THE CLINICAL UTILITY OF THE ASSESSMENT OF LEARNING POTENTIAL FOLLOWING BRAIN INJURY

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Table of Contents

List of Figures

List of Tables

Table of Appendices

Abstract

Our current evidence base for predicting outcome following an acquired brain injury (ABI) identifies factors such as the severity and impact of the injury, as well as pre-injury information as potential predictors. However current physical, medical and neuropsychological predictors are inadequate. There is a great deal of confusing and conflicting information which makes it difficult for the professionals involved in the care of those who have suffered an ABI to determine how much improvement an individual can be expected to make and what is the appropriate intensity of a rehabilitation programme. As a result patients can receive a range of treatments from different services over several years without indicators to reliably gauge outcome for all the effort both patients and staff put into this change process.

The empirical research reported here suggests that limitations with current outcome predictors are that they fail to consider the individual as an active participant in their recovery process. This research explores the utility of the theory of learning potential and dynamic assessment as a tool in the field of ABI to assess the potential of an individual to adapt, and their ability to engage in the recovery process. Learning potential measures a latent or dormant ability that is brought out by a third party during dynamic training. It was predicted that dynamic testing, as opposed to simple static test administration of the same tests, could reveal important additional information to predict outcomes of ABI. In this research dynamic testing involved a pre and post test administration that sandwiched a training element. Learning potential using the Explicit Verbal Learning system was investigated with an adapted, dynamic version of the Wisconsin Card Sorting Test (WCST). Non-Verbal Learning potential was investigated with a dynamic version of the Ruff Light Trail Learning Test (RULIT) and Latent Implicit potential to learn using the Tower of Hanoi (ToH).

A Rasch Analysis Model was used to examine the data in terms of the construct validity and hierarchy of the items of each test and the individuals who completed it, both pre and post-training. Individuals were grouped into different dynamic learner classifications according to their position on this scale.

The results indicate a clear advantage in outcome prediction using dynamic testing. Of the three aspects considered, the measure of learning potential that added most to our understanding about the individual and outcome was the assessment utilising the Verbal Learning system (Dynamic WCST). The assessment measuring Latent Implicit learning potential (ToH) also added significantly to predicting ABI outcome. The assessment of learning potential using the Non-Verbal/Visuospatial Learning system (RULIT) however, did not add further information to help prediction of outcome.

The information from the above model guided multiple regression analyses to examine the predictors of ABI outcome using each of the measures of the Community Integration Questionnaire (CIQ) as the dependent variables. Independent variables were Dynamic Verbal learner status (derived from Rasch); socio-economic status; severity of injury; predicted pre-injury intellectual functioning; education levels and current intellectual functioning. With integration status as the dependent variable (measured by the Total CIQ), Dynamic Verbal learner status and socio-economic status were the only significant predictors. Subscales tapping specific aspects of integration were not predicted by any the independent variables other than Social Integration scores, which were predicted only by pre-injury and current intellectual functioning.

Collectively these results indicate that learner status may help determine the extent to which an individual can adapt following an acquired brain injury and that this latent ability significantly influences their outcome. These dynamic assessments have clinical implications in determining the level of support or treatment that an individual may require.

Chapter 1 : Literature Review

1.1 Defining Brain Injury

Acquired brain injury (ABI) is a term that includes acute (rapid onset) brain injury of any cause (British Society of Rehabilitation Medicine & Royal College of Physicians, 2003). Acquired brain injuries are often identified and classified by the nature of the injury; they can be broadly categorised into the five sections listed below.

- Trauma: A traumatic injury can be thought of as open or closed. A traumatic open head injury is caused by a force that damages the skull and a traumatic closed head injury is caused by a traumatic event that does not damage the skull but does damage the brain (e.g. Blows to the head that cause the brain to jolt inside the skull with enough force to disrupt neurons and cause physiological damage).
- Vascular Accident: A vascular accident refers to a stroke or a subarachnoid haemorrhage (where blood leaks from an artery into the space between the protective outer layers of tissue that surround the brain and, as a result, puts pressure on the brain).
- Cerebral Anoxia (Cerebral anoxia is a lack of oxygen to the brain which can result in cell death).
- Other toxic or metabolic insult (e.g. hypoglycaemia)
- Infection (Meningitis or Encephalitis) or other inflammation (Vasculitis)

Of these classifications, the most frequent to affect the UK population are stroke and traumatic brain injury (TBI). Males are the most likely to be affected, between the ages of 15-29, and after the age of 65 (George, 2005).

Severity of injury refers to the effect that the injury has had on the individual at onset and is quantified by the degree of unconsciousness. Typically this is measured using the Glasgow Coma Score (Teasdale & Jennett, 1974). This assessment tool along with others will be discussed in more detail in the section 1.4.

The 2003 national guidelines estimate the number of people requiring hospitalisation following a head injury at 275 per 100,000 per year. Of these, 25 will experience a moderate to severe injury. Of the 25 per 100,000, 10-20% will experience a severe disability or prolonged coma and the remaining 65-85% will make a good physical recovery. There is little to no information provided in the national guidelines that relates to the cognitive or psychosocial consequences the brain injury will have. Of the remaining 250 per 100,000 people who did not experience a severe to moderate injury, there is no information about the impact their injury had on them.

It is well established that acquired brain injury will often result in cognitive, behavioural, emotional and physiological impairment. However, at this point in time there are no conclusive measures that enable us to predict who will experience what difficulties and to what degree. There are measures relating severity of injury to pre-injury lifestyle factors that are known to influence or mediate outcome measures. These, however, are often flawed and none are able to account sufficiently for the variable and often unexpected recovery that individuals make, despite the degree of their injury.

The aim of this research is to outline the impact that an acquired brain injury can have on cognitive, behavioural and emotional function, to explore techniques in outcome prediction and re-define our understanding of outcome and recovery. It will critically appraise the evidence base in relation to outcome prediction and will add to this current knowledge by introducing dynamic assessment, a relatively new assessment technique to brain injury. This technique will be compared in terms of its clinical utility to the standard neuropsychological assessments currently available with particular emphasis on its ability to predict outcome and its potential for identifying adaptability.

1.2 Outcome and Brain Injury

Having summarised the causes, incidence and nature of ABI, this next section will outline the range of difficulties that it can cause. It will summarise the different ways that outcome is measured and predicted, and will critically appraise the current evidence base. Following sections will introduce the concept of recovery and compare this to the outcome models currently applied to the brain injury field. The definition and role of rehabilitation will be discussed as a moderating influence on injury and outcome. Other factors that affect outcome will also be outlined.

1.2.1 The Impact of Brain Injury

Is it understood that lesion locality will have a significant effect in determining the manifestation of the clinical symptoms a person can experience following brain injury (Shallice, 1988). Unfortunately it is rare that only one part of the brain is affected following an acquired brain injury. This is primarily due to secondary consequences of the trauma or further acute incidences e.g. hypoxia (British Society of Rehabilitation Medicine et al., 2003). This means that an individual is likely to experience a diffuse brain injury, as opposed to a focal one, which could affect many regions of the brain. A diffuse brain injury makes predicting the nature and degree of difficulties that a person will experience very difficult. The range of functions that are frequently affected following an ABI can be categorised into four large groups, these are physical function, communication, cognitive function, and behavioural / emotional function (Lezak, 2004a). The following section will summarise the range of difficulties that people can experience within these categories.

Physical function: Physical symptoms following an acquired brain injury can range from headaches to paralysis. Within this range, other difficulties commonly seen are with abnormal muscle tone, problems with coordination and ataxia (shaky movements and unsteady gait). Senses can also be affected, for example loss of sense of smell or taste or hypersensitivity to touch, visual or hearing problems. There can be problems with dysphagia (swallow reflex), which can impact eating and drinking ability, and increase the risk of aspiration (food and drink entering the wind pipe) which in turn increases the risk of infection within the lungs. Individuals who have suffered an ABI are also more at risk of developing epilepsy.

Communication: Every aspect related to communication could be affected following brain injury, this includes problems with pronouncing words (dysarthria), understanding words (receptive dysphasia), being able to use the right words (expressive dysphasia) as well as with reading and writing.

Behavioural and Emotional: There is a large range of behavioural or emotional changes that an individual could experience following an ABI. Many of the changes frequently observed are an understandable reaction to the sense of personal loss and are often a reaction to the necessary adjustments that are required following a significant life event. Other difficulties can be a direct result of the physiological impact to the brain. Common behavioural changes are around problems with anger and disinhibited behaviour across several areas of functioning. There might also be difficulty with motivation and initiation; these changes are often associated with the frontal lobes. Individuals can also find themselves emotionally labile or with a different temperament. The changes that are frequently reported regarding emotion are often attributed to the limbic system.

Cognitive (The focus of this research will be on this classification of function): An acquired brain injury can impact any area of cognitive function and often more than one area is affected. These impairments can have a far reaching effect on the individual's ability to carry out their day to day living. Common cognitive abilities that can often be affected are memory; attention; concentration; and executive function. Executive function can be thought of as an umbrella term that includes a range of abilities such as planning and organisation, concept attainment, problem solving, impulsivity and error correction. Another frequently occurring cognitive consequence that can confound all the other difficulties is a lack of insight or self-awareness. Lack of insight can have a negative impact on self-monitoring which in turn can affect social interaction and the safety of that person. It also can impede motivation to engage in rehabilitation programmes (Flashman & McAllister, 2002).

This research will be examining the effect that cognitive impairment can have on an individual's life and will explore how cognitive function and learning potential can predict outcome. First it will be necessary to define outcome.

1.3 Measuring the Impact of Brain Injury

Measuring outcome is an extremely difficult task in brain injury because it suggests that there is an endpoint that is static and fixed which can be measured. Clinical research has shown, however, that reaching an endpoint in recovery is unlikely as people are still changing for better and worse years after their injury (Hoofien, Gilboa, Vakil, & Donovick, 2001). For any rehabilitation team it is essential to be able to quantify outcome. Firstly, as it enables an effective way of measuring individual progress through a rehabilitation programme, secondly for audit purposes as it enables rehabilitation teams to show their value/worth. Finally for research purposes it allows a comparison to be made between individuals and for knowledge learned to be sent back to clinical practice. Unfortunately the research to date has been inconclusive, and as a result outcome prediction is still not an exact science; this will be discussed in more detail in the following section.

Many of the problems in relation to outcome prediction appear to be caused by semantics. The word 'outcome' has different connotations in different clinical settings. For example, in a hospital setting a good outcome to a medical professional might mean that their patient lived rather than died. To nursing staff it might mean that their patient recovered physically and could be discharged home. To a hospital Occupational Therapist it might mean that the person could independently carry out 'Activities of Daily Living' (such as washing, dressing and making a cup of tea). To a community rehabilitation professional, it might mean that the individual could go back to some kind of employment. Clinical experience has found that, to our Service Users, a good outcome is getting back to as many of the competencies that they used to have, and enjoying similar experiences and options as they did prior to their injury. For many, anything less is a bad outcome.

With regard to measuring the impact of health related conditions the World Health Organisation has taken a positive step to reflect the holistic perspective of the individual. They have moved away from diagnosis and disability (the medical model); towards a more person-centred approach, which considers the impact that health related conditions have on an individual's ability to function in the context of their environment. This system fits within the biopsychosocial model (Engel, 1977; Engel, 1980). The scale they developed is called the International Classification of Functioning (ICF) (World Health Organisation, 2001) and was designed to help describe how people live with their health conditions. The focus is on functioning and participation in activities rather than on their health condition. The ICF works from three perspectives taking into account the body, the individual and society. Impairment in this system is described as any problem in the body function or structure, such as significant deviation or loss that impacts functioning. The aim of the ICF was to move away from the dichotomous definitions of disability and functioning. Instead, these two are put together and the outcome of this is described as the relationship between an individual's health condition and their contextual factors (e.g. their environment, supports and personal factors). In this way outcome can be measured adaptively regardless of the health condition, using the same tool with the same terms.

Using this perspective of disability and impairment it is thought that the best way to assess outcome following an ABI is to understand how an individual is able to carry out common functional roles, e.g. living and working within the community; and perhaps more importantly to understand what changes have occurred to their community integration following their injury. Whilst the ICF has the right concept, it is exceedingly detailed, covering every possible function that could be impacted upon. Until this has been addressed and a more user friendly tool created, an alternative outcome measure will be needed.

Some researchers have used employment as a gauge of outcome following ABI, particularly as it has been found to be important to Service Users. Levack, McPherson & McNaugton (2004) investigated the utility of return to work as a measure of outcome. They compared the range of employment outcomes that clinicians often place hierarchical value on (e.g. competitive employment is a better outcome than voluntary employment). The research found that all the participants put value on working in a paid full-time job, but that other factors were equally important in determining how they viewed their employment, i.e. as a success or failure. These factors included whether the work was viewed as productive and sustainable, as well as how it impacted on their life outside of work and their own personal values and vocational identity. This is an interesting finding and emphasises the importance of an individual's satisfaction as an outcome measure as opposed to a clinician's set goal.

Although employment is an important part of everyday function, it only provides information about certain aspects of everyday life and for many the measure is not comprehensive enough to make it a meaningful outcome measure. A questionnaire that seems to fit within the ethos of the ICF, which has been designed for brain injury and covers different aspects of function, including employment, is the Community Integration Questionnaire.

1.3.1 Community Integration Questionnaire

The Community Integration Questionnaire (CIQ) (Willer, Rosenthal, Kreutzer, & Gordon, 1993) is the most frequently cited measure of outcome following brain injury (Dijkers, 1997; Sander et al., 1999; Kaplan, 2001).

This scale was developed using the World Health Organisation's then current definition of handicap ("...a disadvantage for a given individual, resulting from an impairment, or a disability that limits or prevents fulfilment of a role that is normal (depending on age, sex and social and cultural factors)" (Willer et al., 1993) p. 76). The authors, therefore, defined Community Integration as the opposite of handicap. Despite the WHO moving away from this type of definition, where disability is seen as distinct from normal functioning, this assessment still fits with the new definition of function provided by the WHO, and is still one of the only available outcome tools that has been developed specifically for a brain injury population within the community. Willer et al (1993) designed the tool as available outcome measures were designed specifically for other populations (e.g. Craig Handicap Assessment and Reporting Technique (Whiteneck, Charlifue, Gerhart, Overholser, & Richardshon, 1992)).

Operational definitions for community integration usually refer to employment and independent living. Willer et al (1993) aimed to assess three distinct factors of community living; vocation, family and social. Together with professionals in the brain injury field, they initially developed a forty-seven item questionnaire that was administered to forty-nine people. Factor analysis established three factors from fifteen correlated items. The three sections of the CIQ were labelled Home Integration, Social Integration and Productive Activity and a total CIQ score is also provided. Home Integration considers participation in activities related to operation of the home (e.g. shopping for groceries, preparing meals, doing housework, caring for children and planning social gatherings). The Social Integration scale relates to activities associated with outside of the home (e.g. going shopping, leisure activities and socialising). Productive Activity relates to the extent to which individuals are involved in purposeful activities outside of the home (e.g. employment, education and volunteer activities).

Coefficient alpha for the overall CIQ was .76 which indicated adequate internal reliability. A second pilot of the CIQ was administered to 16 people and test-retest reliability coefficient was .91 for individuals and .97 for family. Subscales coefficients for brain injured individuals were found to be .93 for Home, .86 for Social and .83 for Productive Activity. Scores for family members were .96 for Home; .90 for Social and .97 for Productive activity. The authors of this questionnaire took the correlations between family members and patients as evidence for inter-rater reliability. Further evidence for test-retest reliability was provided by Sander et al (1997; 1999).

Some criticisms of the CIQ have been raised in a paper by Diijkers (1997) regarding the inconsistency in the metrics (e.g. on some items of the assessment doing things independently receives a high score whereas in other sections doing things independently is not viewed positively). It was also noted that despite the authors basing their definition of community integration on the WHO definition of handicap, they failed to account for all six dimensions that were highlighted (omitting physical independence, orientation, economic self sufficiency and mobility). An interesting fact is that despite the test being developed over ten years ago, and it still being used to measure outcome, no normative data has been provided. This would be a valuable and much needed contribution (Sander et al., 1999; Kaplan, 2001). Without norms an alternative suggestion to make the scores more meaningful is to measure the change in integration levels following injury, getting a measure of pre-injury levels and comparing it to post- injury levels. (Dijkers, 1997; Van Baalen et al., 2003).

In more recent years others have developed scales for measuring community integration, one of which being the Community Integration Measure (CIM) (McColl, Davis, Carlson, Johnston, & Minnes, 2001). This had nine factors, identified by brain injury survivors who defined what is important for community integration success. These were: 1) know the rules and how to follow them, 2) know their way around, 3) are accepted for who they are, 4) have people in the community with whom they feel close, 5) have relationships with different kinds of people in the community, 6) find things to do in their leisure time, 7) have something to do that makes them feel productive and worthwhile, 8) have some degree of independence, 9) have a suitable place to live. Comparison of the CIM and a revised edition of the CIQ have shown that they measure different aspects of community integration, with the CIM focusing on the more individual experiences, and the CIQ more on objective and observable facts (Minnes, Carlson, & McColl, 2003).

The CIM is a very useful assessment that focuses on the personal experience of the individual and, clinically, is a useful way of understanding how the individual rates their own outcome. For the purpose of this research, however, the CIQ will be used, as it provides a more objective and therefore comparable outcome measure. Whilst the CIM taps into personal and emotional feelings of integration which requires insight and psychological mindedness, the CIQ can be completed based on observable information provided by the client and their family.

1.4 Predicting Outcome

The evidence base for prognosis and outcome following brain injury is both vast and contradictory. The majority of outcome prediction research currently focuses on information taken at the acute stage of recovery such as Glasgow Coma Scale (GCS) (Teasdale et al., 1974) scores, and length and depth of Post Traumatic Amnesia (PTA).

The GCS is a widely used tool that measures the degree of unconsciousness following head injury. The assessment provides a standard score for observable behaviours that determine the level of consciousness of an individual. The scores range from fully awake and alert (15/15) to completely unresponsive (3/15). The GCS assesses three modalities of function; eye, verbal and motor responsiveness. The assessment uses a fifteen-point scale divided into the three aforementioned categories with a total score of four for optimal eye responsiveness (eyes open spontaneously), five for the optimal verbal response (orientated) and six for the optimal motor response (obeys command). These three behaviours are scored according to the best observable response and are then summed to give a total GCS score. The severity of the head injury is often classified according to the GCS score (severe: 3-8, moderate: 9-12 and minor: 13-15), although arguments have been made that providing a total score for the GCS is misleading because it suggests that the three subscales are connected. The amalgamated score also prevents a clear understanding of the individual's performance on each subscale making it a weaker scale in monitoring change in levels of consciousness over time (Koch & Linn 2000).

The strength of the GCS lies in its simplicity, it takes little time to administer and can be used across disciplines. It is most useful in the acute stage and scores recorded during the first twenty-four hours have predictive ability for outcome in an untreated population (Koch & Linn, 2000). GCS has been found to have good predictive power following ABI with more predictive ability than site of injury, age, CT abnormality or surgical intervention (Bishara, Partridge, Godfrey, & Knight, 1992). Other research has found relationships between depth of coma and severity of cognitive impairment one year post- injury, (Dikmen, Machamer, Winn, & Temkin, 1995). These results, however, found such variance within the severity levels that the authors had to conclude that cognitive performance could not be accurately predicted by severity of injury. Studies have suggested that the GCS is more than capable of accurately predicting outcome at either end of the severity scale but is not sensitive enough to discriminate between the less severe impairments (perhaps due to its weak internal validity) (McCullagh, Ouchterlony, Protzner, Blair, & Feinstein, 2001; Koch et al., 2000).

Although the GCS is a helpful assessment and in practice is frequently used in the acute stage, there are weaknesses to it that may relate to the variance in prediction scores that have been found. A clinical problem that has been reported is down to the inter-rater reliability. Whilst the rules for scoring the GCS are clear; in practice problems have been found within the clinical setting (Koch et al., 2000). The variance in reliability has been shown to be due to other factors that have contaminated the presentation of the patient (Stambrook, Moore, Lubusko, & Peters, 1993). It is often the case that when patients suffer a traumatic brain injury they are under the influence of alcohol or illicit drugs. The GCS score only measures the depth of unconsciousness as a direct consequence of the injury, with no consideration to what factors might be contributing to the score. It is also common that following a traumatic injury, patients may need to be sedated to keep them stabilised – in this situation any GCS score would not accurately reflect the individual's depth of unconsciousness, as a result of their injury. Clinicians also experience difficulty when scoring patients who have a tracheostomy and are therefore unable to verbalise. It is recommended that a 'T' is marked for the verbal response instead of a score, however more often than not, only a total GCS score is reported. Despite these difficulties the GCS is still the most commonly used assessment tool for measuring levels of unconsciousness following head injury and is still used as an indicator of outcome.

Another measure that can be collected at the acute stage and is thought to have prognostic abilities is the length of time that an individual experiences Post Traumatic Amnesia (PTA). PTA can be described as a period of confusion and clouded consciousness following a head injury. There are several scales available that measure the severity of PTA (Galviston Orientation and Amnesia Test (GOAT)

(Levin H., O'Donnell, & Grossman, 1979), Westmead Post Traumatic Amnesia scale (Shores, Marosszeky, Sandanam, & Batchelor, 1986). These were developed to provide an objective view of the individual's orientation to time, place and person and concurrent memory. PTA is most accurately measured if the scales are used consistently over a period of days allowing the clinician to track changes over time (McFarland, Jackson, & Geffen, 2001). Because it is common for an individual suffering from PTA to experience periods of time where clarity of memory and orientation is restored, it is important not to consider someone 'out of PTA' unless they have scored above the cut-off for three consecutive days (Shores et al., 1986).

Like the Glasgow Coma Scale, Post Traumatic Amnesia assessments provide a total score allowing for a clear determination as to whether a patient is above or below the cut-off. More recently studies are beginning to take notice of the direction of recovery i.e. the order of recovered symptoms. This hierarchy of symptoms should allow for a clearer understanding of each patient's recovery (McFarland et al., 2001).

