shallice, T. (1997). *The Hayling and Brixton Tests.* Bury St. Edmonds, UK: Thames Valley Test Company.
- Buxbaum, L. J., Schwartz, M. F., & Carew, T. G. (1997). The role of semantic memory in object use. *Cognitive Neuropsychology, 14,* 219-254.
- Buxbaum, L. J., Schwartz, M. F., & Montgomery, M. W. (1998). Ideational apraxia and naturalistic action. *Cognitive Neuropsychology, 15*, 617- 643.
- Cabel, D.W., Cisek, P., and Scott, S.H. (2001). Neural activities in primary motor cortex related to mechanical loads applied to the shoulder and elbow during a postural task. *The Journal of Neurophysiology, 86*, 2102– 2108.
- Carter, C. S., Braver, T. S., Barch, D. M., Botvinick, M. M., Noll, D., & Cohen, J. D. (1998). Anterior cingulate cortex, error detection, and the online monitoring of performance. *Science, 280*(5364), 747-749.
- Chainay, H., & Humphreys, G. W. (2001). The real object advantage in agnosia: Evidence of a role for shading and depth in object recognition. *Cognitive Neuropsychology, 18,* 175-191.
- Chainay, H., & Humphreys, G. W. (2002). Neuropsychological Evidence for a convergent route model for action. *Cognitive Neuropsychology, 19*, 67-93.
- Code, C., & Gaunti C. (1986). Treating severe speech and limb apraxia in a case of aphasia. *Br J Disord Commun, 21,* 11 – 20.
- Cooper, R.P., & Shallice, T. (2000). Contention scheduling and the control of routine activities. *Cognitive Neuropsychology, 17*, 297 – 338.

- Cooper, R.P., Schwartz, M.F., Yule, P., & Shallice, T. 2005. The simulation of action disorganization in complex activities of daily living. *Cognitive Neuropsychology*, 22, 959-1004.
- Cubelli, R. Marchetti, C. Boscolo G., & Della Sala S. (2000). Cognition in action: Testing a model of limb apraxia. *Brain and cognition, 44*, 144– 165.
- De Renzi, E. 1989. Apraxia. In Boller, F. & Grafman, J. (Eds) *Handbook of Neuropsychology*. Amsterdam: Elsvier.
- De Renzi, E., Faglioni, P., & Sorgato, P. (1982). Modality-specific and supramodal mechanisms of apraxia. *Brain*, *105*, 301– 312.
- De Renzi, E., & Lucchelli, F. (1988). Ideational apraxia. *Brain*, *111*, 1173 – 1185.
- De Renzi E. & Scotti G. (1970). Autotopagnosia: Fiction or Reality? *Archives of Neurology ,23*, 221–227.
- Donkervoort, M., Dekker, J., Stehmann-Saris, F. C., & Della Sala, S. (2001). Efficacy of strategy training in left hemisphere stroke patients with apraxia: A randomised clinical trail. *Neuropsychological Rehabilitation, 11*, 549 – 566.
- Farah M J. (1990). *Visual agnosia: Disorders of object recognition and what they tell us about normal vision*. Cambrige, MA: MIT Press.
- Ferreira C. T, Giusiano B., Ceccaldi M, Poncet M. (1997). Optic aphasia: evidence of the contribution of different neural systems to object and action naming. *Cortex, 33*,499-513.
- Fery, P. & Morais J. (2003). A case study of visual agnosia without perceptual processing or structural description impairment. *Cognitive Neuropsychology, 20*, 595–618.
- Forde, E. & Humphreys, G.W. (1995). Refractory semantics in global aphasia:

On semantic organization and the access-storage distinction in neuropsychology. *Memory, 3*, 265-308.

- Forde, E. M. E. & Humphreys, G. W. (1997). A semantic locus for refractory behaviour: Implications for access-storage distinctions and the nature of semantic memory. *Cognitive Neuropsychology, 14*, 367-402.
- Forde, E.M.E. & Humphreys, G.W. (1999). Category-specific recognition impairments: A review of important case studies and influential theories. *Aphasiology, 13*, 169-193.
- Forde, E. M. E. & Humphreys, G. W. (2000). The role of semantic knowledge and working memory in everyday tasks. *Brain and Cognition, 44*, 214-252.
- Forde, E. M. E. & Humphreys, G. W. (2002). Dissociation in routine behaviour across patients and everyday tasks. *Neurocase, 8*, 151-167.
- Forde, E. M. E., Humphreys, G. W. & Remoundou, M. (2004). Disordered knowledge of action order in action disorganization syndrome. *Neurocase, 10*, 19- 28.
- Forde, E. M. E., Rusted, J., Mennie, N., Land, M. & G.W. Humphreys (2009). The eyes have it: An exploration of eye movements in action disorganization syndrome. *Cortex.*
- Forti, S., Humphreys, G.W., & Watson, D.G. (2005). Eye movement in search in visual neglect. *Visual Cognition, 12*, 1143–1160.
- Frith, C. D. (2000). The role of dorsolateral prefrontal cortex in the selection of action, as revealed by functional imaging. In S. Monsell and Driver (Eds) *Attention and performance, XVIII,* Cambridge, MA: MIT Press.
- Giovannetti, T., Libon, D. J., Buxbaum, L.J., & Schwartz, M.F. (2002). Naturalistic action impairments in demantia. *Neuropsychologia*, *40*, 1220–

1232.

- Goldenberg, G., Daumuller, M., & Hagmann, S. (2001). Assessment and therapy of complex activities of daily living in apraxia. *Neuropsychological Rehabilitation*, 11, 147 -169.
- Goldenberg, G., & Hagmann, S. (1998). Therapy of activities of daily living in patients in apraxia. *Neuropsychological Rehabilitation, 8,* 123 – 141.
- Grafman, J. (1989). Plans, actions, and, mental sets: Managerial knowledge units in the frontal lobes. In E. Perecman (Ed) *Integrating theory and practice in neuropsychology*. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.
- Grailet, J. M , Seron X., Bruyer, R., Coyette, F., & Frederix, M. (1990). Case report of a visual integrative agnosia. *Cognitive Neuropsychology, 7,* 275–310.
- Graziano, M. (2006). The organization of behavioral repertoire in motor cortex. *Annual Review of Neuroscience, 29,* 105 – 134.
- Graziano, M., Taylor, C., Moore, T. (2002). Complex movement evoked by microstimulation of precentral cortex. *Neuron, 34,* 841–851.
- Hayhoe, M. (2000). Vision using routines: a functional account of vision. *Visual Cognition, 7,* 43–64.
- Hayhoe, M. (2004). Advanced in Relating Eye Movement and Cognition. *Infancy, 6,* 267–274.
- Hayhoe, M. M., and Bensinger, D. G. & Ballard, D. H. (1998). Task constraints in visual working memory. *Visual Research, 38,* 125–137.
- Heaton, R. K., Grant, I., & Mathews, C. G. (1991). *Comprehensive norms for expanded Halstread-Reitan battery*. Odessa, FL: Psychological assessment Recourses.
- Hebert, D. and Roy, E. (2002). Limb Apraxia: A clinical perspective.

Geriatrics and Aging, 5, 15 – 21.