PTA has been found to be very useful in predicting outcome after head injuries, (Bishara et al., 1992). Unfortunately the standardised scales are not commonly used in hospital settings, and this will often mean that the hospital staff have to make subjective determinations about whether the individual is suffering from PTA or not. These estimations weaken the understanding of the individual's rate of recovery. Clinically, it has also been observed that conducting assessments regarding orientation to time and place is difficult to do in a hospital setting. This is because it is not uncommon for people who are not experiencing PTA to forget what day of the week it is, or which county the hospital is in, so the hospital environment either masks or exacerbates the symptoms. Some questions that are included on the GOAT referring to recollection of how the individual got to hospital and what they recalled just prior to the accident are also clinically meaningless as it is rare that people are ever able to recall this information. People frequently either guess or provide information that they have been told; making it no longer an assessment of memory, but of logical reasoning.

Clinical experience has established that it is rare for standardised PTA scales to be used as routine by hospital staff in the acute setting. This means that information which has valuable predictive power in relation to outcome is lost. Often it is only when the individual is being seen by a specialist brain injury team that this information is collected, or perhaps a retrospective estimation is attempted to be calculated, which is often far from accurate. This makes a measure of PTA difficult to use as an outcome predictor.

1.4.1 The Role of Cognitive Assessment to Predict Outcome

Neuropsychological assessments are frequently used to guide estimations of severity regarding outcome, despite not being designed for that purpose. Although cognitive tests were not designed to measure outcome, it is understandable why clinicians and researchers want to investigate cognitive function. There is a logical relationship between cognitive impairment and its impact on day-to-day ability. Research investigating the relationship between cognitive impairment and functional activities has found that people with good intellectual ability, memory and learning are more likely to be independent in managing personal finances, and require less environmental structure and assistance (Farmer & Eakman, 1995). The authors found that many cognitive functions (e.g. immediate verbal memory, attention, abstract reasoning and fine motor coordination) were not significantly associated with successful completion of instrumental activities of daily living (IADLs) (for example managing money, driving, preparing a complex meal), although verbal processing was. The authors concluded that these certain cognitive functions may be easier to compensate for and that cognitive function alone is not enough to predict functional outcome.

Other research (Kibby, Schmitter-Edgecombe, & Long, 1998) explored the ecological validity (ecological validity refers to a test's ability to reflect real life functioning) of some neuropsychological assessments (the Wisconsin Card Sorting Test and the California Verbal Learning Test) and found that the measure of perseverative responses predicted occupational status rather than job performance. This is an interesting finding, and suggests that some assessments do have a role in predicting ecologically valid outcomes, although possibly small facets of outcome as opposed to overall function.

Further research investigating outcome for people with different severity ratings of brain injury between six and twenty-four months post-injury found that there was a positive relationship between severity of injury and level of cognitive impairment (Hellawell, Taylor, & Pentland, 1999). The authors' view was that cognitive impairments are indirect markers that reflect functional outcome, as opposed to being measures of outcome themselves. This conclusion re-emphasises the utility of neuropsychological assessment as a guide to impairment, rather than as an end point that reflects the individual's outcome. Colantonio et al (2004) further supported this by concluding that cognitive impairment was related to activity limitation. Their research also found a significant correlation between the individual's self rated health and Instrumental Activity of Daily Living. Ezrachi et al (1991) found that cognitive functions were the best predictors of employability prior to a rehabilitation programme, but that after the programme the best predictors of outcome were acceptance and measures of awareness. Cognitive factors that also predicted post-programme outcome were visual processing and verbal categorical reasoning.

1.4.2 Emotion and Outcome

In a ten year follow up study Hoofien et al (2001) concluded that there are permanent difficulties following brain injury. The employment rate of brain injured individuals was lower than the national average, although the authors comment that it was higher than other studies have found. Common types of employment were usually low level clerical and work stability was found to be generally low. With regard to predicting outcome, the authors investigated four functional aspects; vocational, family, social and independence in activities of daily living (ADL). The first three were found to be related to psychiatric symptoms and not to intellectual abilities, whereas only independence in ADL was related to IQ and not psychiatric symptoms. The authors concluded that the factors which influence long term disability are more related to psychiatric and behavioural difficulties rather than cognitive aptitudes and abilities. This finding is supported by the research mentioned earlier (Ezrachi, Ben, Kay, & Diller, 1991) which found that acceptance and awareness were the most efficient post-programme predictors of both employability and work status.

1.4.3 Other Factors Related To Outcome

A recent investigation (Ownsworth & McKenna, 2004) reviewed fifty empirical research studies to assess which are the most consistent predictors and indicators of employment outcome. They identified that the best predictors are pre-morbid occupational status, functional status at discharge, global cognitive functioning, perceptual functioning, executive functioning, and involvement in vocational rehabilitation as well as emotional status.

1.5 Rehabilitation and Outcome

Rehabilitation has been defined in terms of a concept and a service. The concept is the

> "Process of active change by which a person who has become disabled acquires knowledge and skills needed for optimal physical, psychological and social function."

The service is the

> "Use of all means to minimize the impact of disabling conditions and to assist disabled people to achieve their desired level of autonomy and participation in society"

Cited in (British Society of Rehabilitation Medicine et al., 2003).

Rehabilitation in brain injury is an important concept to discuss. As with the term outcome, 'rehabilitation' will have different meanings in different settings. The definition of 'rehabilitate' in the Oxford Dictionary (Oxford University Press, 1997) is "to restore to effectiveness or normal life by training, especially after imprisonment or illness". In brain injury this definition can be misleading. As the impact of a brain injury can be physical, cognitive, communicative, emotional and behavioural, it is important to be clear to family and Service Users about the purpose and limitations of rehabilitation. Clinical experience has shown that during the initial stages of recovery, families and Service Users are most keen to fix what is obviously changed, e.g. physical impairments, speech difficulties, and epilepsy. It can often be in these areas that the best results are seen. It can be at this point that the more debilitating cognitive, emotional or behavioural impairments surface, and the true impact that the brain injury has had, becomes known.

Rehabilitation comes in different shapes and sizes and as such there is a great deal of conflicting information regarding the efficacy of different styles of intervention. Despite the differences in the packages, the ultimate goal is frequently reported as aiming to get the individual back to the roles they had pre-injury where possible. Butler et al (1989) report that this usually entails vocational readjustment or rehabilitation. More recently Sorbo, Rydenhad et al (2005) recommended using the new ICF to set goals, and tailoring their rehabilitation package to each individual's needs.

In reaction to the rising pressure on the NHS to streamline finances in the public spending budget there has been a recent surge in interest in the efficacy of rehabilitation and when it is best to implement these packages. Once again, the findings have been mixed, e.g. Sorbo and colleagues (2005) asked 'What makes the difference in outcome after severe brain damage?' Their research concluded that outcome was helped by early-formalised rehabilitation; a continuum of care and a long-term follow up. Early formalised rehabilitation was defined as "...formalised interventions by a specialised brain injury rehabilitation team within fifty days...", and outcome was assessed at two years post injury in the form of interviews, clinical features, Functional Independence Measure (FIM) (Keith, Granger, Hamilton, & Fielder, 1987), Glasgow Outcome Scale (GOS) (Jennett & Bond, 1975) and Extended GOS (Teasdale, Pettigrew, Wilson, Murray, & Jennett, 1998). The vague definitions of rehabilitation unfortunately do little to guide clinicians, as they fail to quantify levels of intensity or focus of rehabilitation. As this research was set in a hospital environment they relate to very specific and limited goals set by professionals as opposed to Service Users themselves. The difficulties arising from the semantics of 'outcome' are illustrated here; outcome is measured from a very functional perspective with little attention paid to the individual's experience of getting back to their old roles.

Recent research has attempted to answer the frequently asked question of 'When should rehabilitation be commenced and what should it look like?' (Chesnut et al., 1999; Bajo & Flemminger, 2002). Both studies concluded that the available evidence is unclear and insufficient to create national guidelines or standards. Bajo and Flemminger's research indicated that some areas of dysfunction have an obvious focus for rehabilitation e.g. physiotherapy for hemiplegics etc, but that in the domain of cognitive and behavioural problems there is little consistent information available. One thing is unfortunate but certain; the cost implications of specialised inpatient rehabilitation means that it is becoming more and more important to ascertain the efficacy of these services and whether the outcome they achieve is worth the cost to the fund holders.

These are interesting points, but not questions that will be addressed directly by this research. The efficacy of rehabilitation services is an important topic but, as all of the participants in this research will have undergone different rehabilitation programmes and will be at differing stages of recovery; this topic is beyond the remit of this study. It is hoped that this research will be able to add to the evidence base in predicting who may be best placed to benefit from rehabilitation, by investigating the measure of learning potential; this will be discussed in more detail in section 1.8.

As the focus of this research is on understanding the impact of cognitive impairment following an ABI, a following section (1.7) will outline the current models that are used to reflect normal cognitive function. This is with a view to understanding the theoretical and practical implications of impairment in each domain. Prior to this, however, section 1.6 will explore the differences in meaning between outcome and recovery and provide a definition that will be applied to this research; this is felt particularly prudent in light of the difficulties highlighted earlier in relation to the studies measuring and predicting outcome.

1.6 Outcome versus Recovery

This chapter has discussed some of the limitations of using the term 'outcome' following an ABI. It has shown the importance of prognosis in guiding clinicians, Service Users and their families towards realistic expectations of future functioning. The current evidence base has shown that factors which predict outcome often centre around the severity of the injury or its resulting cognitive impairment. These variables have been shown to have relationships with outcome but there are often inconsistencies in findings which cannot account for the recovery rates of some. This research suggests that the evidence base has failed to comprehensively account for outcome because it has failed to consider the individual and what they bring to their recovery process.

A model that has been developed in the mental health setting which takes a much more person-centred approach is Anthony's (1993) recovery model, where recovery is defined as:

> "...a deeply personal, unique process of changing one's attitudes, values, feelings, goals, skills, and/or roles. It is a way of living a satisfying, hopeful, and contributing life, even with limitations caused by the illness. Recovery involves the development of new meaning and purpose in one's life as one grows beyond the catastrophic effects of mental illness." (p.19)

In the recovery model it is the individual's responsibility – where possible, to enable change by firstly being insightful into their impairments and secondly to be willing to want to work towards their recovery. It puts an onus on the individual to take an active role in their recovery, shifting the focus of control back to the individual rather than to external agencies such as medical and health professionals. It requires the individual to step out of the sick role, and work on developing their self-awareness and self-acceptance (Darton, 2002). Where an individual cannot show insight into their impairments they cannot show a willingness to work towards recovery and therefore the recovery model does not apply. In these situations, an individual cannot be abandoned and must be cared for until they are ready to take the first two steps (Munetz & Frese, 2001).

An individual with insight into their impairments, and how these impact their ability to carry out daily activities, is likely to be motivated to change. If they have more control over their rehabilitation programme, e.g. being involved in designing it, choosing how they receive it, they may be more committed to it. In the mental health settings the recovery framework is embraced by psychologists whenever they "assist a person in realising his or her potential as a unique human being who is not defined by an illness" (Frese & Davis, 1997). It could therefore be seen as the role of the health professional to enable the individual to understand their impairments and to show them their limitations and capabilities. Perhaps more importantly it is essential for the professional to determine the level at which to tailor the intervention. This should be dependent on the individual's readiness to change (Prochaska, DiClemente, & Norcross, 1992), as well as their potential for development (Darton, 2002). With this in mind it is possible to show an individual how much they can live outside of their impairments rather than how their impairments restrict them.

Although this model is designed for individuals with complex and enduring mental health problems, it sits comfortably with the evidence that has shown that self-awareness and acceptance are moderating factors for predicting outcome (Ezrachi et al., 1991) and that interpersonal psychiatric symptoms – such as depression, loneliness and sense of burden, affect outcome (Hoofien et al., 2001). The Recovery model works from a person-centred approach and can therefore be used to conceptualise recovery and outcome following acquired brain injury. This is further reinforced by Newnes (2006), a clinical psychologist who suffered an ABI and described his process of recovery as "a new way of seeing himself as he was and is". Newnes asks the question “Do we recover, or do we move on, assimilate, or adjust?” (p.48)

1.6.1 Factors that influence recovery

Factors other than those relating to the severity or impact of an acquired brain injury have been shown to have an influence on recovery. These include pre-injury lifestyle such as productivity and education, and socioeconomic status (SES), as well as misuse of alcohol and drugs.

Research has found support for each of these as having a moderating effect on outcome, with each factor influencing certain aspects of it. For example Hoofien, Vakil et al (2002) found that SES factors were significantly related to cognitive, vocational, psychiatric and social outcome, whereas acute measures of severity were related most to functional outcome.

Research investigating the impact of drug and alcohol misuse has found that intoxication at the time of the injury has implications regarding length of stay in hospital and is correlated with poorer discharge status. A history of substance misuse has an influence on mortality rates and poorer neuropsychological outcome (Corrigan, 1995; Kelly, Johnson, Knoller, Drubach, & Winslow, 1997; Solomon & Malloy, 1992). Substance misuse following ABI can also complicate recovery (Bombardier, 1995).

1.7 Cognitive Impact of Brain Injury

As this research aims to investigate whether a measure of learning potential is useful in predicting recovery, it is important to outline the factors which could affect learning ability. Therefore this section will be dedicated to outlining a range of cognitive functions that may be compromised following an ABI, as well as what impact these can have on functional ability. A current and appropriate model will be applied to each of the cognitive functions to outline the theoretical and practical issues that they create. Cognitive and neuropsychological models have been chosen as they best guide professionals to understand normal and impaired cognitive function, along with the implications of managing them. They ensure that we can explain, understand and predict performance in different domains (Wilson, 2002). Outlining these models of cognitive ability will guide the expectations of function and how this can impact on recovery as well as affect learning potential.

The range of cognitive functions is vast and overwhelming and often different terms are applied to the same ability. There appear to be an almost infinite number of models which all seem to describe a miniscule element of ability. Whilst all of them have an important part to play in understanding cognitive function, they are not all helpful for this research. On this basis it was decided that broad areas of cognitive ability would be covered in a cursory fashion. Particular attention will be paid to the dimensions that have a significant impact on functional ability following ABI and those which could play an important part in shaping learning ability.

A useful classification for the range of cognitive functions was outlined by Lezak (2004a), who considered that cognitive function could be broadly categorised into receptive functions, memory and learning, thinking processes and expressive ability. Within these categorisations there are a number of functions which have been represented visually in Figure 1 on the following page.

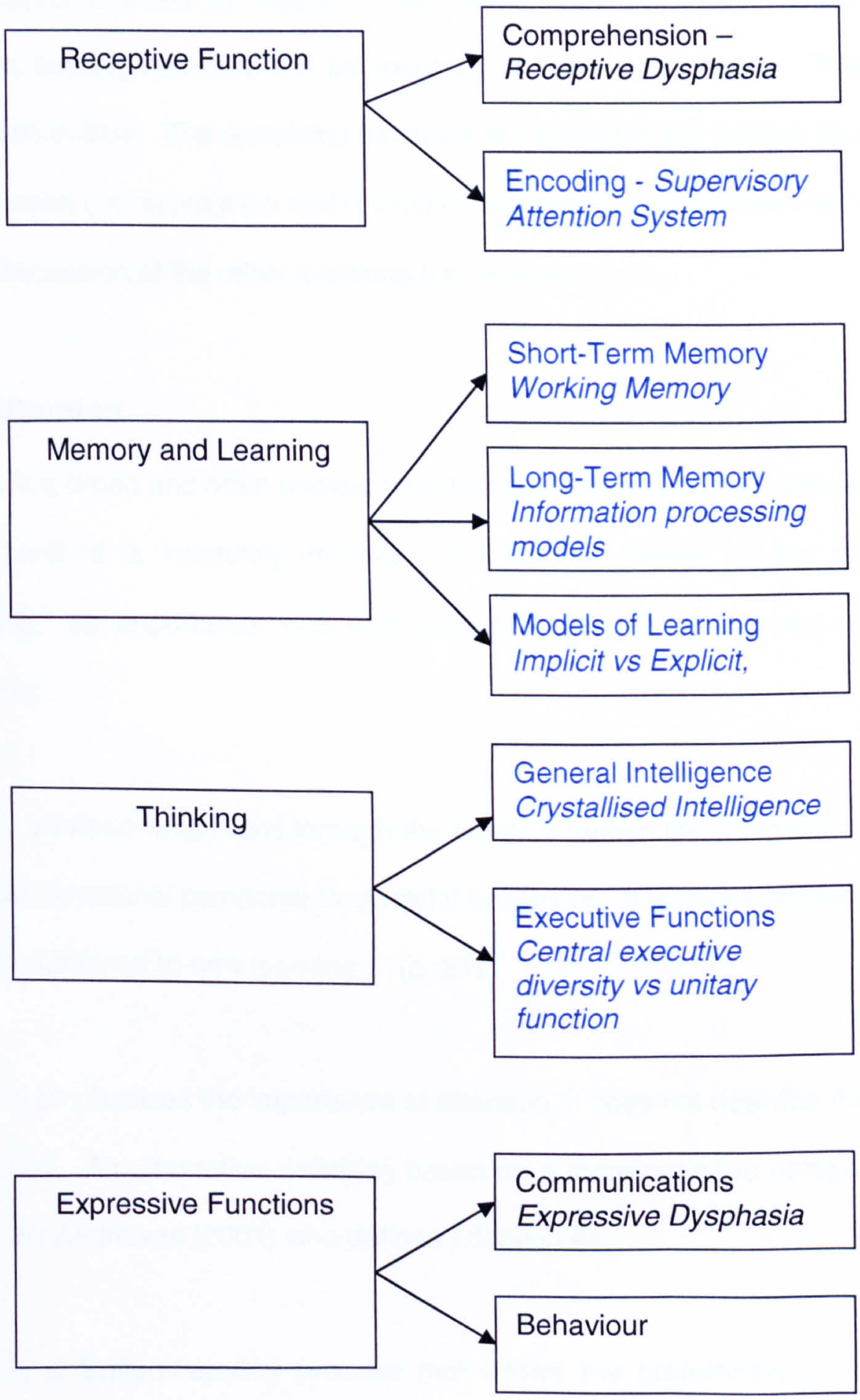

Figure 1: Visual Representation of Lezak's Classification of Cognitive Function, with models chosen to represent each function.

The functions outlined in Figure 1 that could have an effect on the patient population investigated here will be explored in more detail below. These have been shown in blue. The remaining functions are those felt not to have an effect on this population (i.e. expressive and receptive dysphasia), or that have been covered through discussion of the other functions (i.e. behaviour).

1.7.1 Attention

Attention is a broad and often unclear term that has never been well defined. On an intuitive level, it is incredibly important and has an impact on the majority of functioning. Its importance was well outlined by Wood (2005) who wrote that attention is:

> "...a thread which runs through the fabric of human life, integrating cognitive and emotional components of social behaviour. It is also a process which is fundamental to new learning..." (p. 218)

Whilst this emphasises the importance of attention, it does not describe the process in any detail. An alternative definition based on a more cognitive perspective was provided by Andrewes (2001) who defines attention as:

> "... a limited-capacity process that allows the preferential processing of certain sensory or imaged information at the expense of other stimuli" (p. 204)

Attention appears to consist of several subcomponents, which are not entirely distinct, but can be separated. These subdivisions consist of selective, divided and sustained attention and processing speed.

1. *Selective attention* refers to one's ability to choose what is being attended to; impairments can result in problems with distractibility and inability to focus.
2. *Divided attention* refers to an ability to focus on two tasks at once; impairments here can result in people having problems multi-tasking.
3. *Sustained attention* refers to one's ability to maintain attention for long periods of time. Impairments with this system can leave people feeling fatigued more easily, slowing down and becoming more error-prone if forced to concentrate over long periods.
4. *Processing speed* refers to an ability to apply oneself for a period of time (and the relative speed that a task can be completed within that time). Impairments in this area of function will mean that people function at a slower level than they would have pre-injury.

Even though it has long been recognised that attentional disorders reflect a variety of mental and neural processes (Posner & Petersen, 1990), these processes remain poorly understood. Being able to attend to events is essential for intentional learning. Those with attentional impairments are unable to allocate cognitive resources adaptively. Attention drives the flow of information processing and facilitates, enhances or inhibits other cognitive processes. This means that attention can both drive us toward and withdraw focus away from particular issues. This then allows other issues to be effectively focused on. The primary function of attention is to select information which may be required for further processing and allow us to respond in ways which are in line with the demands of the task.

Attention and the Evidence Base

Research in the field of attention has focussed on understanding how our brain chooses what to attend to (i.e. how do we pick which bits of sensory information we want to focus on?), as well as theorising whether our attention systems work by enhancing relevant information or inhibiting information that is deemed not important. It is commonly accepted that the attention system does in fact do a bit of all of these (Treisman, 2004), depending on the goal and the circumstances.

With regard to how information is attended to, theories have suggested that sensory information can be processed early (e.g. sound) or late (e.g. meaning). Research conducted by Lavie (1995) concluded that the attentional system is capable of attending to information by both means and that this is dependent on the perceptual load, i.e. the more there is to focus on, the less meaningful the analysis (supporting early selection) as opposed to when there is less to focus on (meaning more in depth analysis can be carried out).

Triesman (2004) suggests moving away from an information processing model, where attention is represented as a component of a 'pipeline' along which information flows. She suggests a more interactive system, with re-entry and parallel streams of information being analysed. Her research attributes the ventral areas of the brain for processing "what" information and the dorsal areas for processing "where" information.

Other neuropsychological studies have attempted to identify which areas of the brain are responsible for what functions. Humphreys & Samson (2004) consider the dorsolateral prefrontal cortex as a store for holding information online. Posner & Petersen (1990) identified an 'anterior attention system' in the frontal lobe which they felt played a part in the detecting role of attention and sub-serve semantic associations. They identified a 'posterior attention system' involving the parietal lobe and cortex playing a key role during visuospatial attention. Reisberg (1997) concludes that the parietal cortex is necessary for disengaging or switching a task and that the 'anterior attention system' appears to have a role in co-ordinating and keeping track.

It is generally accepted that attention is viewed as a limited resource, with competition between stimuli putting pressure on ability to perform at optimum level. This is more transparent when both tasks are novel and therefore require effortful processing as opposed to a familiar task which might be carried out automatically. Attention that is elicited automatically with little effort on the basis of everyday environmental cues can be categorised as being 'automatic'. Schneider and Shiffrin (1977) consider automaticity as a sequence of activation which occurs in response to a particular stimulus, thereby requiring minimal effort and negligible conscious processing. In contrast, controlled processes will be a new sequence of activation that is under the conscious control of the individual and, as such, has a limited capacity. The advantage of the controlled processing is that in situations which require considerable task flexibility they are capable of being manipulated and altered. They are initially applied in novel situations where automatic sequencing has never been learned.

For the purpose of this research the Controlled and Automatic Processing model will be used to further the understanding of attention.

1.7.2 The Working Memory Model

Working Memory (Baddeley & Hitch 1974) is the system that allows information (of a limited capacity) to be held active or "on-line" whilst other cognitive functions are being executed. Within the original Working Memory model there are three distinct systems; the central executive and the two slave systems; the phonological loop and visuospatial sketchpad.

This model was originally developed to account for some of the inconsistencies that were found within the then models of Short Term Memory (Atkinson & Shiffrin 1968). It attempted to explain the relationship between types of encoding and Long Term Memory and why it was possible to have an impaired Short Term Memory but intact Long Term Memory (which does not fit an information processing model).

The Phonological or Articulatory loop has been the most researched of all the systems and is thought to be responsible for managing incoming verbal information, it has two parts; an active store where information is rehearsed and processed for storing in the memory systems and a passive store which temporarily accumulates articulatory information. The Visuospatial Sketchpad stores information about appearance and spatial components and possibly kinaesthetic components as well (Baddeley, 2000).

The role of the central executive is to supervise or co-ordinate these two slave systems and there has been much debate about how it does this and what relationship there is between this and other cognitive functions. Researchers have found evidence that the dorsolateral prefrontal cortex plays an important role in the management of the Central Executive System (CES), (McDowell, Whyte, & D'Esposito, 1997; Faw, 2003). As the Central Executive has a lot of organisational elements to it, the relationship between working memory and executive functions has been investigated. Working memory has been described as a system that can be fractionised, e.g. into focusing attention, switching attention, activating representations in LTM, coordinating multiple task performance (Gilhooly, Wynn, Phillips, Logie, & Della Sala, 2002), many of the skills that are often used under the umbrella term of executive functioning. In predicting performance on tests of executive function, the role of working memory and inhibitory processes were found to account for a successful completion (Zook, Davalos, DeLosh, & Davis, 2004). However in another study (Parente, Kolakowsky-Hayner, Krug, & Wilk, 2001) no correlation was found between measures of working memory and a test of executive function. The authors concluded that there is not an obvious relationship between working memory and the role of managing, prioritising, sequencing and optimisation. Kimberg & Farah (1994) report that damage to the frontal lobes (often regarded as the seat of executive function) weakens the association among working memory representations with different elements of working memory being found in different parts of the frontal cortex. Handley, Capon et al (2002a) found that the CES was involved in a wide range of deductive reasoning tasks. Using the Tower of Hanoi (ToH), they identified that the visusospatial sketchpad plays a role – whereas the phonological loop does not. Research into the properties of the Working Memory Model and how it accounts for cognitive impairment has shown that although it does not correlate with learning and retention, it is a predictor of both (Parente et al., 2001). Authors concluded that working memory is therefore an early stage of information processing as opposed to a short term memory storage vault.

In a review article Baddeley (2000) summarised some research that does not sit well with the original model (e.g. there is evidence that the two slave systems are somehow interlinked because when verbal information is visually similar, it is better recalled. Meaning also has an affect on the ability to recall sentences and prose passages). Baddeley subsequently added a fourth component to the model called the episodic buffer (please refer to Figure 2 for a representation of this model). This buffer is also controlled by the Central Executive and like the other two slave systems has limited capacity; however, in addition to this it can integrate knowledge from a variety of sources. The information that this buffer holds contains information about space and time and is thought to feed into and retrieve information from the Long Term Episodic memory.

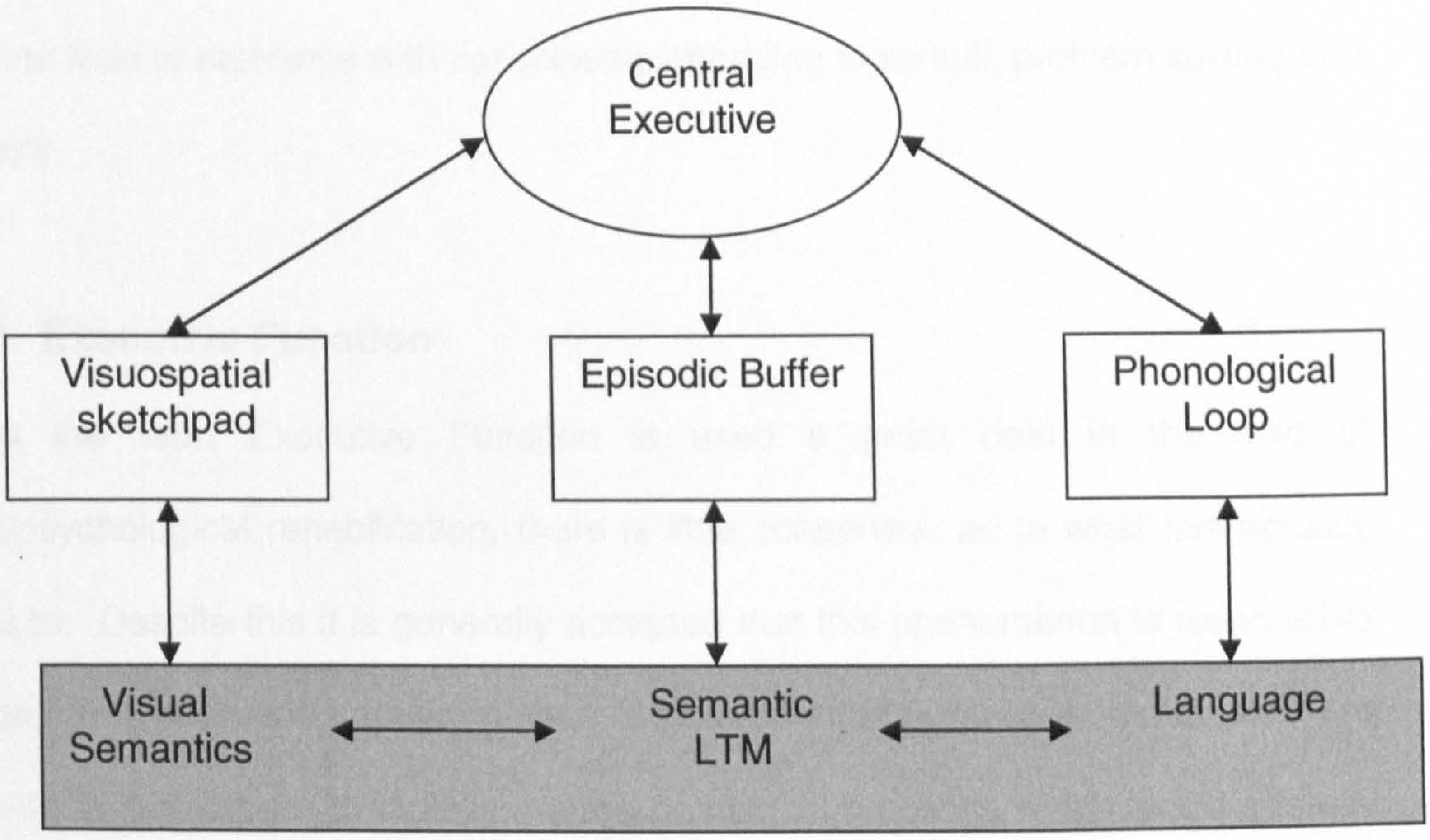

Figure 2: A Visual Representation of the Revised Working Memory Model According to Baddeley (2000)

This model is supported by research (Handley, Capon, Copp, & Harper, 2002a) which found that although working memory can be seen as fitting a multiple resource model, it is best explained when you allow the three factors (Central Executive, phonological loop and visuospatial sketchpad) to correlate, suggesting that they are linked in some way. In the original model this was not possible as the visuospatial sketchpad and phonological loop are distinct and cannot interact.

Their research suggests that the role of the working memory has far reaching consequences and is integrated with several other cognitive functions. There appears to be considerable overlap between functions such as attention and executive function although working memory seems to be distinct from them. Impairment in the working memory system will have an impact on the ability to actively hold and manipulate information, which in turn will influence how well information can be encoded, stored and retrieved. Therefore impairments in this field can lead to problems with consciously attending to stimuli, problem solving and memory.

1.7.3 Executive Function

Whilst the term Executive Function is used a great deal in the field of neuropsychological rehabilitation, there is little consensus as to what this actually refers to. Despite this it is generally accepted that this phenomenon is responsible for the formulation and implementation of goal oriented behaviour. What skills are involved in this appear to include a large number of functions which share a family resemblance i.e. planning, organisation, controlled behaviour (e.g. inhibition), flexible thought and monitoring. Impairment in executive function can influence either discrete or a broad range of abilities. The result of this impairment can be problems with cognition i.e. planning and reasoning or perhaps more obviously with behaviour, such as inhibition and impulsivity, the impact of which can carry considerable risk to the individual.

The model that is felt most suitable for this research to account for the complexity of the Executive Function System is the Supervisory Attentional System (Norman & Shallice, 1986). Interestingly, this model was proposed by Baddeley as one that could explain his Central Executive System for the Working Memory Model. The CES as previously mentioned shares many of the functions that are incorporated under the Executive Function role, which highlights how these systems can be connected and are not distinct. The SAS model accounts for behaviour in different situations by suggesting that certain triggers will activate 'action schemas' which inform our response. In routine situations this process is automatic and requires no 'thought', in situations where there are more than one schema that could be activated, the authors describe how a 'Contention Scheduling' system chooses which of the competing schemas should be activated. Monitoring this process is the 'Supervisory Attentional System' which ensures that the contention scheduling process is activating the correct schema (i.e. when automatic behaviour should be overridden) or in novel situations where there is not an appropriate schema to activate and a new one needs to be generated. The inability to override an 'automatic behaviour' could be thought of as perseveration in frontal lobe dysfunction.

There has been considerable disagreement about whether to label executive function as a unitary system or a set of diverse and dissociable functions, with evidence coming from both camps. Kimberg & Farah (1994) are often cited as supporting the unitary system of executive function, attributing the dorsolateral prefrontal cortex (DLPFC) as the seat of this system. They concluded that it is possible that within the DLPFC there may be distinct functions but that they all have an overall connection. They attribute the dissociations that have been found in tests of executive function to the weakened associations which are created by frontal lobe lesions. These associations connect different representations in part of working memory that was labelled by Goldman-Rakic (1998) as 'representational memory'. Frontal lobe lesions, according to Kimberg & Farah, affect the unitary frontal lobe's ability to access different representations. Miyake et al (2000) conclude that executive functions are both diverse and belong to a universal system. Their research found that the three functions they assessed (shifting set, updating, and inhibition) were all distinguishable but not completely independent. They sensibly point out that as the role of the executive functioning system is to drive and direct all other cognitive functions, no test taps into executive function in its entirety and independent of any other ability. They conclude that poor performance on one test does not justify a conclusion that the individual has executive impairment. They also criticise tests of executive function because often they are validated on the basis of frontal lobe function (assuming that only frontal lobe damage will result in executive dysfunction) whereas people have shown executive difficulty without frontal lobe lesions. Further criticisms of tests of executive function come from Manchester and colleagues (2004), who suggest that the testing environment is so artificial that it might actually mimic the role of the Central Executive itself (e.g. the examiner tells the person what to do which is unlike real life).

In an attempt to bring more detail to what happens to the 'Supervisory Attentional System' (SAS) during a novel situation Shallice, Burgess & Robertson (1996) provide evidence that the SAS is not unitary in that it carries out a single function, but that it could be seen as unitary because it has a collective group of subsystems which all work towards a globally integrated function. They go further and attempt to fractionise what occurs in contention scheduling to its basic components. They created three stages that occur when dealing with a novel situation. The first is 'strategy generation' where a new temporary active schema is created. They suggest that strategy generation can be spontaneous, can come from problem solving, or can consist of special purpose processes (formation and realisation of intentions or episodic memory retrieval). The second stage is where the process that is required to implement the new schema is developed and the final stage monitors this process and makes adjustments if necessary. The processes that occur within these stages are subsystems of the SAS and they moderate contention scheduling.

An interesting finding is that typically tests of executive function are not related to intellectual ability. Duncan et al (1996b) hypothesised that this may be because some subtests of these intelligence tests provide information about crystallised knowledge, i.e. what is already known, whereas others provide information about fluid intelligence (i.e. creative intelligence) such as the WAIS subtest 'progressive matrices'. The authors consider fluid intelligence the more meaningful measure and suspected that executive function abilities are related to this. Their research found that in terms of what affected the shaping of a particular behaviour, this was goal neglect (i.e. being able to identify what is required but not doing it). They concluded that the factors which affect this are novelty, weak feedback and multiple concurrent concerns. Their studies found that there was a relationship between fluid intelligence and executive function and the authors concluded that they are in effect the same thing.

1.7.4 Memory and Learning

To the lay person the words learning and memory are often interchangeable; however for the purpose of this research these functions are not the same thing and will be defined and distinguished in greater detail below. This research will view learning as the process of acquiring information or skill and will see memory as the product of this learning process. The following sections will outline the types of information that can be stored, and the theories behind how this information is categorised. There will then be a detailed description of the model of learning that has been chosen for this research to aid understanding of the processes and systems that are involved in learning.

Memory is typically separated into three functions, the ability to encode, the process of storing and the ability to retrieve information. The encoding process refers to the way that information enters into our long term memory system. Using the Modal Memory System (Atkinson & Shiffrin, 1968) information is filtered by a sensory register and then sent on to the short term memory store. It is in this store that information could be rehearsed so that it would enter the long term memory store. Other views arose when evidence was found that these two types of memory were dissociable. The Levels of Processing model (Craik & Lockhart, 1972) states that learning is dependent on how much thought is given to the information (how deeply it is processed). This theory was weakened, however, as there were problems around how to measure depth of processing, as well as evidence that information could be recalled that had not been attended to deliberately.

1.7.5 Long Term Memory

Information is thought to be stored in the Long Term memory via different encoding systems. Two common stores are for information that is Declarative or Procedural. Declarative Memory relates to stored factual information. It can be further subdivided into information relating to facts (semantic), information relating to a contextual time, or events (episodic). It can also include autobiographical information relating to the individual's life (however this will not be discussed in any detail as it does not relate to this research project). Procedural knowledge has been referred to as 'how to' facts. This is thought to relate more to the types of information that are less easily expressed verbally and often are less conscious.

For this reason it is often thought of as implicit knowledge. The types of information that can be stored in the procedural memory system are physical activities that have become automatic (e.g. driving a car or swimming). It is thought that the basal ganglia and cerebellum affect the ability to store information procedurally (Goldberg, Saint-Cry, & Weinberger, 1990).

1.7.6 Retrieval

Studies of retrieval can provide good insights into the processes that are employed in the storage of information, yet considering its importance there has only been a relatively small amount of published information concerning it. Whilst it is understood that there are different types of long term memory systems (e.g. semantic and episodic), it is also important to understand the way that this information is stored within each information system. The most popular theories have focussed on the declarative memory systems. The ability to retrieve information is often compared to a library. The vast array of information stored needs to be catalogued in a meaningful way in order for this information to be found again. The theories that are currently used to articulate semantic memory are expressed through the neural and computational models where memories are represented as chunks of information that are networked together. Original models (e.g. Quillian's Teachable Language Comprehender,(1969)) were based on hierarchical systems. There are now however, more flexible network structures, and associations can be seen as being strong or weak (allowing the system to express the fact that memories can be connected with varying strengths). These types of systems began as the Spread of Activation Models (Collins & Loftus, 1975). The Parallel Distributed Processing model was first introduced by McClelland & Rumelhart (1988). It is proposed that within the brain there is a combination of networked units. These units are activated in response to certain stimuli and become organised into modules. The units within each module are highly connected and communicate within other modules. With regard to accessing these stored pieces of information, a cue is required (external; from the environment, internal; as a controlled search, or due to the proximity of that information to something currently activated). Each time this information is activated, it is strengthened and the threshold required to bring it 'online' is reduced. It has been questioned as to whether these units can be mapped directly onto the brain and if they represent neurons. The authors felt that a unit is likely to be a number of activated neurons and perhaps the information is stored in the trace (of fired neurons) as opposed to in the neurons themselves. This suggestion is similar to the consolidation system discussed by Andrewes (2001) whereby certain areas in the cortex are assumed to be altered when information becomes part of the long term memory system. Within this suggestion Andrewes makes mention of Hebb's (1949) theory of a cell assembly, where a group of brain cells are habitually fired in a particular way resulting in them changing in structure. This change allowed a better strength of firing and thus resulted in a permanent circuit (which was the memory).

Despite there not being a comprehensive model that accounts for Long Term Memory Storage and Retrieval it is thought that these connectionist models provide the most interesting and helpful ways of viewing memory. These new models are appealing because they move away from a pure cognitive model of memory and towards a neuropsychological perspective. They go beyond the box and arrow techniques often applied and provide real-time evidence that accounts for how memories are created, stored and retrieved.

1.7.7 Learning

Before applying a model of learning it is best to begin by defining what learning is. If memory is to be thought of as a product of learning, then learning must be the process (both active and passive). Whilst in cognitive psychology learning is often thought of as the process related to memory, it also applies to social learning and classical conditioning, and so the definition should be inclusive of these. A comprehensive definition of learning has been outlined by Lachman (1997): -

> "Learning is the process by which a relatively stable modification in stimulus-response relations is developed as a consequence of functioning environmental interaction via the senses."

Learning can be characterised according to whether it was done actively (explicit learning) or incidentally (implicit learning). These models of learning serve this research well as there is a good evidence base that although they are interacting and co-operating parts of the same system (Reber, 1993), they are relatively dissociable (Shanks & St.John, 1994) and that implicit learning is more robust to brain injury than explicit learning (Kessels & de Haan, 2003; Glisky & Schacter, 1989; Glisky & Schacter, 1987; Evans et al., 2000).

It has been suggested that the distinguishing factor between explicit and implicit learning is the role of declarative knowledge (Kirkhart, 2001). Kirkhart's study found that the ability to express information declaratively on an explicit task determined the accuracy of success and therefore served as a guide during learning, but for an implicit task it did not.

Implicit learning has been described as less conscious learning, this is because learned associations can occur without the individual being aware of it. It has been suggested, however, that just because an individual cannot verbalise information, it does not mean that it was unconscious (Shanks et al., 1994). Researchers into this field stress the importance of removing all the explicit elements which could be impacting performance (Reber, 1993). It should also be as clear as possible that there is a causal relationship between the implicit knowledge being measured and the thing which is responsible for the change in behaviour (as opposed to other explicit factors) (Shanks et al., 1994).

Implicit learning is thought to be the default system used in learning and it acts as the foundation process for the development of tacit knowledge (Reber, 1993). It is also thought of as decaying less easily over time, when compared to explicit knowledge, and does not appear to be related to the depth of encoding (Berry & Dienes, 1993). A possible weakness of knowledge learnt implicitly is that it can only be accessed in certain ways. This means that it is not best assessed in forced choice and free recall situations (which are best suited to declarative knowledge).

Explicit learning can be thought of as the process of encoding and storing all other forms of information. It is thought of as more active because the individual is more consciously aware of the process of learning the information and is able to express it more easily. In a similar way to impairments of executive function, impairments in explicit learning can have a broad or discrete impact on the individual. Explicit learning can be affected overall, which would result in the individual struggling to encode and therefore recall any new information. Alternatively discrete aspects of explicit learning could be affected, such as only visual or verbal information.

Implicit learning will be discussed in the context of the errorless learning technique in more detail further on in this chapter (section 1.12).

1.8 Learning Potential

The previous sections have outlined the impact that an acquired brain injury can have on cognitive functioning. As the connection between cognitive impairment and functioning is both intuitive and epistemologically verified, it is very common in the field of neuropsychological rehabilitation for a comprehensive battery of cognitive assessments to be completed to build a cognitive profile. This can aid the prediction of potential difficulties that an individual may encounter in their life. The range of neuropsychological assessments available today is vast and covers every measurable cognitive function. Research in brain injury has found evidence that neuropsychological scores are related to ultimate diagnosis (Lezak 2004), employability (Sbordone & Long, 1996 & Wilson, 1993 cited in Lezac 2004) and functional impairment (Colantonio et al., 2004). In contradiction to these findings, however, further research suggests that measures of impairment do not translate into everyday function (Cicerone & Tupper, 1986), and are unable to provide accurate predictive information relating to the functional outcome of a brain injured patient (Sbordone & Guilmette 1999). Further research has concluded that outcome prediction following ABI is difficult (Bajo et al., 2002; Chesnut et al., 1999). So despite neuropsychological assessment having an important role in informing clinicians about the nature of an individual's impairment, it is unable to account for the variability in outcome that is often seen clinically. This suggests that other moderating factors remain unaccounted for.

One of the weaknesses of applying neuropsychological assessment to outcome prediction is likely to be related to the context in which it was developed. Cognitive assessment was originally developed in the 1900s (Binet & Simon, 1908;

Spearman, 1904) in an attempt to quantify intelligence. After the First World War, when injured soldiers were experiencing difficulties following head injuries these tests were used to aid their diagnosis (Lezak, 2004a). The scores were compared to the information collected from tests on the normal population and so provided normative information to enable a comparison of function and a guideline regarding the nature and severity of the injury.

Until the development of scanning equipment, these neuropsychological assessments, along with observation of behaviour, were the only means of forming a diagnostic opinion (Cicerone et al., 1986). As technology advanced, however, and brought us CT, MRI and fMRI scanning equipment, the cognitive tests became redundant as diagnostic tools (Kibby et al., 1998).

As the need for diagnosis from cognitive testing was removed, neuropsychological assessment began to be applied in informing severity of impairment and in predicting outcome. Assessment scores are applied to a theoretical model of cognitive function and reasoned predictions are made regarding how performance will translate in real life settings. So despite being designed for a different purpose (intelligence testing then diagnosis of injury) these tests were eventually used to predict outcome. Criticisms regarding the lack of ecological validity of these tests began to peak in the 70's and 80's (Hamers & Resign, 1996). Comments centred on the unnatural situation in which tests are conducted, and about how frequently the tests are modified, which affected the standardisation (Sbordone, 2001).