- Heilman, K. M. (1973). Ideational apraxia– A re-definition. *Brain, 96*, 861–864.
- Heilman, K. M., and Rothi, L. J. G. (1985). Apraxia. In Heilman, K.M. and E. Valenstein, E. (Eds) *Clinical neuropsychology.* New York, Oxford University Press. 131–150.
- Heilman, K. M., and Rothi, L. J. G. (1993). Apraxia. *Clinical Neuropsychology.* Oxford University Press, New York.
- Heilman, K. M. and Rothi, L. J. G. (1997). Limb apraxia: a look back. In: L. J. Rothi and K. M. Heilman (Eds). *Apraxia: the Neuropsychology of action*, Psychology Press. 7–28.
- Hillis, A.E. & Caramazza, A. (1995). Cognitive and neural mechanisms underlying visual and semantic processing: Implications from 'optic aphasia'. *Journal of Cognitive Neuroscience, 7,* 457-478.
- Howard, D. & Patterson,K. *The Pyramids and Palm Trees Test*. Bury St. Edmonds, EK: Thames Valley Test Company.
- Humphreys, G. W. & Forde, E. M. E. (1998). Disordered action schema and action disorganization syndrome. *Cognitive Neuropsychology, 15,* 771-811.
- Humphreys, G.W., Forde, E.M.E. & Francis, D. (2000). The sequential organisation of action. In S. Monsell & J. Driver (Eds.), *Attention and Performance XVIII.* Cambridge, Mass.: MIT Press.
- Humphreys, G. W., Forde, E. M. E., & Riddoch, M. J. (2001). The planning and execution of everyday actions. In Rapp, B. (Ed) *The handbook of cognitive neuropsychology* . Philadelphia, PA, Psychology Press. 565–589.
- Humphreys, G. W., & Forde, E. M. E. (2005). Naming a giraffe but not an

animal: Base-level but not subordinate naming in a patient with impaired semantics. *Cognitive Neuropsychology, 22,* 539–558.

- Humphreys, G.W., Forde, E.M.E., & Francis, D. (2000). The organization of sequential action. In S. Monsell & J. Driver (Eds), *Attention and performance (vol. 18).* Cambridge, MA: MIT Press.
- Humphreys, G. W. & Riddoch, M. J. (2006). Features, objects, action: The cognitive neuropsychology of vision from 1984-2004. *Cognitive Neuropsychology, 23,* 156-183.
- Joe, W. Q., Ferraro, M., & Schwartz, M. F. (2002). Sequencing and interleaving in routine action production. *Neurocase, 8*, 135– 150.
- Kay, J., Lesser R. & Colheart, M. *The Psycholinguistic Assessment of Language Processing in Aphasia.* London: Psychology Press.
- Kertesz, A. (1979). *Aphasia and associated disorders.* New York: Grune and Stratton.
- Land, M. F. (1993). Eye-head co-ordination during driving. Proceedings of the IEEE System, *Man and Cybernetics Conference, Le Touquet, 3,* 490–494.
- Land, M. F. (1994). Where we look when we steer. *Nature, 369*, 742–744.
- Land, M. F., & Furneaux S. (1997). The knowledge base of the oculomotor system. *Philosophical Transactions of the Royal Society of London. Series B, 325,* 1231–1239.
- Land, M. F., Furneaux, S. M., & Gilchrist, I.D. (2002). The organization of visually mediated actions in a subject without eye movements. *Neurocase, 8*, 80–87.
- Land, M. F., Furneaux S., & Rusted, J. (1999). The role of vision and eye movemens in the control of activities of daily living. *Perception, 28,* 1311–

1328.

- Land, M. F., & Hayhoe, M. (2001). In what ways do eye movements contribute to everyday activities? *Vision Research, 41*, 3559– 3565.
- Land, M. F., & Hayhoe, M. (2002). In what ways do eye movements contribute to everyday activities? *Vision Research, 41*, 3559–3565.
- Land, M. F., Mennie, N., & Rusted, J. (1999). The role of vision and eye movemens in the control of activities of daily living. *Perception, 28*, 1311–1328.
- Lashley, K.S. (1951). The problem of serial order in behavior. In L.A. Jeffress (Ed.), *Cerebral mechanisms in behavior.* New York: Wiley, 112–136.
- Liepmann, H. (1900, 1905, 1906/1988). The clinical picture of apraxia. In Brown J.W. (Ed) *Agnosia and apraxia: Selected papers of Liepmann, Lange, and Potzl.* Hillsdale, NJ, Lawrence Erlbaum Associates, Inc.
- Liepmann, H. (1905). Die linke Hemisphaere nd das Handlen. *Muechner Medizinische Wochenschrift, 49,* 2322–2326, 2375–2378.
- Leipmann, H. & Mass, O. (1907). Fall von linksseitiger Agraphie und Apraxie bei Rechtsseitiger Lahmung. *Journal Für Psychologie und Neurologie, 10,* 214– 227.
- Luria, A. R. (1966). *Higher cortical function in man.* New York, Basic Books.
- Maher, L.M. & Ochipa, C. (1997). Management and treatment of limb apraxia. In Rothi, L.J. , Heilman, K.M. (Eds). *Apraxia: The neuropsychology of action.* Hove: Psychology Press, 75 – 91.
- Maher, L.M., Rothi, L.J.G. & Greenwald, M.L. (1991). Treatment of gesture impairement: A single case. *American Speech and Hearing Association, 33,* 195 pp.

- Martin, G. N. (2006). *Human Neuropsychology (2nd edition).* Europe: Prentice Hall.
- Miltner W. H. R., Braun, C. H., & Coles, M. G. H. (1997). Event-related brain potentials following incorrect feedback in a time-estimation task: Evidence for a “generic” neural system for error detection. *Journal of Cognitive Neuroscience, 9,* 788– 798.
- Moores E., Laiti L., & Chelazzi L. (2003). Associative knowledge controls deployment of visual selective attention. *Nature Neuroscience, 2,* 182 – 189.
- Morady K. & Humphreys, G. (2009a). Comparing action disorganization syndrome and dual-task load on normal performance in everyday action tasks. *Neurocase, 15*, 1–12.
- Morady, K. & Humphreys, G.W. (2009b). Real object use facilitates object recognition in semantic agnosia. *Neurocase*.
- Norman, D. A. (1981). Categorization of action slips. *Psychological Review, 88,* 1- 15.
- Norman, D. A., & Shallice, T. (1980). Attention to action: Willed and automatic control of behaviour. *Center for Human Information Processing (CHIP) Technical Report 99*. San Diego, University of California.
- Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. Davidson, G. Schwartz, & D. Shapiro (Eds). *Consciousness and self regulation: Advances in research and theory, Vol. 4.* New York, Plenum Press. 1-18.
- Ochipa, C., Maher, L.M. & Rothi, L.J.G. (1995). Treatment of ideomotor apraxia. *Journal of International Neuropsychol Soc, 2*, 149.
- Ochipa, C., Rothi, L. J. G., & Heilman, K. M. (1992). Conceptual apraxia in

alzheimer's disease. *Brain, 115*, 1061– 1071.

- Ochipa, C., Rothi, L. J. G., & Heilman, K.M. (1994). Conduction apraxia. Journal of Neurology, *Neurosurgery and Psychiatry, 57,* 1241– 1244.
- O'Regan, J. K. (1990). Eye movements and reading, In: Kowler, E. (Ed) *Eye Movements and Their Role in Visual and Cognitive Processes.* Amesterdam: Elsevier, 395–453.
- Papagno, C., Della Sala, S. & Basso, A. (1993). Ideomotor apraxia without aphasia and aphasia without apraxia: the anatomical support for a double dissociation. *Journal of Neurology, Neurosurgery and Psychiatry, 56*, 286 – 289.
- Pilgrim, E., & Humphreys, G. W. (1991). Impairment of action to visual objects in a case of ideomotor apraxia. *Cognitive Neuropsychology, 8,* 459–473.
- Pilgrim, E., & Humphreys, G. W. (1994). Rehabilitation of a case of ideomotor apraxia. In M. J. Riddoch, and G. W. Humphreys (Eds) *cognitive neuropsychology and cognitive rehabilitation.* Hove, UK, Lawrence Erlbaum Associates Ltd. 271–285.
- Poeck, K. (1983). Ideational apraxia. *Journal of Neurology, 230,* 1–5.
- Posner, M. I., and Snyder, C. R. (1975). Attention and cognition control. In R.L. Solso (Ed) *Information processing and cognition*. Hillsdale, NJ, Lawrence Erlbaum Associates Inc. 55– 85.
- Price, C. J. & Humphreys, G. W. (1989). The effects of surface detail on object categorization and naming. *Quarterly Journal of Experimental Psychology, 41A*, 797-828.
- Pülvermuller, F. (1999). Words in the brain's language. *Behavioral and Brain*

Science, 22, 235-336.