The weaknesses of neuropsychological assessments as ecologically valid tools of outcome prediction are now widely acknowledged (Cicerone et al., 1986; Sbordone, 2001). However, they are still frequently used for this purpose. Instead, researchers suggest that they should be seen as a tool that can provide a snap shot of impaired function following brain injury at the start of the rehabilitation process – much like an x-ray provides an image of a broken bone before treatment. Perhaps if considered this way, neuropsychological assessments could be seen as providing an understanding of how bad the damage is and the type of treatment that will be required in order to compensate for the possible effect it may have. It is the beginning of the process of understanding ability rather than the end. This view point is supported by several researchers, e.g. Lidz (1995), who emphasised that when predicting outcome, a moderating factor to be considered is the treatment that an individual receives. He suggests that diagnosis should be linked to treatment through assessment; using the information that the neuropsychological tests provide to guide treatment rather than as a measure of outcome.

With regard to understanding how much potential a person has for recovery, attention turns to a theory which developed in educational psychology, and that more recently has been applied in different areas of research, e.g. mental health disorders (Woonings, Appelp, Kluiter, Slooff, & van den Bosch, 2003; Wiedl, 1999), learning disability (Campione & Brown, 1987; Budoff, 1987) and brain injury (Cicerone, 1999). The theory is often referred to as 'Learning Potential' or cognitive modifiability and is thought to be measured using a more dynamic style of assessment. Learning potential is a measure of latent ability, i.e. an ability that is dormant and unobservable but that can be tapped into and brought about by a third party. The extent of this latent ability determines the improvement an individual can make in their development through interaction with others. Having this kind of information in the field of brain injury would create a tool that enables a practitioner to accurately assess or predict someone's potential degree of recovery and their ability to engage in and benefit from a rehabilitation programme. Clinically this information would be enormously valuable. It would prevent an individual having to attempt an unfocused rehabilitation programme and fail, and would also allow fund-holders to refocus scarce resources on patients most likely to benefit. Learning ability has been identified throughout the ages as an important factor that tells us about intelligence and adaptability (Guthke & Stein, 1996; Lidz, 1987; Thorndike, 1922; Fernandez-Ballesteros & Dolores Carero Garcia, 1993). The difficulty has always been in how to measure it.

1.9 Dynamic Assessment

Dynamic assessment was developed to address the shortcomings of standard intelligence assessments for school children, and although there has been some debate about who is responsible for this theory, it is most commonly attributed to the work of Vygotsky (Griogorenko & Sternberg, 1998; Sternberg & Griogorenko, 2002) with his theory of the Zone of Proximal Development (ZPD).

1.9.1 Vygotsky – Zone of Proximal Development (ZPD)

Vygotsky's (1978) work was amongst the earliest to investigate the relationship between learning and development. He outlined the three current theoretical standpoints that attempted to explain the relationship and rejected each of them. The theories at that time were that 1) learning is external and not related to development; it was suggested that the process of learning benefits from developmental achievements (e.g. theorists such as Piaget's (1968) and Binet's (1908; 1909) views were that it is not possible to learn until the appropriate development has occurred). 2) Learning is development; e.g. development is the mastery of reflexes or habit formation (James, 1899); 3) Learning is a result of separate but distinct systems (physiological maturation and development (Koffka, 1925)). Vygotksy proposed an alternative theoretical view, which was that learning and development are interrelated and begin on the first day of life.

With regard to measuring developmental levels, he suggested that it was possible to distinguish actual mental development (what the child can do on their own) from the level of potential development (i.e. performance beyond actual development brought about by interaction with adults or more capable peers). This theory seems to sit in a social constructionist perspective as it states that the potential development exists only in the interaction between the child and the more capable peer.

Vygotsky's opinion was that when determining the level of schooling for mentally impaired children, the standard tests were inadequate because they only reflected the child's current developmental point in isolation, as opposed to the potential development that could be brought about through a more naturally occurring interaction with teachers or more capable peers. It is through that interaction that the internal developmental process is established. He proposed that assessments should reflect the more natural interaction where learning and development takes place, and that scores should focus on the improvement that an individual makes following instruction or guidance. The degree of improvement reflects the potential of that individual to take on information and apply it (their zone of proximal development). This more interactive and dynamic style of testing was thought to address some of the problems with the standard style of assessment. It would make the testing situation more realistic (e.g. the individual receives feedback on their performance as opposed to the one directional, static situation) and remove the culturally and educationally biased format of the standardised test. This would give those who might be unfamiliar with a test situation the same chance as others to utilise the guidance. The dynamic test does not measure what someone already knows, but it does measure their potential for learning; it identifies the potential for change, and goes about inciting that potential. The principal differences between the standard static assessments and the dynamic style of assessment are that the dynamic tests measure the process of learning, whereas the static assessments measure the product of what has been learnt. The interaction between the examiner and examinee is two-way as opposed to the very unnatural unidirectional communication that occurs in the standard static assessment. This means that the dynamic assessments introduce the role of feedback into the testing procedure (Griogorenko et al., 1998; Sternberg et al., 2002).

Vygotsky's theory influenced research in two separate fields. One was in understanding from a social constructionist viewpoint how information was passed on and how it influenced development. The other investigated ZPD as a means of improving upon the current assessment technique used to quantify cognitive functioning on an individual level (Griogorenko et al., 1998).

Although Vygotsky has been credited with the theory, he did not put it into practice. There are four main approaches that have been developed in the field of dynamic testing; these are principally authored by Feuerstein (1979), Budoff (1987), Campione & Browne (1987) and Guthke (1977).

These researchers have each developed a different approach to measuring learning potential and each of them will be outlined briefly below.

1.9.2 Feuerstein – Mediated Learning Experience and the Learning Potential Assessment Device

Feuerstein et al (1979) developed the Learning Potential Assessment Device (LPAD). The authors' perception of intelligence was that it was global and modifiable. Feuerstein felt that development came about after direct exposure or following a one-to-one interaction. This change was labelled a 'Mediated Learning Experience' (MLE). Feuerstein's view was that the MLE may be prevented in certain environmental situations and by certain conditions. Absence of mediated learning experiences would result in cognitive impairment and motivational factors.

The LPAD was developed to assess children's cognitive modifiability and to identify what must be done in order for MLE to occur. It does not assume that the test itself results in changes, only that it assesses what is preventing the MLE from occurring as well as the person's potential to change, and to quantify the intervention required. Feuerstein et al (1987) describe three factors crucial for consideration in the testing of learning potential; 1) the modality of presentation, 2) novelty and complexity, and 3) co-operation.

During the testing with the LPAD the examiner has an essential role, it is their responsibility to identify the problems during the testing and to create strategies to remedy them. Because this is an exceptionally individual approach it is difficult to standardise and although internal consistency and test-retest reliability have been found to be acceptable, inter-rater reliability has not been (Vaught & Haywood 1990 in Grigorenko et al 1998). This finding suggests that there is a strong examinee related influence which, considering the role of the examiner, is not surprising.

1.9.3 Budoff – Standardisation of Learning Potential

Budoff (1987) was keen to develop Feuerstein's work by standardising the training element of the dynamic test. The theory was developed through work with disadvantaged children with low IQs. The training stage for Budoff was where the examiner directed the examinee's attention, explained the crucial aspects of the test and guided the examinee so that they would master every essential skill required. Standardisation was not exact, but more established than in the LPAD. Budoff originally classified individuals as High Scorers (those who did well independent of intervention), Learners (those who benefited from training) and Non Gainers (those who were unable to benefit from training). After criticism of how broad these classifications were, however, he rated performance along a continuous scale using residualised scores. The post-test scores consider original performance, influence of practice effect and influence of training. Budoff acknowledged that there were problems in interpreting the results in a way that can transfer to other tasks or real world situations. He also identified that there is currently no way to translate the results of the studies into treatment programmes.

1.9.4 Campione & Brown – Graduated Prompts

Another approach to be discussed here is the Graduated Prompts theory (Campione et al., 1987). This technique for measuring learning potential is quite different to other techniques in that it focuses on how much instruction is required to reach a specified outcome, as opposed to how much improvement a person can make following guidance. The hints provided are hierarchical, starting very generally and ending in direct instruction; hints are only provided if the individual has not reached the target outcome. The hints given are compared to how far the information can be transferred onto different test questions and a ratio of this is calculated. The authors' research found good concurrent and predictive validity. Researchers also found that there is an age related effect on being given hints, with young children welcoming tips but more elderly people interpreting hints negatively – taking it as a sign they were failing. This is an interesting point and one which will be considered for this research.

Despite the positive results, there have been concerns about using hints with people who have different cognitive profiles (Griogorenko et al., 1998). It was thought that other cognitive impairments could be influencing ability to take on the information provided, meaning that Learning Potential Scores are actually reflecting cognitive impairment. A proposal made by Griogorenko and Sternberg (1998) was to investigate the correlation between this measure of learning potential and cognitive function.

1.9.5 Guthke

Guthke's (1977) contribution to learning potential also consisted of pre and post-training tests. There was long-term (seven days) or short-term training, where intervention was part of the test and more like Schmidt's (1971) testing limits. Post-test performance was found to predict outcome. However, there were methodological concerns around the emphasis of standardisation. Guthke's work emphasised the importance of test scores being comparable, but as a consequence of this his assessment procedure became very similar to that of the psychometric assessments that were being criticised.

1.10 Dynamic Assessment in other settings

All of the research above relates to child development. However, more recently this approach has been applied to other fields of work. The first to see the potential of dynamic assessment in brain injury were Ben Yishay and colleagues (1970). Their goal was to study the relationship between competence and ability to profit from cues. The authors found a linear relationship between initial competence and ability to profit from guidance (a person with less competence needs more cues). General predictions could be made here about how this might translate into a rehabilitation setting; however the research was not taken further to verify this. A limitation of this study was that it only looked at group analysis rather than individual differences. Cicerone et al (1986) offered a more detailed theoretical proposal on the applicability of dynamic testing in relation to predicting rehabilitation potential. They outlined five considerations that the new assessment must incorporate:

1. Potential improvement with training.
2. Levels of modifiability.
3. Quantification of levels of intervention required to bring about a set level of change.
4. How deep does this change go, e.g. does change generalise?
5. What are the individual's strengths in order that these can be exploited for change?

Lamport-Hughes (1995) applied this operationalisation of rehabilitation potential in order to establish who would be a good candidate for cognitive rehabilitation. The Wechsler Memory Scale (WMS) Associate Learning subtest was used as a measure of new learning as it came closest to Vygotsky's definition of ZPD. Authors concluded that when considering suitability for rehabilitation, factors that should be considered are new learning, age, time of intervention, pre-morbid functioning and motivational factors. Whilst the WMS associate learning test is really not a test of dynamic learning, this is still a significant finding, suggesting that learning ability predicts who will benefit from rehabilitation. Another interesting finding was that severity of injury did not predict outcome despite it being significantly related to neuropsychometric predictor variables. The author concluded that this implies that severity is diagnostic but not prognostic.

In other fields the pre-test – train – post-test design has been applied to predict 'readiness for rehabilitation' (Wiedl, 1999). The author used the Wisconsin Card Sorting Test (WCST) with a psychiatric population to establish cognitive modifiability and to predict ability to profit from rehabilitation. Utilising an Errorless Learning approach in the training stage of the test and using a residual of linear regression (with additional consideration of ceiling performance on pre-test scores) individuals were classified in a similar format to Budoff's original categories (High Scorers, Learners, and Non-retainers) and evidence was provided that High Scorers and Gainers were able to profit from rehabilitation interventions whereas Non-retainers were not. This research was taken further (Woonings et al., 2003) to establish if learner status had predictive ability for psychosocial rehabilitation (as opposed to more specific rehabilitation goals such as medication management, problem solving skills, etc). This research incorporated a control group (which received no training, only a second administration). The findings were that pre-test WCST was significantly related to psychosocial outcome but post-test was not, except for the control group (improvement without instruction). These findings are not as surprising as the authors might have initially thought. It is actually quite reasonable that a measure of independent improvement might predict outcome better than improvement after training as those individuals who could improve on their own may need less guidance or rehabilitation. Other moderating factors were that an easier version of the WCST was used which may have created ceiling effects for improvement. In addition to this, there were difficulties with using the reliable change indices. When measuring this type of assessment, it is possible that the cut-off set for a clinically and statistically reliable change may have been too low – so that everyone following training will have reached the cut-off for change, making the test not sensitive enough to discriminate between performances.

Having identified the different ways of measuring learning potential and the different fields that have found it helpful, it is potentially worthwhile exploring the evidence base which relates to what physiological factors (other than severity of injury) may mediate the impact that disease, damage or old age has on the brain. A theory that has been developed and applied, primarily in relation to Alzheimer's disease, but is beginning to be applied in the field of brain injury is that of Cognitive Reserve (Stern, 2002). More recently a connection has been made between Dynamic Assessment, Cognitive Reserve and Brain Injury; this will be outlined below.

1.11 Cognitive Reserve

Cognitive reserve is a theory which explains why the same physiologic change in two people (from damage, disease or age) can result in different clinical manifestations (Stern, 2002). Stern has been responsible for a great deal of the development of this theory, focussing principally on Alzheimer's disease, although the theory is also applicable to the normal population, young and old.

There are two ways of conceptualising the model of cognitive reserve, either as a passive or active process of the brain. Both theories relate to the threshold of function that the brain has following pathology, before function is affected. This theoretical threshold is thought to be either a by-product of brain size, or the number of synapses in the brain (the passive view) or is determined by the brain's efficiency in using networks or its ability to use alternative networks when the usual network is unavailable (the active view).

1.11.1 Passive Models of Cognitive Reserve

One of the most well known models of the passive theory is that of the Brain Reserve Capacity (BRC). A comprehensive review of this model is available by Satz (1993). BRC can be best considered in the field of Alzheimer's disease (AD). In AD it is understood that the physiological implication of the condition is that the brain's synapses are affected, eventually resulting in clinical symptoms. Brain Reserve Capacity explains that there are individual differences in the number of synapses in the brain and that an individual with more synapses will have a delayed onset of symptoms compared to an individual with the same amount of synaptic damage/loss but less 'spare' synapses. The onset of symptoms can be thought of as crossing the threshold and BRC is thought to delay and buffer this onset so that even past this threshold (and therefore once the disease has been diagnosed) the individual with more BRC may experience a less severe effect of the disease. Stern (2002) describes Katzman's theory on the progression of AD pathology (Katzman, 1993), which also postulates a theory of reserve that mediates diagnosis of the disease - as individuals with more reserve have a later expression of symptoms. Further support for the passive model of cognitive reserve came from Latt et al (1996 cited in Ropacki & Elias, 2003), who found that brain size was the most significant predictor of dementia in Parkinson's disease. In the field of brain injury Kesler et al (2003) investigated whether brain size (Total Intracranial Volume TICV) relates to outcome. They found that an increase in TICV protects against the effects of traumatic brain injury (TBI).

1.11.2 Active Model of Cognitive Reserve

In the active model, reserve is thought of as the efficiency of the brain to utilise its networks or to find alternative networks if the normal ones are not available. It is worth noting that the author (Stern, 2002) distinguishes between the process of cognitive reserve and compensation. In cognitive reserve the brain is adapting in the face of difficulty, either being efficient or bringing in other networks when usual networks are not enough (due to damage or inefficiency). In compensation the brain will bring in networks not usually used by the undamaged brain, to compensate for damaged networks.

A reasonable assumption might be that if cognitive reserve is a measure of the brain's efficiency, an indirect measure of cognitive reserve could be provided by pre-injury intellectual functioning, occupational attainment and levels of educational achievement. Evidence to support this theory has been provided by Stern and colleagues (1994 cited in Scarmeas & Stern, 2003).

1.11.3 Cognitive Reserve and Brain Injury

Ropacki et al (2003) applied the theory of cognitive reserve to a brain injury population. Their investigation focused on the impact that external factors had on individuals with the same levels of cognitive reserve. Their results found that alcoholism, drug abuse, psychiatric illness or previous neurological insult decreased the effectiveness of cognitive reserve.

1.11.4 Cognitive Reserve and Learning Potential

Baltes, Kuhl & Sowarka (1992) have made the connection between cognitive reserve and learning potential. They redefined the concept of cognitive reserve to incorporate three separate levels of function; baseline performance (static, standard assessments), Baseline Reserve Capacity (best performance in optimal conditions), and Developmental Reserve Capacity (potential following intervention). Their view is that this Developmental Reserve Capacity (potential) is moderated by the amount of cognitive reserve each individual has. They hypothesised that this measure of potential will have a better predictive validity than pre-training scores, thus making dynamic assessment a tool for measuring developmental cognitive reserve and a tool for early diagnosis. Their research supported this hypothesis.

1.11.5 Dynamic Testing for this Research

Having identified that there is a place for dynamic testing in the field of acquired brain injury and that there are interpersonal, pre-injury and physiological factors which influence degree of learning potential, this research aims to explore what factors will influence learning potential (interpersonal, physiological, pre-injury). This research aims to follow the criteria set by Lidz (1995) in developing the dynamic assessments. His suggestion was that dynamic tests must have a more interactive relationship between the examiner and the examinee, the assessment must focus on processes (usually metacognitive) that are brought about in the interaction to reveal how the examinee is engaging in the problem solving process, and thirdly that the results focus on the information related to the responsiveness of the individual.

With regard to the style of dynamic assessment that this research will adapt, consideration was paid to the two schools of thought in which the different approaches to dynamic testing, outlined above, can generally be placed. One approach focuses on how to establish a quantifiable measure of learning potential (Budoff, Campione & Brown, Guthke); the other prioritises the qualitative experience of individual flexibility and focuses on the individual process of learning (Feuerstein 1979). Minick (1987) brings our attention back to Vygotsky's main aim, which focused on the interaction between the child and the adult and how this interaction could be applied pragmatically. This was opposed to measuring the product of this interaction, which is the amount of improvement or how much intervention was required. He criticises the quantitative approach for measuring the product of the interaction as opposed to the process. He recognises however that Feuerstein's approach, which is more process orientated, is limited in being able to provide quantitative information and that the author's assumptions into the processes of change are largely intuitive.

Despite recognising the implications of focusing on quantifying change and not solely on the process of learning potential, this research will be using a quantitative technique in establishing a measure of learning potential. This has been done in order to maintain standardisation whilst still in the early stages of understanding this field. It might be possible at a later date to collect a more qualitative and individual account of change, but in terms of recovery prediction, information needs to be comparable. Despite not following Feuerstein's approaches closely, this research does share many of his views, primarily his outline of what is crucial in the testing of learning potential, (modality of presentation, novelty and complexity and cooperation required for task solution.) Also like Feuerstein, it is acknowledged here that change does not come about in the test setting; it only identifies how much intervention is required for change to occur. This research also aims to explore more deeply his views that change is a global construct. It will investigate change across different learning systems to compare performance and identify whether different processing structures will provide different predictive properties related to outcome or not. This means that our research will have a battery of assessments identifying learning potential. Although this has been criticised in Feuerstein's work (Griogorenko et al., 1998), who point out that difference scores were not comparable, this problem will be addressed in this research by using Item Response Theory to convert change scores (please see Chapter 2, section 2.5 for more information).

As mentioned earlier, this research will adapt a quantitative approach to analysis and like Budoff's work, will standardise instruction. Instruction will be seen as a tool to direct the examinee's attention, to explain the crucial attributes to the task and the testing procedure and to guide the examinee in mastering all actions that are necessary for finding the right solution. A difference for this research will be that the training process will be much more explicit, where examinees are trained exactly on how to pass the task. This has been done for several reasons. The first is that it removes any problems with inter-rater reliability because there is a script. The second is that exact instruction (with error prevention during the training stage) has been shown to be a helpful technique for the retention of information with memory impaired individuals. This approach is known as 'errorless learning' and is hoped to overcome some of the difficulties outlined previously in applying a dynamic test to people with different cognitive profiles. This research will therefore be utilising the same approach used by Wiedl (1999).

1.12 Errorless Learning

Errorless learning is the theory which suggests that reducing errors during the encoding phase will increase the likelihood that correct information is recalled later on. It was developed originally by Terrace (1963) with his operant discrimination learning work with pigeons. Jones & Eayrs (1992) were the first to apply it in a rehabilitation setting, for people with a learning disability. It was first realised as a neuropsychological rehabilitation technique by Baddeley & Wilson (1994). There is substantial support for errorless learning as a tool for increasing memory in severely memory impaired individuals (Evans, Levine, & Bateman, 2004; Kalla, Downes, & van den Broek, 2001; Kessels et al., 2003; Riley, Sotiriou, & Jaspal, 2004; Squires, Hunkin, & Parkin, 1997; Hunkin, Squires, Parkin, & Tidy, 1998). However there have been problems around generalising this skill, e.g. applying the learned skill beyond the test (Kessels et al., 2003; Tailby & Haslam, 2003), as well as with ecological validity, e.g. names being recalled with a first letter clue, which is unrealistic in an everyday situation (Evans et al., 2000).

Within the theoretical model, research has found conflicting evidence supporting which memory systems are responsible for the success of errorless learning. The original authors (Baddeley & Wilson, 1994) report that the system being capitalised upon is the implicit memory system, whereas others have suggested the explicit system (Hunkin et al., 1998; Evans et al., 2000). Support for the implicit memory system comes from evidence suggesting that following an ABI, explicit memory can be significantly affected, but implicit memory is typically left untouched. This is often the case with people suffering from amnesia (Kessels et al., 2003; Glisky et al., 1989; Glisky et al., 1987; Evans et al., 2000), although evidence has also been found to the contrary (Schacter 1987). Clinicians have tried to take advantage of this unimpaired system, instead of having to rely on the usually impaired explicit memory system, by attempting to encourage learning implicitly. A potential difficulty with this implicit system, however, is that it has been found to not deal well with errors. It is thought that this is because it is the role of the explicit memory system to discriminate between correct and incorrect choices. This means that if learning is conducted with the trial and error process using the implicit memory system, there is as much chance that the errors will be recalled as the correct choices. Baddeley and Wilson, therefore, developed the technique of learning tasks through the implicit memory system (typically functional tasks as opposed to the more explicit semantic information tasks) by enabling the subject to successfully complete the task and preventing them from making any errors.