- Rayner, K. (1995). Eye movements and cognition processes in reading, visual search, and scene perception. In: Findlay, J.M. Walker, R. and Kentridge R.W. (Eds) *Eye Movement Research: Mechanisms, Processes and Applications.* Amsterdam: North-Holland, 3–22.
- Reason, J. T. (1979). Action not as planned: The price of automatization. In G. Underwood & R. Stevens (Eds), *Aspects of consciousness*. London, Academic Press, 67–89.
- Reason, J. T. (1984). Lapses of attention in everyday life. In R. Parasuraman & D.R. Davies (Eds), *Varieties of attention.* Orlando, FL: Academic Press.
- Reason, J. T. (1990). *Human error.* Cambridge, England; New York: Cambridge University Press. 302.
- Reed, C. L., Caselli, R. J., and Farah, M. J. (1986). Tactile agnosia: Underlying impairment and implications for normal tactile object recognition. *Brain, 119,* 875– 888.
- Reina, G. A., Moran, D. W., Schwartz, A. B. (2001). On the relationship between joint angular velocity and motor cortical discharge. *Journal of Neurophysiology, 85,* 2576– 2589.
- Riddoch, M.J. & Humphreys, G.W. (1987a). A case of integrative visual agnosia. *Brain, 110,* 1431 – 1462.
- Riddoch, M.J. & Humphreys, G.W. (1987b). Visual object processing in optic aphasia: A case of semantic access agnosia. *Cognitive Neuropsychology, 4,* 131-185.
- Riddoch, M.J. & Humphreys GW. (1993). *The Birmingham Object Recognition Battery (BORB),* London: Psychology Press.

- Riddoch, M. J., Humphreys, G. W. & Price, C. J. (1989). Routes to action: Evidence from apraxia. *Cognitive Neuropsychology, 6*, 437- 454.
- Riddoch, M. J., Humphreys, G. W., Akhtar, N., Allen, H., Bracewell, R. M., & Schofield, A.J. (2008). A tale of two agnosias: Distinctions between form and integrative agnosia. *Cognitive Neuropsychology, 25*, 56-92.
- Riddoch, M.J., Humphreys, G.W. & Coltheart, M., Funnell, E. (1988). Semantic systems or system? Neuropsychological evidence re-examined. *Cognitive Neuropsychology, 5*, 3-25.
- Rothi, L. J. G, Mark, L., & Heilman, K. M. (1986). Pantomime agnosia. *Journal of Neurology, Neurosurgery and Psychiatry, 49*, 451– 454.
- Rothi L. J. G, Ochipa C., Heilman K. M. (1991). A cognitive neurosychological model of limb apraxia. *Cognitive Neuropsychology, 8*, 443 – 458.
- Rothi, L. J. G., Ochipa, C. & Heilman, K. M. (1997). A cognitive neurosychological model of limb praxis and apraxia. In: Rothi L. J. G., Heilman, K. M., (Eds) *Aprxia: The cognitive neuropsychology of action.* Hove: Psychology Press, 29-49.
- Roy, E. A. & Square, P. A. (1985). Common considerations in the study of limb, verbal and oral apraxia. *Advances in Psychology, 23*, 111– 161.
- Rumiati, R. I., Zanini, S., Vorano, L., & Shallice, T. (2001). A form of ideational apraxia as selective deficit of contention scheduling. *Cognitive Neuropsychology, 18*, 617 – 642.
- Rusted, J. & Sheppard, L. (2002) Action-based memory in Alzheimer's disease: A longitudinal look at tea making. *Neuroscase, 8*, 111-126.

- Scott, S.H. & Kalaska, J. F. (1997). Reaching movement with similar hand paths but different arm orientations. I. Activity of individual cells in motor cortex. *The Journal of Neurophysiology, 77,* 826–852.