Researchers began to question this original theory (i.e. learning via the implicit memory) when evidence was found that errorless learning worked only on an explicit task, rather than on the implicit memory test (Hunkin et al., 1998). This resulted in the development of a theory for the role of the residual explicit memory system, which has been supported by further research (Tailby et al., 2003). This theory suggests that it is the reduction of errors and repetition, as opposed to utilisation of the implicit learning system, which improves outcome of memory retention. Other research has found support for the role of both memory systems (Page, Wilson, Sheil, Carter, & Dennis, 2006) whereas some have found inconclusive evidence for either (Squires et al., 1997). One might argue that, practically speaking, it makes no difference, so long as it works. Clinically, however, it is useful to understand why errorless learning works. If error reduction and repetition works by using the explicit memory system, perhaps there is some scope for errors. However, if it is using the implicit memory system, this indicates that no errors can be made, and suggests that there are certain tasks where errorless learning may not be applied, (e.g. in tasks that are completely explicit e.g. learning facts or new information). Page et al. (2006) identify that in this field of research often different questions are being asked, i.e. is the learning that happens under errorless learning through implicit memory, or is the advantage of errorless learning over trial and error due to implicit memory? Perhaps the advantage of error reduction is that it strengthens associations in the implicit memory system but the explicit memory system is also involved. Squires et al (1997) concluded that errorless learning works because it removes errors at the learning stage during encoding as opposed to accessing the implicit memory at cued recall.

Pragmatically, removing error from a learning situation creates its own problems. It involves heavy experimenter involvement, so much so that the examinee can often become quite passive and uninvolved. Although the process of learning the information is subconscious (it is through the process of repetition and removal of errors that the encoding takes place), it is still necessary for the examinee to feel involved in the process. Despite these problems there has been overall support for the utility of errorless learning methods for improved learning with memory impaired individuals (Kessels et al., 2003; Squires et al., 1997; Tailby et al., 2003). There has been, however, some discrepancy in findings, e.g. Evans et al. (2000). Their research aimed to replicate the findings of Baddeley and Wilson but was unable to. Instead they found that route learning was best learnt through trial and error, although they hypothesised that this was due to the amount of effort that went into the learning. With face-to-name associations, there was no difference between errorless and errorful learning until an additional guided imagery technique was attached to the errorless technique. The authors concluded that an important factor was effort, allowing a deeper encoding to occur. This hypothesis has been supported by others, (Riley et al., 2004; Squires et al., 1997; Tailby et al., 2003; Jones & Eayrs, 1992). Kalla et al. (2001) suggested that the incongruence between the original study and that of Evans et al. could be related to methodological scheduling differences. In Baddeley & Wilson's (1994) paper only a single test was used, whereas for Evans' research this test was followed by others which allowed for the generation of errors, which could have affected the performance.

Despite some research to the contrary, there is significant evidence to support the use of errorless learning with memory impaired individuals to facilitate the provision and retention of information. With evidence suggesting the importance of active involvement of the examinee this research aims to use errorless learning within the training intervention and hopes to increase recall by involving the examinee as much as is possible.

1.13 Conclusion

In conclusion, this research aims to adapt standardised assessments by applying a dynamic testing technique to them. This will allow a measure of the improvement that individuals can make with guidance. The style of dynamic assessment to be applied was drawn from that of Guthke and Budoff with a quantitative test – train – test approach as opposed to a hierarchical hints technique. The training element will be applied using the errorless learning approach where individuals will be told exactly how to do the task and will complete the test with support from the experimenter whose role during the training will be to prevent the participants from making errors and to facilitate active involvement from the participant. Participants will then retake the test and a comparison of their performance will be made; in this sense the style of assessment will mimic that of Wiedl (1999).

Chapter 2 : Investigations into How to Represent Meaningful Change

The common reasons for assessing change are to gauge recovery, to assess the effectiveness of a treatment or intervention and to assess the impact that moderator variables have on outcome (Schottke, Bartam, & Wiedl, 1996). The aim of any kind of therapeutic intervention is to see movement from 'dysfunctional functioning' towards 'functional functioning' (Jacobson & Traux, 1991b). With pre-test – train – post-test dynamic assessment, however, the aim is to find a measure of change which reflects learning potential. Previous research has used the measure of improvement that an individual can make following instruction as a reflection of the potential a person has to learn. It is possible, though, that the difference in performance between the first and second administration of the test is due to some other factor. Measuring the improvement assumes that the pre and post tests are the same, or are measuring the same thing. This may not be true, since it is possible the training element, which is fundamental to a dynamic assessment, could have altered what the test was designed to measure (or what is actually measured in the first administration). This is particularly true where normal standardised assessments that were not designed for a dynamic training intervention are applied in dynamic testing research (i.e. Ben Yishay, Diller & Gordon (1970), Woonings et al (2003) & Wiedl (1999)).

This chapter will firstly discuss the considerations that are necessary when measuring change with dynamic testing; it will then explore the common methods that are used to measure change over time and discuss the strengths and weaknesses of applying these methods to a dynamic testing situation. The chapter will conclude by outlining the method that will be most suited to measuring learning potential for this research.

2.1 Considerations in Measuring Change with Dynamic Assessment

Measuring change once you have trained a person how to pass a test is complicated. After a dynamic training intervention, the individual's performance is no longer reflecting their unique contribution to the test, but also how they have managed the information given to them about how to pass it. The change in performance therefore may no longer be reflecting the process of learning, but may also be reflecting a change in the test's construct and face validity, brought about by the dynamic training intervention. For example in Wiedl's (1999) research, where participants were trained on how to pass the WCST, the baseline performance measured what the test was originally designed to measure, i.e. flexibility in thought, shifting set, perseveration, concept attainment etc. Performance in the post-training measure, however, might not be reflecting these executive functioning skills, instead they could be providing a measure of the individual's ability to take on information and apply it, or perhaps their individual cognitive profile (for example poor memory or attention, which affects the ability to retain the information or apply it consistently). If the pre and post-training tests are measuring different things, this will make a comparison between them very difficult. It will be necessary to ensure that the impact the training has had, not only on the person but also on the test, is understood so that this potential change in construct, face and internal validity can be accounted for and then, if necessary, controlled for. In order to ensure that the score represents learning potential only, it is necessary to outline all the factors that could influence the scores so that attempts can be made to address them. It is also necessary to establish a method for identifying how much change is needed in order to reflect a clinically meaningful measure of learning potential, as opposed to a statistically meaningful change. As training is likely to create a statistically significant change for the majority of individuals (after all they are being told how to pass the task) it is important to find a criterion that reflects a change which is clinically meaningful to the population.

With these issues in mind the questions that need to be asked when considering how to measure change following dynamic training intervention are:

1) Does dynamic assessment alter the validity of the assessment tools (Are the pre and post-assessments measuring the same thing, and if not, what is the post measure tapping into and is it a useful measure?)?
2) How statistically significant must the change be to be considered clinically significant (Is the measure of change reflecting learning potential, and is this clinically meaningful?)?
3) How reliable is the assessment being used to reflect change after training (What chance is there that any differences that have occurred are down to weak assessments?)?
4) What kind of effect size is expected in the measure of learning potential?

2.2 Considerations when Measuring Change over Time

The easiest way to identify change over test occasion is to ensure that the same assessment tool for both the pre and post-test conditions is used. Consideration should also be paid to the external moderating factors that could be influencing the scores; these will need to be controlled for. Other considerations should ensure that the change observed is a consequence of the intervention rather than poor test – re-test validity, regression to the mean or practice effects.

In measuring change over time, different techniques have been applied, with varying attempts to address the many factors that influence performance. The common methods of measuring change have been outlined below. Once outlined, the different techniques will be compared and the most suitable for application in the field of dynamic testing will be chosen.

2.2.1 Difference Scores

Calculating change over time would be most simply achieved by measuring the difference in performance between the first and second trials. This method, however, fails to consider factors that may influence performance such as measurement error and chance, and it also fails to take account of the impact that the first performance would have in determining the amount of change possible (ceiling effect). In the interpretation of the observed change score, therefore, it is not possible to assume that those individuals with a larger difference are performing better than those with a smaller difference.

2.2.2 Normative Information

Using norms to give an indication of improvement over test occasions can be very useful. If we remember that the aim of any therapeutic intervention is to move an individual away from 'dysfunctional function' towards 'functional function' then the percentile ranges from a normal distribution are a very helpful way to represent this. Dysfunction is often defined as two standard deviations outside of the mean of the functional population. Using the normal distribution curve this means that anything below the third percentile is statistically dysfunctional. If there is normative information about a functional population available, then it is possible to validate the success of the intervention by assessing whether the individual has moved from a dysfunctional range to within functional limits. This is illustrated below in Figure 3.

If there is normative information regarding dysfunctional and functional populations that are not overlapping then it will be very clear whether the person has improved enough to move from one population to the other (making the improvement meaningful clinically), as is illustrated in Figure 4.

If the normative distribution curves are overlapping, then it would be possible to observe whether the individual has moved closer to the mean of the functional population when compared to the dysfunctional population. Please see Figure 5 for an illustration of how this could be seen.

As normative data is not always available another method must be used to determine whether a statistical and meaningful change has occurred. Two methods are often used, applying a cut-off such as one or two standard deviations above the mean of the population or using a reliable change index. Both will be explored below.

Figure 3: A Normal Distribution Indicating the Movement Required For Performance to Move from the Dysfunctional To Within the Functional Range

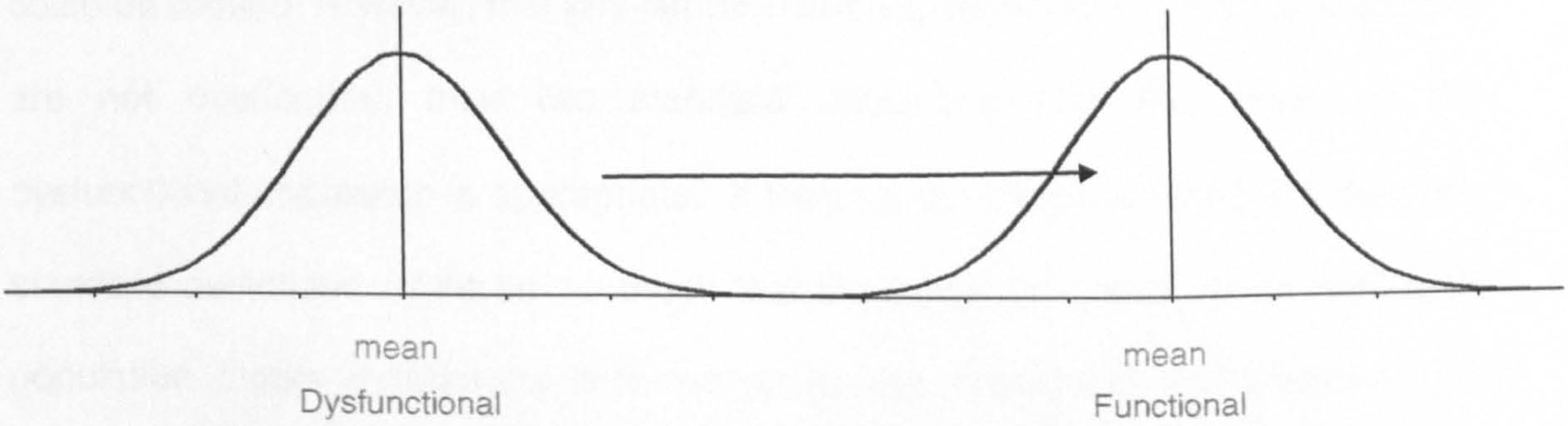

Figure 4: Non Overlapping Normal Distribution Curves Indicating Movement from the Dysfunctional To the Functional Range

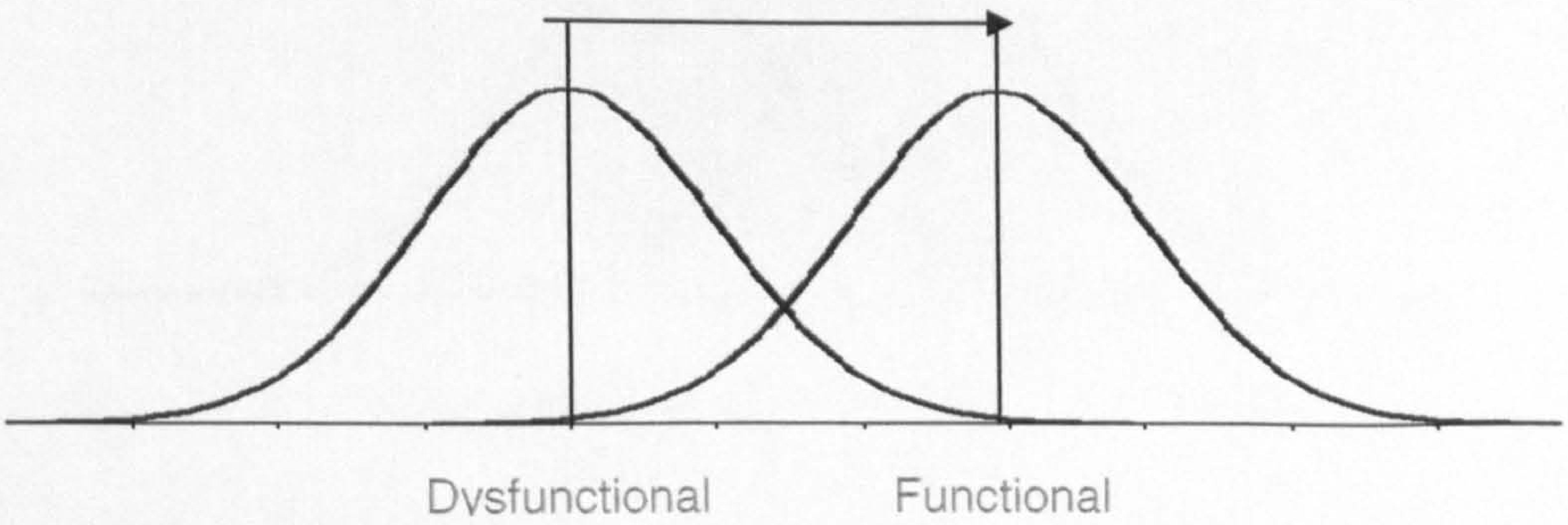

Figure 5: Overlapping Normal Distribution Curves Indicating Movement from the Dysfunctional To the Functional Range

2.2.3 Cut-offs such as one or two standard deviations

When norms are not available it is necessary to pre-determine how much change will be required to be regarded as significant. It is therefore not uncommon for a cut-off to be applied to the data to determine whether each individual's performance has improved enough to cross a threshold or not. A common cut-off that is applied in research is one or two standard deviations from the mean of that population. This method has been considered arbitrary and fails to account for change that can occur from chance, practice effects or a measurement error (Bruggemans 1997). It could be argued, however, that any cut-off could appear arbitrary. If the populations are not overlapping then two standard deviations from the mean of the dysfunctional population is appropriate. If the populations are overlapping then two standard deviations might be so much that it passes the mean of the functional population (figure 6 illustrates this example), and perhaps in this instance, one standard deviation from the mean of the dysfunctional population would be sufficient.

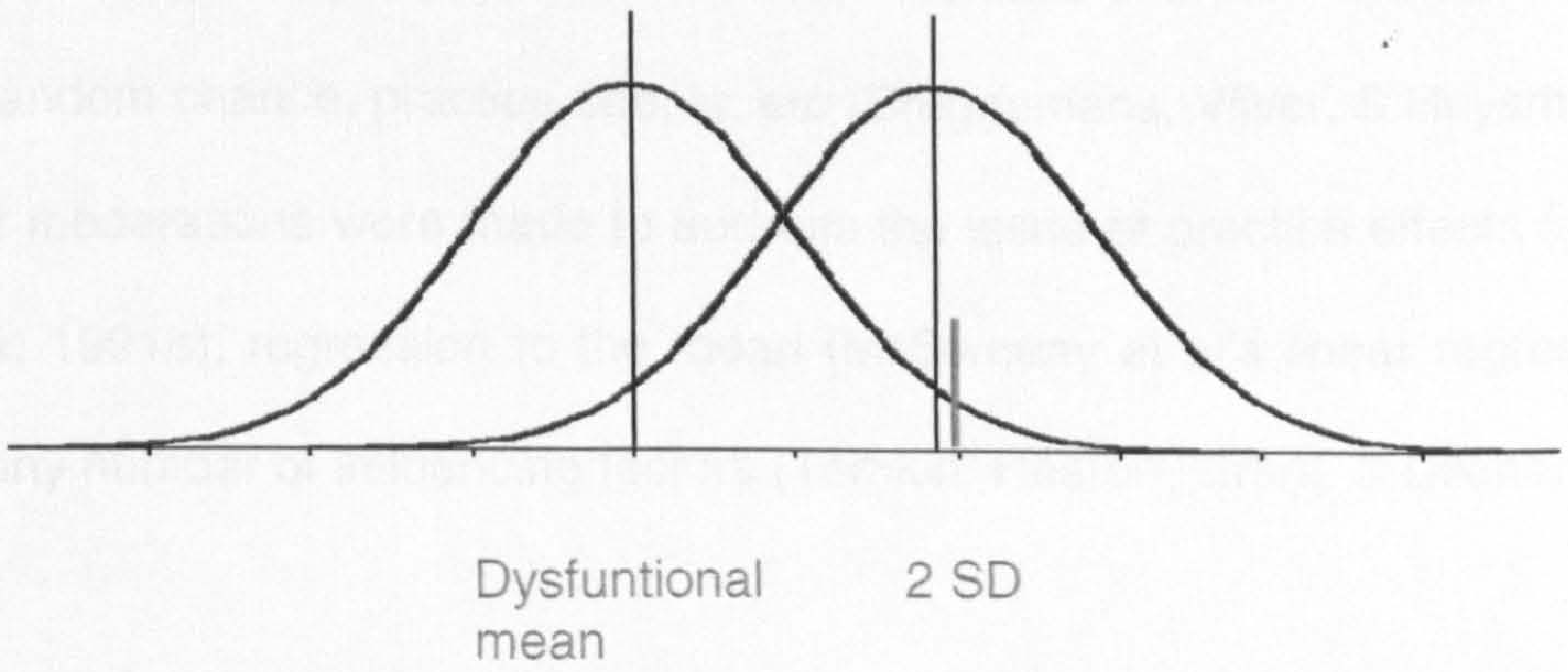

Figure 6: Overlapping Normal Distribution Illustrating How Two Standard Deviations above the Mean of the Dysfunctional Population Can Be Greater Than the Mean of the Functional Population

2.2.4 Reliable Change

Jacobson & Truax's (1991b) Reliable Change Index (RCI) addresses some of the problems that the 'difference scores' method creates by taking into account the standard error of difference (variance that can occur by chance) when considering the difference score. The calculation used considers whether the change that has occurred is more than a consequence of a weak assessment by allocating a cut-off point which determines whether a clinical and statistically significant change has occurred. Reliable change takes the post-test score and subtracts it from the pre-test score; this number is then divided by the standard error of difference between the two test scores. (The standard error describes the spread of the distribution of change scores that would be expected if no actual change had occurred). Since the introduction of the Reliable Change Index, newer improved models have been developed to address some of the factors which were not controlled for by the original Index. For example there were concerns because the reliable change index uses observed change scores rather than estimated true change scores (therefore not controlling for the random error – which includes standard error of measurement and random chance, practice effects, etc (Bruggemans, Vijver, & Huysmans, 1997). Other moderations were made to address the issue of practice effects (Jacobson & Traux, 1991a), regression to the mean (McSweeny et al's linear regression 1994) and any number of influencing factors (Temkin, Heaton, Grant, & Dikmen, 1999).

Jacobson and Truax suggest using confidence intervals to create boundaries in performance, in order to address the risk of measurement error which can be created in applying a discrete cut-off. Unfortunately despite the reliable change method addressing many of the weaknesses that the difference scores create, it still fails to account for the ceiling effect. It is still possible for a person to not appear to have improved clinically and statistically simply because their score was too high on the first trial.

2.3 Measuring Change for Dynamic Testing

Each of the methods outlined above has strengths and weaknesses when applied to a dynamic testing technique. The difference-score approach, which in outcome assessment is probably the weakest statistically, would enable a very clear comparison between individuals of how much change took place following dynamic assessment. The statistical weaknesses that the difference-score approach brings (as outlined above) are overshadowed by the large impact that the errorless learning training intervention will have on performance. The impact of practice effects, chance and measurement error are minimal comparatively. The difference-score method does create problems in providing one single score, reflecting only the amount of movement the individual has made, as opposed to providing information about what the pre-training performance was like compared to the post-training performance. It is felt that including this information is also very important particularly whilst so little is known about the impact that a dynamic training intervention has on the validity of a test. As this research aims to use various tests, each of which contain several measures, it is also felt important to consider them in the context of their individual internal and construct validity. This will allow an understanding of whether the training element has an effect on, or completely alters what the test was originally designed to measure. Measuring the simple difference assumes that the tests at both occasions are the same.

Using normative information is very helpful but unfortunately the norms available could only apply to the pre-training administration of the tests. The post-training version would not apply because after the person has been told how to complete the test it should not be as difficult to pass and so the norms would be irrelevant. It is hoped that in the future, norms would be available for dynamic versions of standard tests as this method has a great deal of clinical potential.

Using a one or two standard deviation cut-off again has its strengths and weaknesses. It is possible to take information from the pre-training administration scores, to establish a cut-off that would be expected in the post-performance administration. In considering what this cut-off should be, the pre-training performances were considered. The decision as to whether to use a one or two standard deviation cut-off for the pre and post-training administration fell to the one standard deviation. The decision was made because it was established that there was an overlap in performance between the dysfunctional (brain injury) and functional (normative) populations. This overlap means that some of the brain injury population were scoring within usual limits on the first administration of the tests. For this reason, it was felt that an improvement of two standard deviations over the two trials would be impossible for a significant proportion of the sample (ceiling effects) and so one standard deviation was used instead. The one standard-deviation cut-off was felt to be more reasonable as well as making more clinical sense because the two standard deviation cut-off is usually applied to the functional population to separate out those who are statistically dysfunctional.

Using this cut-off system would also not create ceiling problems as it would consider and reflect the information collected at both the pre and post-training administrations of the test (so an individual could be shown to have either moved from below to above cut off or to have been functioning at above cut-off on both occasions etc).

Whilst in most other situations the most efficient way of measuring a clinical and statistical change would be to calculate a reliable change index when investigating the effect of applying a dynamic intervention to a standard assessment, in this instance the RCI may not be the most appropriate choice. Reliable change is, in many ways, similar to measuring the difference between pre and post scores, with the addition of considering chance and setting a cut-off that is meaningful. Its limitations for dynamic research centre on problems with ceiling effects (it is possible that the individual will be performing too well on their first trial to reach clinical change after training), and in not considering the pre and post performance independently. Like the simple-difference approach, reliable change only provides information about how much change occurred and whether this reached the cut-off. Again as this research is attempting to understand the impact that dynamic testing intervention has on the validity of the tests; it is felt important to explore the information provided at both the pre and post-training stages. Further consideration should be given to the usual probability limits that are applied in the reliable change index. Usually the cut-off chosen reflects a certainty that the change score did not occur by chance and is meaningful; however this should surely be set to a higher level when you have trained a person on how to pass a test. It is not known how much change should have occurred to make it meaningful clinically in a dynamic testing situation. Hopefully as more is understood it might be possible for this to be reflected.