- Schwartz, M. F. (1995). Re-examining the role of executive functions in routine action production. In Grafman J., Holyoke, K.J. and Boller, F. (Eds) Annals of the New York Academy of Sciences, 769. *Structure and functions of the human prefrontal cortex* . New York, New York Academy of Sciences. 321–335.

- Schwartz, M.F. (2006). The cognitive neuropsychology of everyday action and planning, *Cognitive Neuropsychology, 23,* 202–221.
- Schwartz, M. F., & Buxbaum, L. J. (1997). Naturalistic action. In L. J. G. Rothi & K. M. Heilman (Eds.), *Apraxia: The Neuropsychology of action.* Hove, UK, Psychologh Press. 269–289.
- Schwartz, M.F, Buxbaun, L. J., Montgomery, M., Fitzpatrick-Desalme, E. J., Hart, T., Ferraro, M., Lee, S. S., & Coslett, H.B. (1999). Naturalistic action production following right hemisphere stroke. *Neuropsychologia, 37,* 51- 66.
- Schwartz, M. F., Fitzpatrick-DeSalme, E. J., & Carew, T. G. (1995). The Multiple Objects Test for Ideational Apraxia: Etiology and task effects on error profiles. Abstract. *Journal of the International Neuropsychological Society, 1,* 149 pp.
- Schwartz, M. F., Mayer, N.H., Fitzpatrick-Desalme, E. J., & Montgomery, M. W. (1993). Cognitive theory and the study of everyday action disorders after brain damage. *Journal of Head Trauma Rehabilitation, 8,* 59- 72.
- Schwartz, M. F., Montgomery, M. W., Buxbaum, L. J., Lee, S. S., Carew, T.

G., Coslett, H. B., Ferraro, M., Fitzpatrick-DeSalme, E., hart, t., & Mayer, N. (1998). Naturalistic action impairment in closed head injury. *Neuropsychology, 12,* 13 – 27.

- Schwartz, M.F., Montgomery, Fitzpatrick-Desalme, E., Ochipa, C., Coslett, H.B., & Mayer, N.H. (1995). Analysis of a disorder of everyday action. *Cognitive Neuropsychology, 12,* 863-892.
- Schwartz, M. F., Reed, E. S., Montgomery, M., Palmer, C., & Mayer, N. H. (1991). The quantitative description of action disorganization after brain damage: A case study. *Cognitive Neuropsychology, 8*, 381-414.
- Shallice, T. (1972). Dual functions of consciousness. *Psychological Review, 79,* 383 – 393.
- Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London, B298*, 199 – 209.
- Shallice, T. (1988). *From neuropsychology to mental structure.* Cambridge University Press.
- Shallice, T., Burgess, P. W., Schon, F., & Baxter, D. M. (1989). The origins of utilization behaviour. *Brain, 112,* 1587 – 1598.
- Shiffrin, R.M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127 – 190.
- Sirigu, A., Duhamel, J. R. & Poncet, M. (1991). The role of sensorimotor experience in object recognition. *Brain*, *114*, 2555-2573.
- Smania, n., Girardi, F., Domenicali, C. Et al. (2000). The rehabilitation of limb apraxia: A study in left-brain damaged patients. *Archive of Physician Medical Rehabilitation, 81,* 379 – 388.