2.4 Categorising Change

Of all the methods outlined above, the two that were felt to have the most potential for this research were the cut-off and reliable change index techniques. As outlined previously, both of these have strengths and weaknesses and at this stage in the process it is unclear which will provide the most meaningful information. For this reason Study One will conduct analyses using both techniques and will adopt the one that is the most meaningful.

Having identified how participants' change scores can be reflected on each test item, a method is required to consider this information in the context of the other items of the test. It is also necessary to be able to compare each individual's performance to that of their peers, as well as identifying the effect that the dynamic assessment has had on the nature and context of the test. A method that has been found to be very useful when working with dynamic assessment is Item Response Theory (Sternberg et al., 2002), and within that the unidimensional Rasch Analysis Model (Rasch, 1960).

2.5 Rasch Analysis

Rasch Analysis takes categorical information from a test that consists of several items and creates a hierarchical rank of item difficulty. It is unlike more commonly used ranking techniques such as rank ordering, or Guttman Scaling, because it works on probability rather than using True Scores. As a probabilistic model, Rasch makes predictions based on the information available; this provides the additional benefit of it not being sample or test dependent and means it can manage missing data more effectively.

The fundamental advantage of using the Rasch Model when ranking item difficulty is the additional information the model creates. By taking the information about each individual's responses to every item (e.g. correct or not correct) it is able to place, using a logarithm of odds algorithm, the individuals on the same hierarchical scale as the items. The model does this by calculating the probability of a person completing a specific item on a task successfully and divides this by the probability of them failing the item. This algorithm creates a Logarithm of Odds (Logit) interval scale, on which both person and item can be plotted. The Rasch equation using dichotomous data can be represented as:

$$Pni(x=1) = f(Bn - Di)$$

Pn is the probability
i is any given item
x is any given score (1 is the correct response)
Bn is the person's ability
Di is the item difficulty
f is the function

The equation therefore states that the probability of person n getting a score of 1 (using binary data) on any given item is a function of the difference between a person's ability and an item's difficulty (Bond & Fox, 2001).

The basic premise of Rasch is simple. The analysis compares every person's performance on every item. If everyone passes only one item, then it has the highest probability of being the easiest item to pass. If only one person passes all the items they could be considered the highest scorer when compared to all the others in the sample. The Rasch analysis uses category data (where a low number is of less value then a higher number).

In addition to the Rasch model creating an interval scale from categorical data, (on which items can be plotted according to their difficulty and individuals according to their ability), it is also able to provide information about whether both the items and the individuals belong to the same unidimensional construct. This means that it is possible to evaluate the validity of the assessment by providing information about whether each item belongs to the same construct. This technique can also be used to establish patterns of response within the population and whether an individual is responding in a significantly different way (suggesting that perhaps they do not understand the test or are malingering for example). This could be a useful diagnostic tool for recognising people functioning outside of the population, or identifying test items that do not fit a construct.

This information is represented in terms of fit statistics and two scores can be applied; Outfit and Infit. Outfit data is unweighted and sensitive to any outlier data; it measures the average mismatch between data and model. Infit data, which is information-weighted mean-square goodness of fit data, is sensitive to irregular inlier patterns. It measures the weighted average or squared residuals; so remote responses have less weight than proximal responses (Wright & Mok, 2004). Wright

& Mok suggest that in analysis Infit is the better measure to use and so this was chosen for the purpose of this research.

The model also provides information about each item's standard error score, which allows for a reliability co-efficient to be calculated for the test and the participants in it. It also measures for spread of distribution for items of the test and the distribution of participants along the hierarchy. Moreover it allows for an investigation into the ability of the scale to discriminate between levels of people ability and items. Sampson & Bradley (2005) suggest that a score over one for either the person or item separation indicates that there is adequate discrimination for the construct between participants and items, substantiating a well defined variable.

Chang & Chan (1995) identified four different ways that Rasch can be applied when assessing change over time/test occasion. These are summarised below.

1. The simplest technique involves applying a separate Rasch analysis for each occasion of testing. This would result in two sets of Rasch data to be compared.

```
         +  David
         +
  Item 5 +
         +  Janine
         +
         +
         +
         +
         +
         +
         +
         +
  Item 1 +  Peter
         +
  Item 3 +
         +  Julie
         +
  Item 2 +
         +
         +  Lisa
         +
         +
         +
         +
         +
         +
         +
  Item 4 +
         +  Su

     TIME ONE
```

```
         +
         +  Janine
         +  David
         +
         +  Lisa
         +
         +
         +  Peter
         +
  Item 1 +
         +
         +
         +
         +  Su
         +
         +  Julie
  Item 5 +
  Item 2 +
         +
         +
  Item 3 +
         +
         +
         +
         +
         +
         +
  Item 4 +
         +

     TIME TWO
```

Figure 7: Two Item Maps, Each Showing the Hierarchy of Item Difficulty and Person Ability over Test Occasion

The item maps in Figure 7 illustrate an example of how Rasch analysis can model information collected about item difficulty and person ability over test occasions. The map on the left is for the first test occasion (pre- training) and the map on the right for the second test occasion (post-training). The map on the left shows that the easiest item to pass (that at the bottom of the list) is item 4, followed by 2, 3, 1 and finally the hardest, which is 5. The person at the bottom of the item map, Su[1],

---

[1] Any name used as an example in this research was chosen at random and is not referring to any participant included in the study

is plotted, below the easiest item; this means that there is a 75% probability that she did not pass the easiest item and therefore any of the items above it. Peter is plotted opposite item 1. This means that there is a 50% chance that he passed that item and as he is above item 4, 2 and 3 it means that there is a 75% chance he passed those items and a 25% chance that he passed the hardest item (5). The item map on the right shows that the items and the people are in different order; this means that whatever occurred in between the two administrations has altered the performance of the individuals but also the difficulty of the items. Now Janine is the highest scorer, and whilst item four remains the easiest item to pass, item 1 is the hardest, but is lower down the map when compared to the hardest items of the other map.

The remaining three techniques use all the data (for both pre and post-testing occasions) in one Rasch analysis by altering the focus of the analyses.

2. The second method focuses on the performance of the individual for both the test occasions. This is achieved by assuming that for both the pre and post analysis, the test items are constant (this method assumes that the training interval has not altered the validity or difficulty of each item making it possible to track the movement of each individual from pre to post-training). In order for this to be possible the first and second trials will be merged so that the analysis assumes that only one trial took place and that instead of two trials there are twice as many people (person 1 and person 1a). The same person would therefore be plotted as two individuals. This method allows the examination of individual movement on the Logit scale; an individual's performance for each trial can be compared by measuring the distance between their pre and post plots on the Logit scale.

```
           +  David (pre)
           +  Janine (post)
    Item 5 +  David (post)
           +  Janine (pre)
           +  Lisa (post)
           +
           +
           +  Peter (post)
           +
           +
           +
           +
    Item 1 +
           +  Peter (pre)
    Item 3 +  Su (post)
           +  Julie
           +
    Item 2 +
           +  Lisa (pre)
           +
           +
           +
           +
           +
           +
           +
           +
    Item 4 +
           +  Su (pre)
```

Figure 8: An Item Map Showing the Hierarchy of Item Difficulty and Person Ability over Test Occasion (Occasion Items as Constant)

Figure 8 illustrates the item map which plots each individual's movement over test occasions. It assumes that the test items remain the same and so in the analysis people's scores on trial one and two are entered as if they are different people (doubling the amount of people in the sample). This method allows us to see that on the pre-trial Su was unlikely to have passed any of the items, but following the training she passed item 2 and 4 (with 75% probability) and had a 50% probability of passing item 3.

3. The third method reverses the above analysis; the focus is on the test items, and therefore holds the people as constant (again assuming that there is only one administration of the assessment but this time that there are twice as many items). This analysis does not focus on change of person ability, just individual performance on a range of items. By labelling the items pre and post it is possible to examine the way that the intervention has influenced the level of difficulty for each item of the assessment. An example of this is illustrated in Figure 9.

```
                +  David
Item 2 (post)   +
Item 5 (pre)    +
                +  Janine
                +
                +
                +
Item 5 (post)   +
                +
                +
                +
                +
  Item 1 (pre)  +
                +  Peter
  Item 3 (pre)  +
                +  Julie
Item 1 (post)   +
Item 2 (pre)    +
                +  Lisa
Item 3 (post)   +
                +
                +
                +
                +
                +
                +
Item 4 (pre)    +
Item 4 (post)
                +
                +  Su
```

Figure 9: An Item Map Showing the Hierarchy of Item Difficulty and Person Ability Over Test Occasion, (Persons Have Been Held Constant)

In this item map individual movement is not the focus, instead it is possible to focus on the impact that training has had on the ease of the test. For example, item 4 remains in the same place, meaning that the effect of training has not altered the fact that it is the easiest item, conversely item two moved from the second easiest to the hardest item to pass following training. Despite the focus being on the item movement, it is still possible to understand individual ability using this map. For example it is possible to see that David is the highest scorer, passing all of the items of both the pre and post-test, and Su is the lowest scorer, being unable to pass any of the items for both the pre and post-training administrations.

4. The fourth and final method allows for a third factor to be added as an independent variable to the two-factor Rasch analysis. This would allow for other influencing factors to be accounted for. This third factor could be anything e.g. severity of the examiner. This analysis is most useful when understanding outside influences on performance e.g. inter-rater reliability. An example of this can be seen in Figure 10.

```
                     +  David
Item 2 (examiner 2)  +
Item 5 (examiner 1)  +
                     +  Janine
                     +
                     +
                     +
Item 5 (examiner 2)  +
                     +
                     +
                     +
                     +
 Item 1 (examiner 1) +
                     +  Peter
 Item 3 (examiner 1) +
                     +  Julie
Item 1 (examiner 2)  +
Item 2 (examiner 1)  +
                     +  Lisa
Item 3 (examiner 2)  +
                     +
                     +
                     +
                     +
                     +
                     +
Item 4 (examiner 1)  +
Item 4 (examiner 2)  +
                     +  Su
```

Figure 10: An Item Map Showing the Hierarchy of Item Difficulty and Person Ability Over Test Occasion, (Including A Third Factor, e.g. Inter-Rater Reliability)

2.6 Applying Change Scores to Rasch Analysis

2.6.1 Categorising both the Pre and Post Raw Scores Using One Standard Deviation above the Mean

This method of assessing change will produce a cut-off that can be applied to each of the items of the measurement scales for the pre and post-training trials. One standard deviation above the mean of each of the pre-test measures (items) will be used as the cut-off. This allows an observation of those individuals who performed above and below this cut-off both before and after the errorless learning training intervention.

This method splits the data into two categories at time one and time two (above/below cut-off). This will allow for three groups of people to be created, those whose scores had a high probability of falling above the cut-off on the pre-dynamic training administration (Spontaneous Learners). Those who reached the cut-off after the errorless learning dynamic intervention (Guided Learners), and those who could not reach the cut-off either pre or post-training (Non Learners).

With these categories it is possible to compare an individual's functioning before and after training, allowing us to see which individuals cross over the cut-off, which remain above, and which remain below. It will also be possible using the Rasch analysis to plot the pre and post items of the tests separately; this will allow an understanding of any alterations in the construct or face validity of the test following the errorless learning training intervention.

2.6.2 Categorising Differences in Raw Scores Using the Reliable Change Index (RCI)

The Reliable Change method will create a different set of scores for the test but similar categories for the individuals.

Reliable Change looks at the difference between the pre and post scores. However it takes into account, and controls for, change that could have occurred by chance.

For this Reliable Change Index it will be necessary to manually account for those who have reached a ceiling by determining how much change is significant, and therefore those who could not achieve this much change due to their initial scores on the pre-trial being too high. This method focuses on the change in ability of the participants but not on the items of the test and therefore there is only one set of test items included. In the research to be reported here, the individuals will still be classified into three groups: - Spontaneous Learners (those who reached the ceiling in the first trial and therefore could not improve enough to meet the cut-off), Guided Learners (those who reached the cut-off for change, indicating that following training they improved significantly) and Non Learners (those who could not meet the cut-off for change and therefore did not improve significantly).

Chapter 3 : Research Design and Methodology

This research will compare two styles of assessment techniques. One is the standard static version of a test, measuring what an individual can learn independently, and the other is the dynamic assessment approach, where the same test will be modified to provide a measure of learning potential. The interpretation gained from both styles of the assessment will be compared to establish firstly, how performance is related to factors that are known to affect outcome (such as GCS scores, pre-injury cognitive ability, time since injury etc.). The second comparison between these two tests will be to establish which interpretation provides the most clinically meaningful information in relation to recovery.

As Chapter 1, section 1.7.7 outlined, it is generally understood that the brain processes and stores information both explicitly and implicitly. This research considered it prudent to explore learning across different processing systems in order to assess and compare the utility of a measure of learning potential capitalising on different systems. The principal distinction is between implicit and explicit learning. Within the explicit learning system there will be a test which measures function of the Visuospatial Learning system, and another which is dependent upon the Verbal Learning system. It is recognised that these classifications are broad and that the tests that have been chosen are those felt to capitalise on these systems, but that may not have been designed specifically as a measure of them. The two explicit tests will model Vygotsky's theoretical perspective of learning potential (i.e. learning through interaction). The test of implicit learning will be different in that it will measure individual implicit learning over time (with no guidance). Once the three assessments have been investigated independently they will be compared to each other in order to answer two questions:

1) Is learning potential modality specific and dissociable, or as Feuerstein (1979) predicted, a global ability?
2) Is actualised learning ability (i.e. an individual's performance on the first attempt of the test) a better predictor of recovery than a measure of guided learning potential (i.e. an individual's performance following errorless learning training of the test).

This chapter will briefly explain the reasons behind the choice of tests that will be adapted to measure learning potential (a comprehensive description will follow in each of the study chapters). It will then describe the other measures that are included as part of the battery of neuropsychological assessment. The information that will also be collected regarding pre-injury factors and acute information relating to nature and severity of the injury will then be outlined. The chapter will then discuss the research design, inclusion and exclusion criteria, and provide information about the data collection. It will also discuss the statistical properties of the assessment and the power required.

3.1 Choice of the Tests for Learning Potential

To allow the most meaningful comparison across different learning systems, it was deemed necessary to choose tests which had some similar characteristics. When measuring a person's potential to learn, it was felt that the type of assessments used should be complex enough so that they remain challenging to the individual over the two trials and that they include a number of skills that occur in everyday functioning. These skills should reflect the abilities required when encountering a new task (i.e. the ability to understand the concept of a task, think flexibly about it, be able to adapt prior knowledge and transfer it). For these reasons, the tests that were chosen were of executive function. These abilities have been described as the processes that integrate and control most forms of higher mental activity (Cicerone et al., 1986) and appear to be a more fluid form of intelligence (Duncan, Emslie, Williams, Johnson, & Freer, 1996b). This research is basing its understanding of executive function on the Supervisory Attention System originally proposed by Norman & Shallice (1986) (see section 1.7.3).

Having established the type of tests that should be chosen, it was then necessary to choose ones which utilised the different learning systems. One test of implicit learning was chosen, and two for explicit learning. As the tests chosen were those measuring executive function, this research was guided in its choice of explicit tests by the Working Memory model, and therefore decided to choose two tests that tapped into the processing of the two slave systems of the central executive (Duncan, Emslie, Williams, Johnson, & Freer, 1996a). One test focused on primarily verbal processing and the other on visuospatial processing.

The Verbal Learning system is defined for this research as a set of deductive reasoning processes that occur explicitly – and that primarily utilise verbal processing. This will be measured using the Wisconsin Card Sorting test.

The Visuospatial Learning system is defined for this research as another explicit deductive reasoning process, but one that primarily utilises a nonverbal, visuospatial process instead of a verbal one. This will be measured using the Ruff Light Trail Learning Task

Implicit learning is understood to mean a set of problem solving processes that occur subconsciously and where the rules involved in this process are difficult to express. This will be measured using the Tower of Hanoi.

3.1.1 Study One: Investigation into Explicit Verbal Learning Using the Wisconsin Card Sorting Test

The Wisconsin Card Sorting Test (WCST) (Heaton, 1981) is known as a test of executive functioning. A more detailed investigation into the test identifies that it taps into particular abilities including concept attainment, shifting set, flexible thought, and problem solving. For a successful completion there must also be an element of maintained attention, and the ability to inhibit perseverative responses.

This investigation aimed to replicate other research that has adapted the WCST to become a dynamic assessment, e.g. (Wiedl 1999) (Chapter 1, section 1.10). Wiedl's research achieved this by adding an errorless learning training intervention that sandwiched the two administrations of the test. It was originally anticipated for this research that the analysis of the information collected would be similar in design to the previous research (using a reliable change index). However, alternative approaches to understanding the data were also compared to establish which provided the richest information.

It was felt that the WCST was a good choice of measure of learning potential, tapping primarily into the Verbal Learning system. There is a strong explicit verbal element with regard to the individual's internal problem solving process, as well as with regard to the feedback given after each trial (correct/ incorrect). In addition to this, the verbal element is further emphasised when you add the dynamic training intervention, which assumes the form of verbal instruction.

3.1.2 Study Two: Investigation into Non-Verbal Learning Using the Ruff-Light Trail Learning Test

To develop our understanding of dynamic learning, another static assessment was adapted to incorporate an errorless learning training intervention. The task chosen considers a visuospatial system of learning, with similar properties to the WCST. The Ruff-Light Trail Learning Test (RULIT) (Ruff, Light, & Parker, 1996) was considered the most appropriate measure for this. The RULIT is a test of visuospatial learning that involves planning, attention and the inhibition of perseverative responses. Participants are required to learn a route through a group of interconnected circles over several trials. In many senses the test taps into similar abilities as the WCST, but the authors comment that it is designed to not rely on verbal mediation. This test will be discussed in more detail in Study Two (Chapter 6). In order to adapt the test to incorporate a dynamic learning intervention, it was felt important to minimise the verbal instruction of the test. Verbal instruction was therefore kept as limited as possible, and instead participants were given an overlay of the route which they had the opportunity to use, to learn the information necessary to pass the test. This ensured that an error free training period was still being used, but was not relying on the verbal system. It was hoped that by collecting information regarding both verbal and visuospatial learning a better understanding of the processes of learning potential would be gained. This information should add to our understanding of whether learning potential is modality specific or global.

3.1.3 Study Three: Investigation into Implicit Learning Using the Tower of Hanoi

In addition to these tests of conscious learning potential, a test of implicit learning was also incorporated into the 'learning battery'; this was the Tower of Hanoi (ToH). The ToH puzzle was chosen because it also utilises many of the same executive skills as the WCST and the RULIT, i.e. problem solving ability, inhibitory ability, attention and concept attainment. Unlike the previous two tests, which both incorporate an errorless learning style of assessment, the ToH (which is often described as a test of implicit learning) was simply administered twice, with no instruction in between. The improvement in performance over test occasion reflects each individual's latent ability to learn from experience, on a test where the solution is not obvious or explicit. This style of assessment has been added to the battery to compare guided learning to spontaneous and implicit learning, to evaluate which is a better predictor of outcome. It is recognised that including a test that is designed to measure implicit improvement over test occasion is not a true measure of learning potential as defined by Vygotsky (which emphasised that learning comes through the interaction with a more capable peer). However, his theory was developed with children in mind and applies to individuals' first encounters with new and unfamiliar situations. With a brain injured population the experiences of working with impairment will be new or unfamiliar; however unlike the child this adult population will have a wealth of experience that they can draw on but may only be able to access information to varying degrees. It was hypothesised that adults are not dependent upon learning through interaction with a more capable peer but can also learn by drawing on their own resources. A moderating factor might be how accessible these resources remain following injury.

3.1.4 Study Four: Comparative Investigation of the Modalities of Learning and the Clinical Utility of Learning Potential

As this research is investigating which of the measures are the most clinically meaningful, it was felt important to compare different styles of learning (guided versus independent, explicit versus implicit) in order to best understand the influence that these have in predicting recovery. It was hypothesised that guided learning might be a better predictor of outcome for more impaired individuals whereas evidence of a more spontaneous learning might reflect a better outcome for more capable members of the sample.

3.1.5 Other Information Collected

In addition to the tests that are included as the 'learning battery' assessments, information was collected regarding the nature and severity of each individual's injury, pre-injury lifestyle (e.g. years of education, employment, socioeconomic status), demographic information (e.g. marital status, age) and information relating to any existing conditions or factors that may influence performance (e.g. a diagnosis of learning disability, substance misuse etc). In addition to this, a comprehensive battery of neuropsychological assessments was completed in order to provide a cognitive profile of strengths and weaknesses for each individual that may impact upon learning ability. This information was used to compare the predictive utility with measures of learning potential, but also to enable an understanding of which factors might have influenced performance on the 'learning battery'.

A description of the tests that are included in the neuropsychological battery has been included below.

Rey Complex Figure Test and Recognition Trial (RCFT) (Meyers & Meyers, 1995)

In 1941 Rey designed a complex figure to measure visuospatial constructional ability and visual memory in brain-injured persons. Participants are required to copy this complex figure and then immediately after are asked to draw it from memory, and after a delayed period they are asked to recall it again. Osterrieth (1944 in Meyers et al 1995) standardised this procedure.

The RCFT uses Rey's original figure but not Osterrieth's normative data. It also includes a recognition trial to measure the individual's ability to use cues to retrieve information. The RCFT allows an evaluation of the different processes of visual memory, encoding, storage and retrieval.

Logical Memory (Wechsler Memory Scale – III) (Wechsler, 1997)

This is a test of immediate and delayed memory, reflecting concentration and attention. Participants are read a story and immediately after it, are asked to recall as much of it as they can. This is repeated with a second story, which is presented twice, in order to assess learning over trials. After approximately thirty minutes the subjects are asked to recall as much as they can about the stories. They are then asked recognition questions about both stories.

Verbal Paired Associates (Wechsler Memory Scale – III) (Wechsler, 1997)

This word-learning test requires the individual to learn ten pairs of novel, unrelated words. The word pairs are read and then, for the recall trial, one of the words is provided and the individual is required to supply the word that belongs with it. This is repeated for three additional trials. Correct responses are provided if an incorrect answer is given. After approximately thirty minutes, a delayed recall trial is conducted, and a recognition trial which asks that the individual determine whether the word pairs presented were one of the original set or not.

Colour Trail Test (Maj et al., 1993)

Developed from the trail-making test to make a more cross-culturally valid assessment tool, this test provides a measure of attention, visual motor tracking sequencing, mental flexibility and visual conceptual ability. It requires the participant to connect twenty-five circles in numerical order. Following this a further trial requires twenty-five circles to be connected in numerical order, but participants must remember to choose alternate colours, requiring more concentration and the ability to shift set. The first trial of the Colour Trails (Colour Trails One) provides a measure of attention and visual spatial processing, whereas the second trial (Colour Trails Two) includes the more flexible abilities that are thought to involve aspects of working memory.

The Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999)

This is an abbreviated version of the Wechsler Adult Intelligence Scale (WAIS) which contains ten subtests. The WASI contains only four of the subtests (two tests of verbal intelligence and two of performance). Like the WAIS, the WASI is able to provide a score of Full-Scale intelligence and for Verbal and Performance intelligence. In relation to the WAIS, however, it is not as strong at assessing individual strengths and weaknesses, as the range of information that can be gained from four subtests is limited.

Wechsler Adult Intelligence Scale - Revised (WAIS-R) (Wechsler, 1981a)[2]

Please see description of the WAIS above. Two subtests of the WAIS were included in addition to the WASI to provide an assessment of attention.

Digit Span: This is an assessment of auditory attention. Participants are read a series of numbers and asked to repeat them; the list increases with each trial, requiring more attention to attend to the task. Once completed participants are read a series of numbers and asked to repeat them but in reverse order. These two parts are thought to be dissociable.

Digit Symbol: This requires the individual to draw a symbol with a corresponding number using a key provided over a period of 90 seconds. It requires sustained attention and psychomotor performance ability.

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[2] WAIS-R was being used as standard in the ABI Service at the time of data collection. It was thought more prudent to continue to use this in preference to the WAIS III to avoid an unnecessary duplication of testing and run the risk of losing important data. Furthermore, specific WAIS-R subscales are considered robust and in many ways equivalent to their WAIS III counterpart (Pilgrim, Meyers, Bayless, & Whetstone, 1999).

Community Integration Questionnaire (Wechsler, 1981b)

This assessment was developed to help provide a more multifaceted measure of recovery following brain injury. The assessment measures function on three separate but related areas of daily life. These areas are integration in a home-like setting, social setting and productive activities. Please see section 1.3.1 for a more comprehensive description of this questionnaire.

Other Data Collected

As well as the information gathered from the neuropsychological assessment battery, additional information was collected regarding the nature and severity of the brain injury. This included Glasgow Coma Scale Scores recorded at the time of the incident from each individual's medical records (please refer to section 1.4 for more detail on this measure), information regarding the locality of the damage where available (for example if scans were completed), information regarding educational achievement and employment history from either the participant or a close family member. In order to predict pre-injury functioning, an algorithm was applied to the scores from the WAIS. This considers performance on a WAIS subscale with demographic information (e.g. socioeconomic status and education) to predict pre-injury intelligence (Vanderploeg & Schinka, 1995a). As it is recognised that performance on certain subtests of the WAIS can be affected by hemispheric damage to the brain, it was felt important to consider this when calculating pre-injury IQ. Therefore the following rules were applied. As Vocabulary is the most robust measure of pre-injury ability (Vanderploeg et al., 1995a), if the injury was in the right hemisphere, then this was used in the equation (so long as the individual's first language was English and performance was not affected by poor schooling). If this was a concern, then digit span was applied instead. If the injury was in the left hemisphere then the authors suggest that picture completion would be the best subtest to include. However, as this was not collected for this research block design was used.

3.2 Participants

The ABI team provides a county wide service and was set up to ensure that people across Bedfordshire with complex needs following an acquired brain injury had access to rehabilitation in addition to medical, psychological and social care appropriate to their needs.

The team's role is to provide ongoing monitoring, case management and rehabilitation as appropriate throughout a person's recovery process. This often means working with hospitals, specialist units, nursing homes, transitional living units as well as working within the community.

The team is responsible for managing the Continuing Care Funding budget for Bedfordshire patients in addition to managing the block contracts that have been established with certain rehabilitation settings. The team's role could therefore be described as a case management one. Comprehensive assessments drive decisions regarding the type and appropriateness of rehabilitation settings in addition to monitoring and adjusting input throughout the patient's journey towards recovery.

The team primarily receives it's referrals from the acute hospitals in Bedfordshire, enabling them to be involved from the onset of a person's injury; however referrals are also accepted from other professionals at varying stages of recovery.

Patients who are referred to the Acquired Brain Injury Team must meet their criteria detailed below:

- Aged 16 +
- Resident of Bedfordshire or is registered with a GP in Bedfordshire
- Glasgow Coma Scale of ≤ 9
- Lost consciousness for > half an hour
- PTA for longer than 24 hours
- Not currently misusing alcohol and drugs
- Not suffering from a progressive brain disorder

Participants for this research were recruited from the Acquired Brain Injury Service's current caseload, and from Headway (a nationwide charity which has been set up to help people who have suffered a brain injury).

Those from Headway may not have met the ABI team's more stringent inclusion criteria, but did meet the research inclusion criteria. These participants were invited to take part in a research project (of which this research is a small part). Taking part allowed them access to the ABI team; as a part of this research they received cognitive assessment and a feedback session where results were explained with suggestions for compensation strategies. These clients were asked to sign a consent form to say they were happy to volunteer as part of the research project, (Appendices section 3). Ethical approval was obtained from South Bedfordshire

Local Research Ethics Committee; reference number AUG00/4e (Appendices section 1).

Inclusion Criteria

- Evidence of loss of consciousness.
- Within working age range at time of injury (16-64).
- Visit/Admission to hospital within 24 hours of injury.
- Evidence of a brain injury.

Exclusion Criteria

- No evidence of brain injury (i.e. either no reduced GCS Score, no Loss of Consciousness, no objective information e.g. scans or no or minimal Post Traumatic Amnesia).
- Requirement for special education prior to injury.
- Children under the age of 16.
- Progressive disorders.
- Current Drug/alcohol misuse.
- Current Vegetative/minimally conscious state.
- Significant uncontrolled mental health difficulties prior to injury.
- Difficulties with expressive and receptive dysphasia.

Participants who were current Service Users referred to the team immediately following their injury (from the acute setting) were offered the opportunity to complete a battery of neuropsychological assessments (as standard) at approximately six months post injury. This was dependent on them no longer experiencing Post Traumatic Amnesia and appearing to have reached a plateau in their recovery. If Service Users were referred from the community (and therefore usually some time following their injury – ranging from a few months, to several years) then testing was completed at referral, once it was established that they were not suffering from PTA.

The majority of the data required for this study was collected by the ABI service as routine. Service Users were informed of the nature and uses of the testing, i.e. to help guide rehabilitation goals and to allow them and their families to better understand the type of impairments that they were experiencing. They were told that some of the assessments were being used in a new way to understand learning ability and, if they were interested in completing these tests, they were taken through the consent procedure. Patients were informed as standard practice that they did not have to complete any assessments and that they could use as many sessions as necessary to complete the batteries. They were given the option to complete the assessments as part of their involvement with the team, to guide rehabilitation; but it could decide whether or not to have this information included in the research database.

3.2.1 Dynamic Assessment Procedure

For a detailed summary of the dynamic assessment procedure and for a more detailed description of the assessments adapted in a dynamic style please refer to the study chapters.

3.3 Data Collection Process

As a result of the broad range of participants referred to take part in this research programme, it was felt important to clarify the different referral procedures that could bring people to the research. This could be either through a legitimate referral to the team (where the team's criteria were met), or as a referral for neuropsychological assessment through the research programme (where only the research criteria had to be met). Individuals could be referred to the team and the research at any stage in their recovery, which means that there is a lot of heterogeneity regarding brain injury status among the population.

The following page is a flow chart representing the data collection process for participants who took part in the research project (Figure 11).

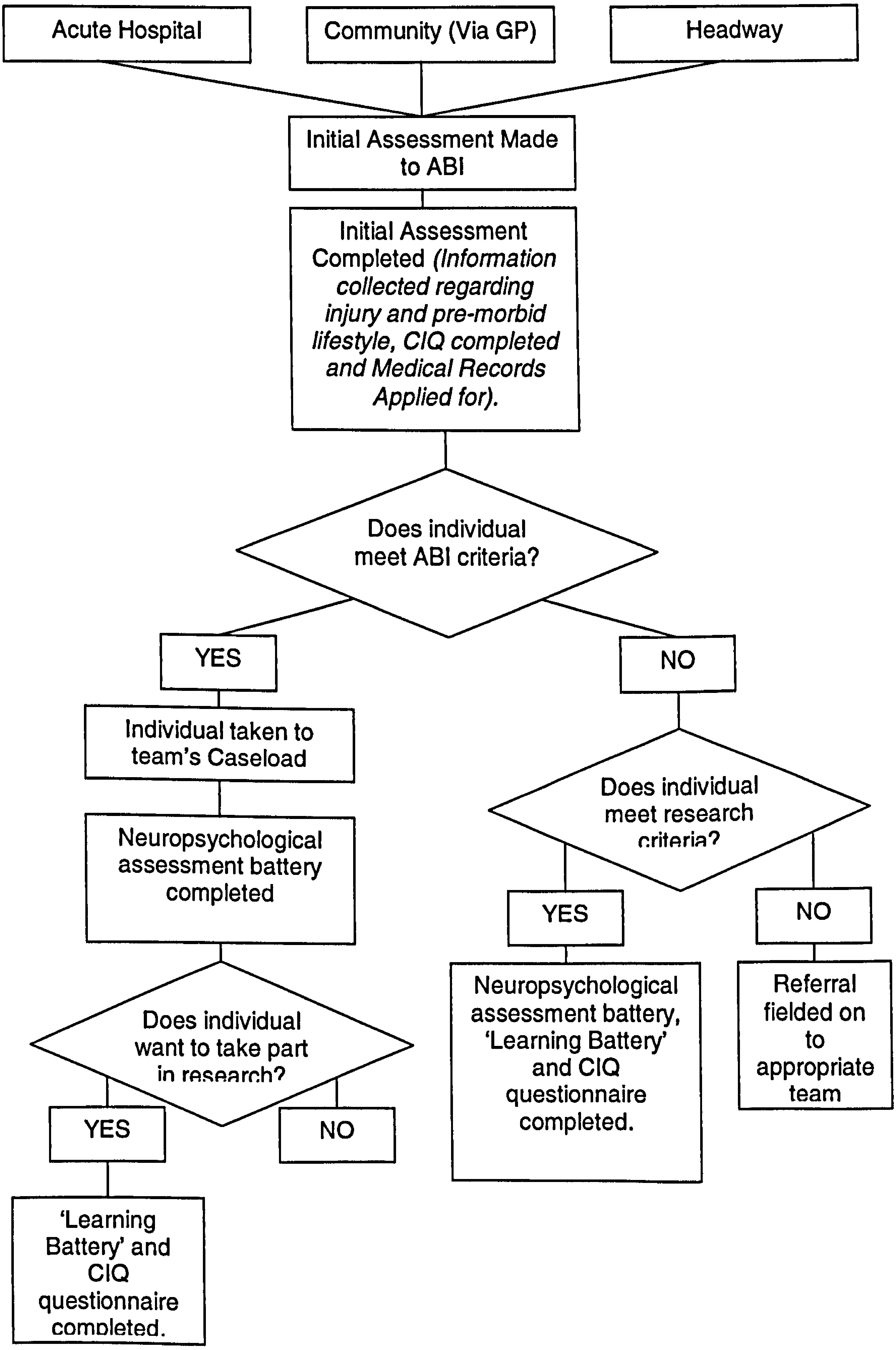

Figure 11: A Flow Chart Representing the Referral Routes for Participants in This Study

3.4 Design:

Due to the pragmatic nature of the investigation this research cannot be classified as an experimental design as it is considered unethical to manipulate conditions with this population. The research therefore becomes an ex post facto case-referent study. Using information collected to identify cognitive ability, the brain-injured sample will be categorised into different groups (independent variable). These groups can then be compared in terms of their experience to the dependent variables (brain injury, recovery, predictive factors, etc.).

3.4.1 Statistical Analyses

Data were originally entered onto Statistica v.6 (Statsoft, 2001; Vanderploeg & Schinka, 1995b). Rasch analysis was conducted using the Winsteps, Rasch Measurement software; version 3.57.1(Linacre, 2005). Following the Rasch analyses, data were analysed using standard statistical methods.

3.4.2 Power Analysis

Power analysis was considered, estimating for a large effect size, as once Rasch analysis has categorised the data it is expected that there will be little overlap between the categories (Cohen, 1988). Predicting a medium effect size would have perhaps been the safer option but people with complex brain injuries are relatively rare and the sampling pool is limited. The Acquired Brain Injury Service receives approximately 30-40 referrals per year and only a proportion of these would have been expected to both meet the study's criteria and agree to participate. A substantial proportion of this research population was expected to be recruited from Headway.

Using Cohen's (1992) guidelines on predicting sample size with power set at 0.80 and α set at .05, it can be anticipated that 42 people will be required for a multiple regression with 5 variables, and 21 people will be required per group for a 3 variable ANOVA. With regard to categorisation it was anticipated that three classifications of learning ability would be created. 1) Those able to perform above the cut-off for the majority of items prior to the dynamic errorless learning intervention (during the standard static assessment trial) (Spontaneous Learners), 2) those able to improve on the second trial (after the training intervention) and therefore score above the cut-off for the post-trial items, but not the pre-trial items (Guided Learners), 3) those unable to improve their performance on the second trial (after the training), and therefore perform below the cut-off for the majority of items both before and after the training intervention (Non Learners). This Classification process is represented diagrammatically in Figure 12.

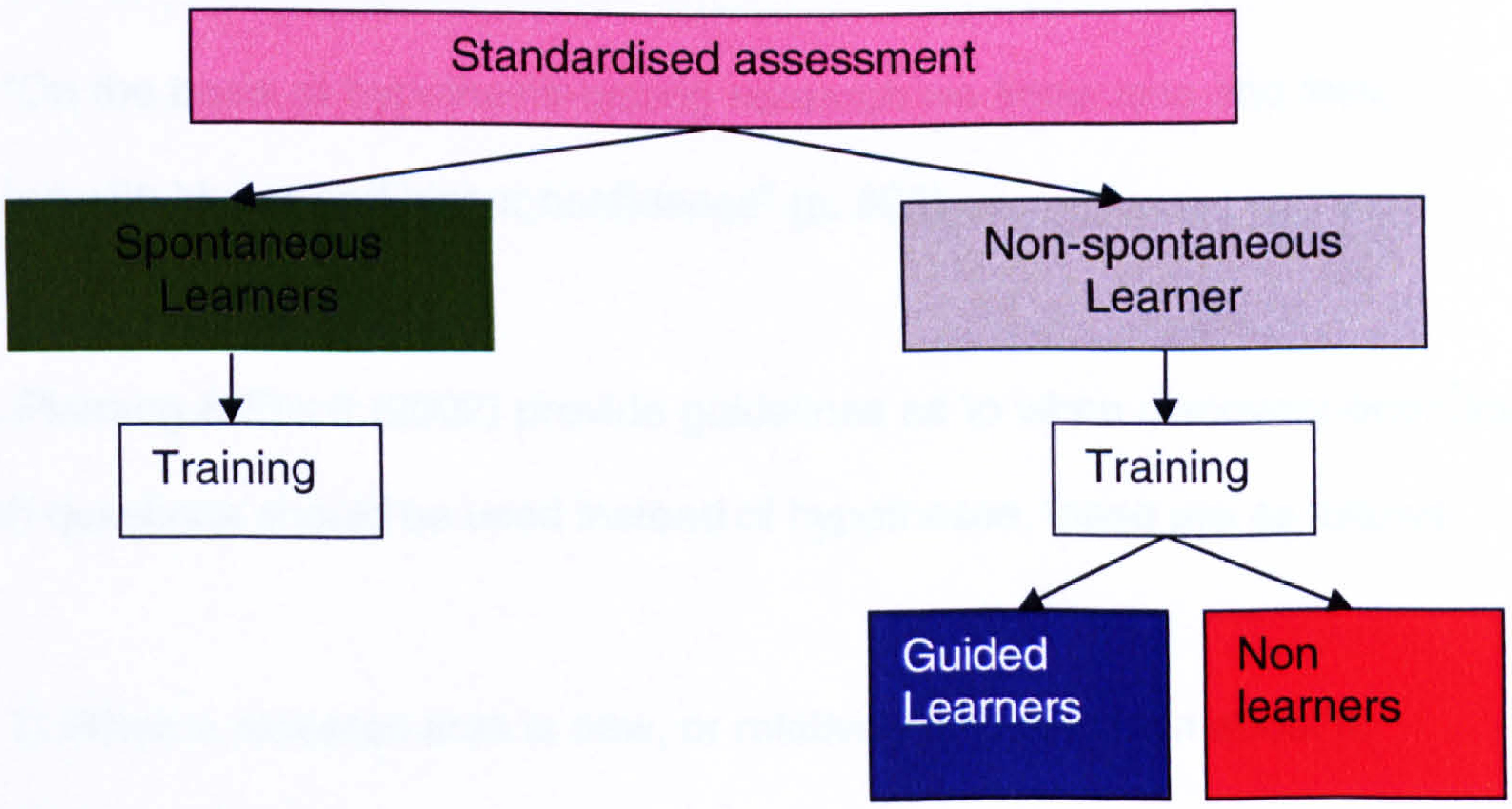

Figure 12: A Flow Chart Representing the Different Classifications of Learner Status to Be Identified By This Research

3.5 Aims and Research Questions

Although the major aim of this research project is to determine if measures of learning ability (either actualised or potential) have more clinical utility than static measures of cognitive assessment, this research will not be conducted with prior formal hypotheses. There are several reasons for this. The first and foremost is that so little is known about the field of dynamic assessment when it comes to brain injury. There is currently no sufficient theory that one can hope to replicate or disprove. It is understood that, in order for the most robust and statistically sound research to be conducted, hypotheses are essential; they add clarity to the investigation and result in a clear confirmation or rejection of a prediction made at the beginning of the research. Despite this, the use of hypotheses has been criticised and labelled as a gate-keeper that does nothing other than confirm or deny what already is known. (Mahrer, 1988).

> "On the basis of hypothesis-testing research we know less and less, but with higher and higher confidence" (p. 696)

Barker, Pistrang & Elliott (2002) provide guidelines as to when discovery-orientated research questions should be used instead of hypotheses, these are as follows:

1) When a research area is new, or relatively little is known about it.
2) When the evidence base of a research area is contradictory.

3) When the topic being researched is highly complex, requiring definition or description.

It is felt that this research met the first and third of these criteria and so it was decided that instead of hypotheses, some more general and exploratory research questions would be asked. These are as follows:

1. To what extent do people with brain injuries have difficulty learning?
2. Does intellectual ability impact learning?
3. Does severity of injury impact learning?
4. Does age have an impact on learning ability?
5. Does time since injury have an impact on learning ability?
6. What impact does learning have on outcome?
7. Does a measure of Learning Potential delineate ecologically valid levels of ability?

The first six of these questions will be applied to the first three studies. In the final study, consideration will be paid to what factors best predict recovery, as measured by the Community Integration Scale and the seventh question will be answered.

Chapter 4 : Results

4.1 Descriptive Statistics

A total of 150 people were referred to the Acquired Brain Injury service during the data collection period. . 128 of these met the research criteria, however of those, 24 were too impaired to engage, 8 disengaged and 4 died. Of the 128 appropriate referrals, 57 were referred from Headway; specifically for this research project, of which 47 chose to participate.

A total of 92 participants underwent some form of neuropsychological assessment; 14 preferred not to continue (due to difficulty engaging in the assessment process). The remaining 79 took part in the battery of learning assessments. 32 (41%) members of this sample were ABI patients, and 47 (59%) were Headway patients. The total sample for Study One (Explicit Verbal study) was 77, for Study Two (the Visuospatial) was 67, for Study Three (the implicit study) was 63. Reduction in numbers over each study was due to attrition or difficulties engaging in all subtests fully.

A summary of these figures is found in Table 1; Table 2 provides demographic information regarding the population, and Table 3 summarises any recorded information relating to the location of damage in the brain.

	N
Number of referrals to the ABI Service	150
Number of referrals from Headway	57
Number of referrals who chose not to participate	10
Number of referrals that met ABI criteria	75
Number that met research criteria	128
Disengaged prior to testing	8
Died	4
Unable to engage in testing/ Disengaged during testing /chose not to continue (i.e. due to poor eyesight, distress etc.)	24
Completed neuropsychological Assessment battery	92

Table 1: Frequencies of participants referred to the research project

		N (%)
Gender	Male	60 (76)
	Female	19 (24)
Age at onset	Mean (s.d.)	31.34 (12.7)
Socio-economic Status (HMSO)	Unskilled	24 (30)
	Semi-skilled	13 (17)
	Skilled	18 (23)
	Intermediate	7 (9)
	Professionals	9 (11)
	Missing	8 (10)
Marital Status	Single	46 (58)
	Married	23 (29)
	Divorced	2 (3)
	Separated	1 (1)
	Partner	3 (4)
	Missing	4 (5)
Cause of Brain Injury	Trauma	60 (76)
	Vascular Accident	8 (10)
	Cerebral Anoxia	6 (8)
	Other Toxic, Metabolic Insult	0 (0)
	Infection	2 (2)
	Missing	3 (4)

Table 2: Demographic Characteristics of the ABI and Research Patients Who Meet Research Inclusion Criteria

Case Note Information Relating To Neurophysiological Injury.	*Number Of People In This Category*
No evidence in notes	15
Frontal	12
Temporal	6
Parietal	4
Fronto-temporal	5
Tempero-parietal	3
Fronto-parietal	2
Other	2

Table 3: Distribution of Damage to lobes

4.2 Preliminary Analysis

An investigation was conducted with the key variables to ensure that the assumptions for parametric testing were met.

Normal Distribution

Key variables that are central to the analysis were tested for assumptions of normality; the Shapiro-Wilks test revealed that some of the variables were skewed. This would suggest that they were not suitable for parametric analysis. However other research has found that parametric analysis is robust against skewed data (Glass, Peckham, & Sanders, 1972). Moreover, Gangestad & Thornhill (1998) go so far as to suggest that using non-parametric analysis for data that does not have a normal distribution increases the risk of Type II error rates without the usual positive effect of decreasing Type I errors, and reduces the power of the assessment. They suggest that parametric assessments are robust enough to cope with the compromised normal distribution and are preferable to non-parametric assessment. With this in mind parametric analysis will be conducted on the data collected.