- Steinthal, H. (1871). *Abriss der sprachwissenschaft*. Berlin. Quoted by J. Signoret P. North. In: Les Apraxies Gestulles. Paris: Masson, 1979.
- Tanaka, J. & Pressnell, L. (1999). Color diagnosticity in object recognition. *Perception and Psychophysics, 61*, 1140-1153.
- Tate, R.L. and McDonald, S. (1995). What is apraxia? The clinician's dilemma. *Neuropsychological Rehabilitation, 5,* 273–297.
- Warrington, E. K. and McCarthy, R. A. (1983). Category specific access dysphasia. *Brain, 106*, 859–878.
- Warrington, E. K. and McCarthy, R. A. (1987). Categories of knowledge future fractionations and an attended integration. *Brain, 110*, 1273–1296.
- Warrington, E.K. and Shallcie, T. (1970). Semantic access dyslexia. *Brain, 102*, 43-63.
- Wechsler, D. (1981). *Wechsler Adult Intelligence Scale, Revised*. San Antonio, TX: The Psychological Corporation.
- Wechsler, D. (1990). *Wechsler Memory Scale*. New York: The Psychological Corporation.
- Wilson, B. A., Alderman, N., Burgess, P., Emslie, H. & Evans, J. (1996). *Behavioural assessment of the dysexecutive syndrome*. Bury St. Edmunds, Suffolk: Thames Valley Test Company.
- Wolk, D. A., Coslett, H. B. & Glosser, G. (2005). The role of sensory-motor information in object recognition: Evidence from category-specific visual agnosia. *Brain and Language, 94*, 131-146.
- Yoon, E. Y., Heinke, D. & Humphreys, G. W. 2002. Modeling direct perceptual constraints on action selection: The Naming and Action Model (NAM). *Visual Cognition, 9*, 615-661.

- Yoon, E. Y. & Humphreys, G. W. (2005). Direct and indirect effects of action on object classification. *Memory & Cognition, 33*, 1131-1146.
- Yoon, E. Y., Humphreys, G. W. & Riddoch, M. J. (2005). Action naming with impaired semantics: Neuropsychological evidence contrasting naming and reading for objects and verbs. *Cognitive Neuropsychology, 22*, 753-767.
- Zwinkles, A., Geusgens, C., Van de Sande, P. & Van Heugten, C. (2004). Assessment of apraxia: inter- rater reliability of a new apraxia test, association between apraxia and other cognitive deficits and prevalence of apraxia in rehabilitation setting. *Clinical Rehabilitation, 18*, 819 – 827

Appendix A

Norms for action schema

- **Make a cup of tea with milk and sugar**
  (kettle, teapot, spoon, teabags, cup, milk, sugar)

  - let the kettle boil
  - put a teabag in the teapot
  - pour hot water into teapot
  - put milk in the cup
  - pour tea into the cup
  - put sugar in the tea
  - stir the tea

- **Make a cheese sandwich and put it in a sandwich bag**
  (bread, cheese, plate, knife, sandwich bags)

  - put bread on the plate
  - put cheese on the bread
  - put the other slice of the bread on top
  - cut the sandwich in half
  - put it in a sandwich bag

- **Wrap a gift**
  (wrapping paper, selotape, gift, scissors, bow)

  - unfold the paper
  - put the gift in the centre
  - cut the paper
  - fold the paper over the gift
  - secure with selotape
  - fix one end
  - fix the other end
  - stick the bow on top

- **Write and post a card**
  (card, pen, stamp, envelope)

  - write the card
  - sign the card
  - put the card in the envelope
  - seal the envelope
  - write the address on the envelope
  - lick the stamp
  - stick the stamp on the envelope

Appendix B

Transitive objects

- Salt-shaker
- Scissors
- Ice-cream scoop
- Razor
- Hairbrush
- Key
- Hammer
- Pen
- Table spoon
- Toothbrush
- Lighter
- Cup
- Knife
- Paintbrush
- Mirror
- Pipe
- Glass
- Measuring cup
- Paperclip
- Eyeglasses
- Whistle
- Torch
- Screwdriver
- Dice
- Ashtray
- Ball
- Comb
- Saw
- Spanner
- Watch
- Shaving brush
- Telephone
- Wooden spoon
- Washing brush
- Teaspoon
- Can opener
- Fork
- Chisel
- Sharpener
- Whisk
- Pliers
- Matches
- Stapler
- Grater
- Pizza cutter
- Ladle
- Clothe peg

Intransitive items

Symbolic gestures

- Wave goodbye
- Snap your fingers
- Hitchhiking
- Salute like a soldier
- Signal stop with your hand
- Blow a kiss
- Signal quiet with your finger to your lips
- Make a “V” for victory
- Come here
- Go away
- Point to me
- Okay sign

Non-symbolic gestures

- Put your hand on opposite shoulder
- Put your fist on your chest
- Put your hand over your ear
- Put your palm on your forehead
- Put your fingers on your chain
- Point to your nose
- Make a circle in the air
- Clap your hands
- Point to the floor
- Join your index fingers
- Point to the ceiling
- Point to your forehead

Copying

Meaningless gesture

- Hand on lips and then forehead
- Hand on nose and the ear
- Two hands open and close
- Hand to forehead and down on the table
- Hand on table makes circle
- Making square on the air

Meaningfull gesture

- Saltshaker
- Saw
- Cup
- Knife
- Toothbrush
- Key

Appendix C

Object Naming

List of objects:

- **Salt shaker** (whistle)
- Scissors
- Ice-cream scoop
- **Razor** (hammer)
- **Hairbrush** (paintbrush)
- **Key** (lighter)
- **Hammer** (razor)
- **Pen** (knife)
- Table spoon
- **Toothbrush** (comb)
- **Lighter** (key)
- Cup
- **Knife** (pen)
- **Paintbrush** (hairbrush)
- Mirror
- Pipe
- Glass
- Measuring cup
- Paperclip
- Eyeglasses
- **Whistle** (salt shaker)
- **Torch** (whisk)
- **Screwdriver** (saw)
- Dice
- Ashtray
- Ball
- **Comb** (toothbrush)
- **Saw** (screwdriver)
- Spanner
- Watch
- **Shaving brush** (washing brush)
- Telephone
- Wooden spoon
- **Washing brush** (shaving brush)
- **Teaspoon**(chisel)
- Can opener
- Fork
- **Chisel** (teaspoon)
- Sharpener
- **Whisk** (torch)
- Pliers
- Matches
- Stapler
- Grater
- Pizza cutter
- Ladle
- Clothes peg

In bold, items used in Experiment 2. In brackets the action used on an incorrect gesture trial.

Perceptual matching

Target object / Matched object

Hammer/ Spanner
Mirror/ comb
Screwdriver/ spanner
Toothbrush/ paintbrush
Whisk/ grater
Razor/ shaving brush
Pipe/ lighter
Knife/ fork
Scissors/ pliers
Hairbrush/ washing brush
Cup/ mug
Glass/ vase
Pen/ pencil
Torch/ lighter
Measuring cup/ vase
Saltshaker/ glass
Can opener/ scissors
Wooden spoon/ ladle
Teaspoon/ ice-cream scoop
Stapler/ hole-punch
Key/ paperclip
Chisel/ saw

Semantic match *(name/object)*

Target object	*Semantically related object*	*Distractor*
Hammer	Nail	Screw
Razor	Shaving brush	Paintbrush
Fork	Knife	Cup
Sharpener	Pencil	Pen
Pipe	Lighter	Torch
Key	Lock	Paperclip
Can opener	Can	Knife
Hole punch	Paper	Card
Saw	Piece of wood	Plate
Spanner	Nut	Nail
Toothbrush	Toothpaste	Soap
Whisk	Bowl	Plate
Scissors	Paper	Sharpener
Mirror	Comb	Toothpaste
Stapler	Staple	Hole punch
Card	Stamp	Sharpener
Paintbrush	Painting colour	Hairbrush
Eraser	Pencil	Pen
Candle	Matches	Torch
Chisel	Piece of wood	Scissors
Tea bag	Cup	Glass
Torch	Battery	Matches
Knife	Onion	Scissors
Ink	Pen	Pencil
Fork	Knife	Saw

APPENDIX D

List of objects in Experiment

5. Scissors
6. Razor
7. Hairbrush
8. Key
9. Hammer
10. Pen
11. Table spoon
12. Toothbrush
13. Cup
14. Knife
15. Paintbrush
16. Mirror
17. Pipe
18. Screwdriver
19. Fork
20. Whisk
21. Pliers
22. Ice-cream scoop
23. Chisel
24. Ladle
25. Wooden spoon
26. Grater
27. Washing brush
28. Pizza cutter
29. Saw
30. Spanner
31. Shaving brush
32. Eye glasses