Prior to any of the parametric analyses an investigation was conducted to establish if there were any outliers that might impact the results. For this research outliers were considered to be scores which fell three standard deviations away from the mean (refer to Figure 13 for an example of an outlier). If outliers were identified, the analysis was conducted both with and without them to establish if they affected significance (Altman, 1991), and if they did they were removed and commented on.

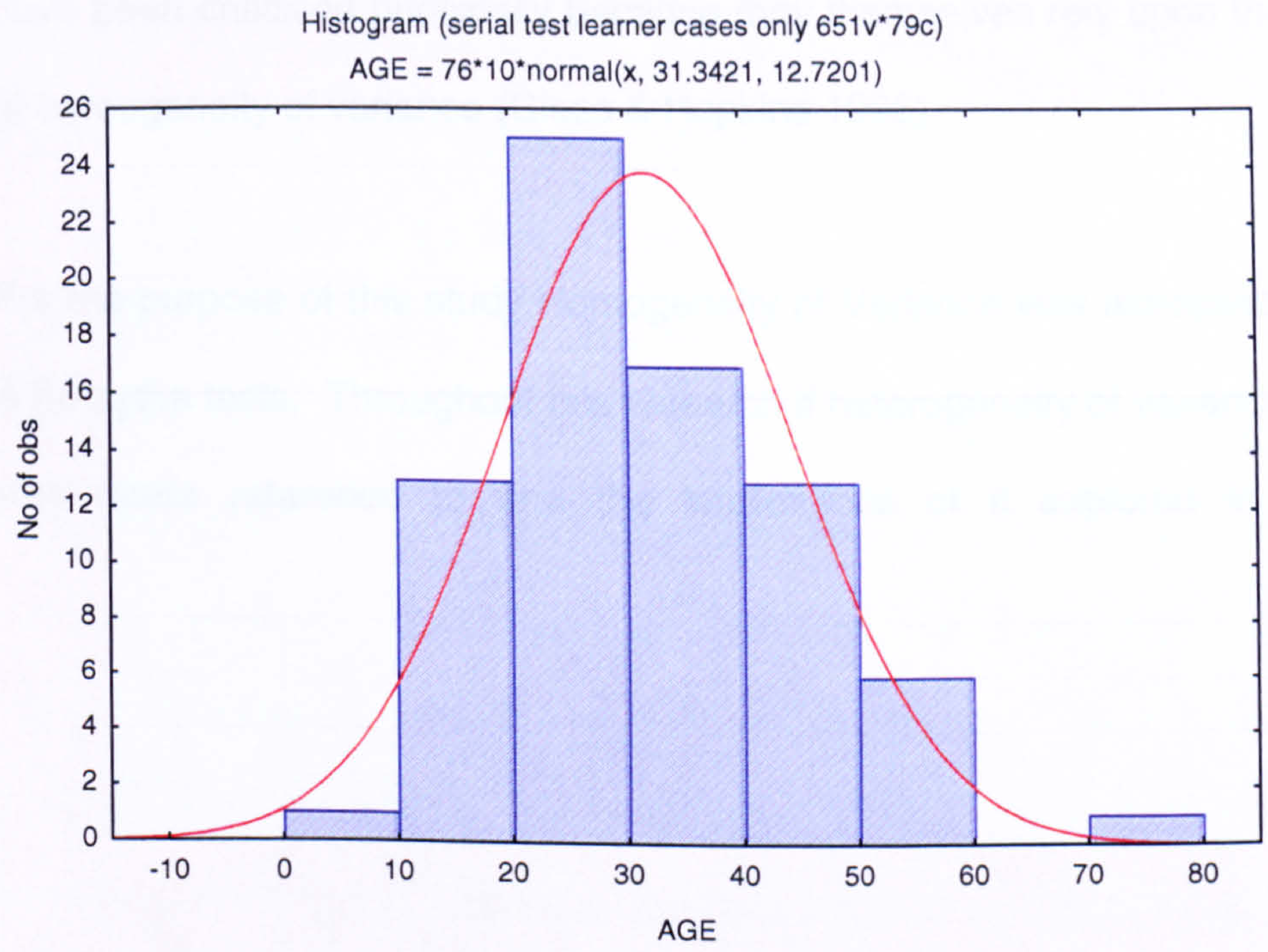

Figure 13: Histogram Illustrating a Normally Distributed Age-Range with One Outlier Falling Outside Of Three Standard Deviations above the Mean

Homogeneity of Variance

As one of the key assumptions in parametric statistics is that all the groups being compared will be similar and, therefore, have an equivalent variance (if the variance is different then adding them together will not be appropriate) then assessments of this variance were conducted for all dependent variables.

There are two main tests that assess Homogeneity of Variance, Levene and Brown & Forsythe. Levene is designed to test this for dependent variables by looking at the standard deviation of each variable's mean. Brown & Forsythe's analysis investigates the standard deviation of the median (this was done so that even if there is a deviation from the normal distribution, error rates are reflected). For both of these tests a significant score reflects heterogeneity of variance. These tests have been criticised principally because they themselves rely upon the assumption of homogeneity of variance (Glass & Hopkins 1996).

For the purpose of this study Homogeneity of Variance was assessed using Brown & Forsythe tests. Throughout this research if heterogeneity of variance was found it was made reference to and the implications of it explored in more detail.

Chapter 5 : Study One: Investigation into Explicit Verbal Learning Using the Wisconsin Card Sorting Test

As discussed in Chapter 3 section 3.1.1, this first study will set out to replicate Wiedl's (1999) investigation into the utility of dynamic learning using the WCST. The aim of this study is to investigate the clinical utility of performance on the standard WCST and to compare this to a dynamic version of the test (which includes baseline performance and performance after an errorless learning training intervention). This is the first of three investigations into learning potential (with a fourth study investigating each test in the context of the others); Chapter 3 section 3.1 describes the reasoning behind the choice of each test. For consistency, the dynamic training administrations of the test have been designed to capitalise on the same processing system that each test taps into. Therefore, if the processing system is verbal then the instructions on how to complete the test are provided verbally and throughout the practical errorless training intervention, verbal reinforcement is given. Alternatively if the learning system is visuospatial then the training element maximises this learning system, minimising the verbal element as much as possible. To stay true to the implicit learning system, there is no training section, simply a second administration of the test (to avoid the test becoming rule based and therefore declarative).

The results of all three studies will be considered in terms of clinical utility in the fourth study (Chapter 8).

Methodology

Please refer to Chapter 3 for overall research design, methodology and information regarding the assessments completed.

The WCST was described briefly in Chapter 3 section 3.1.1. Its design, rationale, administration and content will be described in greater depth below. The standard WCST (Heaton, 1981) is a commonly used neuropsychological assessment (Feldstein et al., 1999; Paolo, Axelrod, & Troster, 1996). It was originally designed to measure flexible thought (Berg, 1948) by assessing the impact that reinforcement had on shifting set. The assessment consists of four key cards; one with a red triangle, one with two green stars, one with three yellow crosses and a final card with four blue circles. There is also a deck of 128 playing cards each containing a combination of the shapes, colours and numbers presented in the four key cards. The participant is informed that they can not be told much about how to complete the assessment but that they must try to sort the cards and will be given feedback on each sort. They are also informed that there is no time limit and that the aim is to get as many correct as possible. The participant must then decide how to match the cards from the deck (to which of the key cards). Unknown to the participant are the rules for the assessment that change periodically. The first rule is to group the cards by colour, and after 10 consecutive correct responses the participant must group the cards by the shape shown on the card and finally by the number of items on the card (regardless of shape or colour). This set of rules then repeats itself so that it is possible to complete the test in a minimum of 60 cards.

Despite its frequent use, there is considerable debate as to what the WCST actually measures. It has been suggested as a measure of abstract reasoning (Artiola, Fortuny, & Heaton, 1996), problem solving and concept formation (Grafman, Jonas, & Salazar, 1990) and conceptual problem solving (Goldman et al., 1996). Other research has focused more on what it does not measure e.g. Paolo et al (1995 cited in Paolo et al 1996) found that the WCST was independent of memory and attention.

A possible reason for the inconsistent outcomes is that the WCST offers several different measures (Total Errors, Total Correct, Failure to Maintain Set, Perseverative Errors, Perseverative Response, Non Perseverative Errors, Conceptual Level Response, Total Categories Completed, and Learning to Learn). The search to understand whether each category taps into its own cognitive function or whether there is a unilateral function to the test has again resulted in contradictory evidence. Some studies have found support for a unitary latent structure (Robinson, Heaton, Lehman, & Stilson, 1980), others for a two factor structure (Greve, Williams, Haas, Littell, & Reinoso, 1996) and some for three factors, (Sullivan et al., 1993). Other research found evidence for both single and multiple structures dependent upon the client group (Goldman et al., 1996). Table 4 below outlines what properties each item of the WCST is thought to consist of.

Trials Administered	This item provides information about how many cards were administered during the test. It can indicate overall performance at either extreme (e.g. if someone completed the assessment using the minimum number 60 or maximum number 128 – suggesting a significant degree of mistakes were made) but on its own provides no indication if the participant successfully completed the assessment. It therefore has no normative data.
Total Correct	As above, this item can be misleading unless it is interpreted in the context of the other scores. This is because an increase of correct items does not correlate with an improved performance. It is possible to get up to 113 correct sorts but still not complete any categories of the test.
Total errors	This item provides information about how many errors an individual made during the assessment.
Perseverative Errors	This item indicates whether the person has continued to sort according to an attempted rule despite being fed back that the sort is incorrect. According to Lezak (2004) this provides information about forming concepts, profiting from correction and conceptual flexibility.
Perseverative Responses	This item reflects a response that had been correct in the previous category, or an incorrect response that has been continued prior to the first category being completed. This item of the WCST has been identified as the best measure of predicting presence or absence of brain damage and frontal involvement (Heaton 1981).
Non Perseverative Errors	This item provides information about responses to the test that do not appear to be related to a Perseverative Response or Error. It could reflect guesses or a non related rule sort (i.e. not related to colour, shape or number). This item is thought to be more strongly connected to neuropsychological functioning for the normal population rather than the brain injured population (Heaton 1981).
Conceptual Level Response	This item provides an indication of whether the individual has gained an understanding of the premise of the test, this is measured by calculating all the sets of three or more consecutively correct responses.
Trials To Complete First Category	This item indicates how many sorts were required before an individual understands and adheres to the concept/rule of the first sort (colour). The minimum number of moves this could occur in is ten and the maximum would be 128 cards (indicating that the individual did not manage to attain the first rule and therefore complete the first category).
Categories Complete	This item indicates how many of the rules the individual managed to work out and adhere to. This can range from 0 to 6 sorts. Lezak (2004 4th ed) cites this item as one of the most widely used scores, along with Perseverative Responses and Perseverative Errors.
Failure to Maintain Set	This item looks at how often a person inexplicably changed their sorting rule after five consecutive correct responses. It has been thought of as a measure of attention for this reason (Greve, Williams, Hass et al 1996).
Learning to Learn	This provides information about the change of efficiency throughout the assessment. It is determined by calculating the reduction of errors in between categories as the test goes along.

Table 4: A Descriptive Summary of Each of the Eleven Items of the WCST

The WCST has shown promise in the face of the changing roles of neuropsychological assessment (please refer to Chapter 1 section 1.8 for information about this), with evidence being found to support it as an ecologically valid tool for predicting functional outcome. For example, performance on this test has been found to correlate with successful return to work (Bulter, Anderson, Furst, Namerow, & Satz, 1989). This information might also be helpful when predicting recovery success; if the WCST is able to provide information regarding return to work it may be tapping into a latent measure of ability to adapt (Sullivan et al., 1993).

For the purpose of this research, a computerised version of the WCST was administered (Heaton, 2003). The computerised version removes the common inter-rater reliability problems and any difficulties that arise due to the complicated nature of the scoring system (Feldstein et al., 1999). Whilst the computerised assessment is yet to prove itself in terms of consistency with the manual version, (Feldstein et al., 1999; Fortuny & Heaton, 1996), this is a non-issue for this research as the focus is on individual change rather than normative data.

5.1 Procedure

Participants completed the neuropsychological battery as outlined in Chapter 3, section 3.1.5 and were required to complete the WCST twice. The first administration is the standard version of the test. The participant was told that they must decide how they will match each card to one of the four key cards; they were also given feedback by the computer after each sort. This pre-training administration will be referred to as the Standard WCST from here on in. Following the standard administration each participant was told that the rules of the test would now be explained to them and that they would be shown how to complete it with no mistakes, and they were also informed that they would then be asked to try the test again on their own. Training adopted an errorless learning technique and involved the participant running through the test with guidance and verbal reinforcement from the examiner, who encouraged as much active involvement from the participant as possible (please refer to Chapter 1, section 1.12 for more detail about errorless learning). For the dynamic trial, (post-intervention trial) participants were asked to complete the test one last time but this time with no help from the examiner (See Appendices 6 for the Standard and Dynamic training scripts.), Figure 14 illustrates the Pre-test – train – Post-test dynamic assessment procedure.

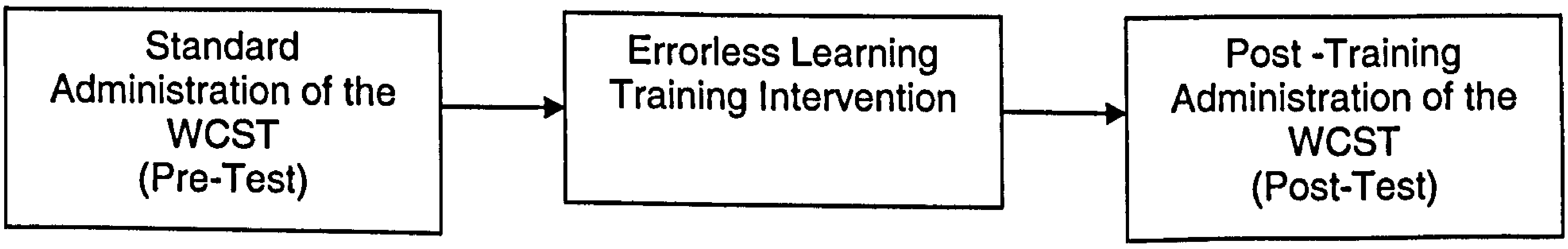

Figure 14: A Flow Chart Representing the Stages of the 'Sandwich Style' Dynamic Assessment Procedure

The measured improvement that each individual makes on their dynamic WCST performance is thought to represent their latent capacity/ZPD/cognitive modifiability. It is hoped that this information will be more clinically useful than the information currently provided by the Standard WCST, which adopts a more static process of assessment. When the term Dynamic WCST is used from here on in, it will be referring to the overall consideration of the pre and post-training performances.

Scoring

The WCST computer programme provides a report that includes the raw scores and where applicable the T-Scores and percentiles are provided for each of the eleven items of the test (outlined in Table 4). With the pre/post administration of the test, two sets of scores are provided for each of these measures. The aim of this study is to find a meaningful way to compare these two scores to represent any improvement that is made.

5.2 Data Conceptualisation and Analysis

For the purpose of this study two Rasch analyses will be conducted.

5.2.1 Statistical Qualities of the Rasch Model

The Rasch model allows a visual representation of how each participant responds to each measure of a test; it plots this information to create a hierarchy of person ability and item difficulty.

As well as hierarchical data, the Rasch model is also able to provide information about the construct validity of the test items being measured. As outlined earlier, the Infit measure has been chosen to reflect the 'misfit' information. Chapter 2, section 2.5 outlines the reasons behind the specific choices of data handling in greater depth.

The first Rasch analysis explores the hierarchy and fit of the items from the Standard WCST performance. This will reflect how the WSCT is commonly used in a clinical setting. This means applying a clinical cut-off to split performance into impaired and non-impaired categories. The cut-off that was applied was the 16th percentile. The 16th percentile was used because it represents one standard deviation below the mean of the population. Clinically, this measure determines functioning below the low average range (and therefore in the impaired range). It is accepted that using discrete cut-offs is problematic and there are preferable methods available e.g. the use of confidence limits (Goodman & Berlin, 1994). However, in order for a unidimensional Rasch analysis model to be used, the data must be split and the 16th percentile cut-off is thought the most appropriate measure available.

A Rasch model using the 25th percentile was also completed but this map only affected the position of seven participants in the study and had little impact on the fit, error and separation abilities of the test. As the 16th percentile is a more clinically relevant separation score it was used instead. (Appendices 9 includes the 25th percentile item map.)

This Rasch model provides information about how the Standard WCST currently defines an ABI population in terms of performance on the test. It also provides information about whether the nine items that have normative information belong to a unidimensional construct or if the different scores are measuring different skills.

The second Rasch analysis considers the performance on both the pre and post-training administrations together. As with the Standard WCST Rasch analysis, the Dynamic WCST Rasch model requires category data (which is then converted into interval data using a logarithm of odds algorithm), and therefore, it is necessary to split the scores. Following an exploration into the utility of the two chosen methods for classifying change outlined in Chapter 2, section 2.3, it was decided that using the reliable change index would not allow a good enough investigation into the impact that dynamic training has on the difficulty and construct validity of the different measures of the WCST (please refer to Appendices 10 for the Rasch map using the reliable change for the WCST). It was therefore decided that the most efficient way to explore the impact of dynamic training on the post administration of the WCST was to count both administrations (pre and post) as independent measures of the same test (doubling the number of items of the test). A cut-off was required for each item (the same was applied to the pre and post items) in order to reflect movement after training). The chosen option for the dynamic WCST Rasch was one standard deviation above the mean of the dysfunctional population (at the time of the initial performance). The reasons for this choice and the limitations of it have been discussed in detail in Chapter 2, section 2.3.

The second Rasch analysis represents how a dynamic test defines the population. Following this a comparison will be made to see which is the most useful.

In order to understand and compare the effectiveness of the Standard WCST versus the Dynamic WCST, participants were categorised according to their placement on the hierarchical map (and therefore their ability to succeed on the test), i.e. those falling in the top range, in the mid range and in the bottom range. Therefore each participant will be classified twice; once according to their ability on the Standard WCST, and once according to their performance on the Dynamic WCST. During the second part of this study, the data analysis will see these groups tested using more conventional statistics (primarily ANOVAs) in an attempt to find answers to the seven research questions outlined in section 3.5. These questions will also be answered by the learner classifications that are created by the Standard WCST Rasch Model (using the 16th percentile cut-off). The significant ANOVAs will be compared to examine if the dynamic version of the test is more useful in separating out the participants and thus providing better information about person ability. The implications of the findings will then be discussed.

5.3 Results

See Chapter 4, section 4.2 for a detailed description of the preliminary analysis.

5.3.1 Part One of the Data Analysis: Rasch for the Standard and Dynamic WCST

A Rasch Analysis was conducted using the information gained from the Standard WCST (pre-training). Figure 15 summarises the hierarchy of item difficulty and person ability as they would be interpreted in a clinical setting using the 16th percentile cut-off.

```
                          items MAP OF persons
                             <rare>|<more>
                       73          +  XXXXXXXXXXXXXXXX
                                      XXXXXXXXXXXXX
                       72          +
                       71          +
                       70          +
                       69          +
                       68          +
Trials to Complete First Category S+
                       66          +
                       65          +
                       64          +T XXXXXXX
                       63          +
                       62          +
                       61          +
                       60          +
                       59          +
                       58          +
                       57          +S XXXX
              Categories Complete  +
                       55          +
                       54          +
                       53          +
                Learning to Learn  +  XXX
                       51          +
                       50         M+M
                       49          +
          Failure to Maintain Set  +
                     Total Errors  +  XXXX
             Perseverative Errors  +
        Conceptual Level Response
         Non Perseverative Errors  +
          Perseverative Responses  +
                       43          +S
                       42          +  XXXXX
                       41          +
                       40          +
                       39          +
                       38          +
                       37          +
                       36          +T XXXXXXXX
                       35          +
                       34          +
                       33         S+
                       32          +
                       31          +
                       30          +
                       29          +
                       28          +  XXXXXXXXXXXXXX
                       27          +  XX
                             <frequ>|<less>
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Figure 15: Item Map Representing the Hierarchy of Difficulty for the Standard WCST Administration Using 16th Percentile Cut-Off

This map shows the hierarchy of the items of the WCST. The Xs on the right of the map represent the participants. This allows for the identification of each participant. The items on the left are the nine measures of the WCST that have normative data and have been split in terms of whether each individual is performing above or below the 16th percentile cut-off. The items and the participants are plotted along an interval logarithm of odds scale, which has been shown as a percentage. The higher up the scale an item is the more difficult it is to reach the cut-off for and the higher up an 'X' is on the scale the higher that individual's level of achievement.

In terms of interpreting this item map it is important to know that the Rasch model is probabilistic. If a person (x) on the right is below an item there is a 25% probability that they could have scored at, or above the 16th percentile cut-off. If they are above the item there is a 75% chance that they have scored at above the 16th percentile cut-off. If they are equal to the item there is a 50% chance. It can be seen that the easiest item to pass (and therefore be performing above the 16th percentile on) is the 'Perseverative Responses item). The hardest item to reach the clinical cut-off is 'Trials to Complete the First Category'.

29 (39%) participants failed to reach the clinical cut-off for the easiest item. This indicates that it is unlikely they scored at or above the 16th percentile for any of the items of the WCST. This means that they are likely to be scoring in the impaired range for every item on this test. 28 (37%) participants reached the clinical cut-off for the hardest item. This indicates that they are likely to have scored outside of the impaired range (greater than the 16th percentile) for every item of the WCST. The remaining 18 participants (24%) are spread across the map.

This distribution had created a large ceiling and basement effect with little spread. The implications of this will be discussed in further detail in the discussion, section 5.4 of this chapter.

Construct validity was assessed using Misfit data. The criterion for assessing Infit statistics is that anything outside the range of -2 and +2 Zstd (Standardised Z scores) is excluded from the unidimensional construct as it failed to meet the criteria set for fit (Bond et al., 2001).

Figure 16 graphically illustrates the way that items have been mapped according to their difficultly (y axis), unidimensional fit (x axis) and the accuracy that each item has in predicting its place on the hierarchy; i.e. its standard error (as represented by the size of the bubble).

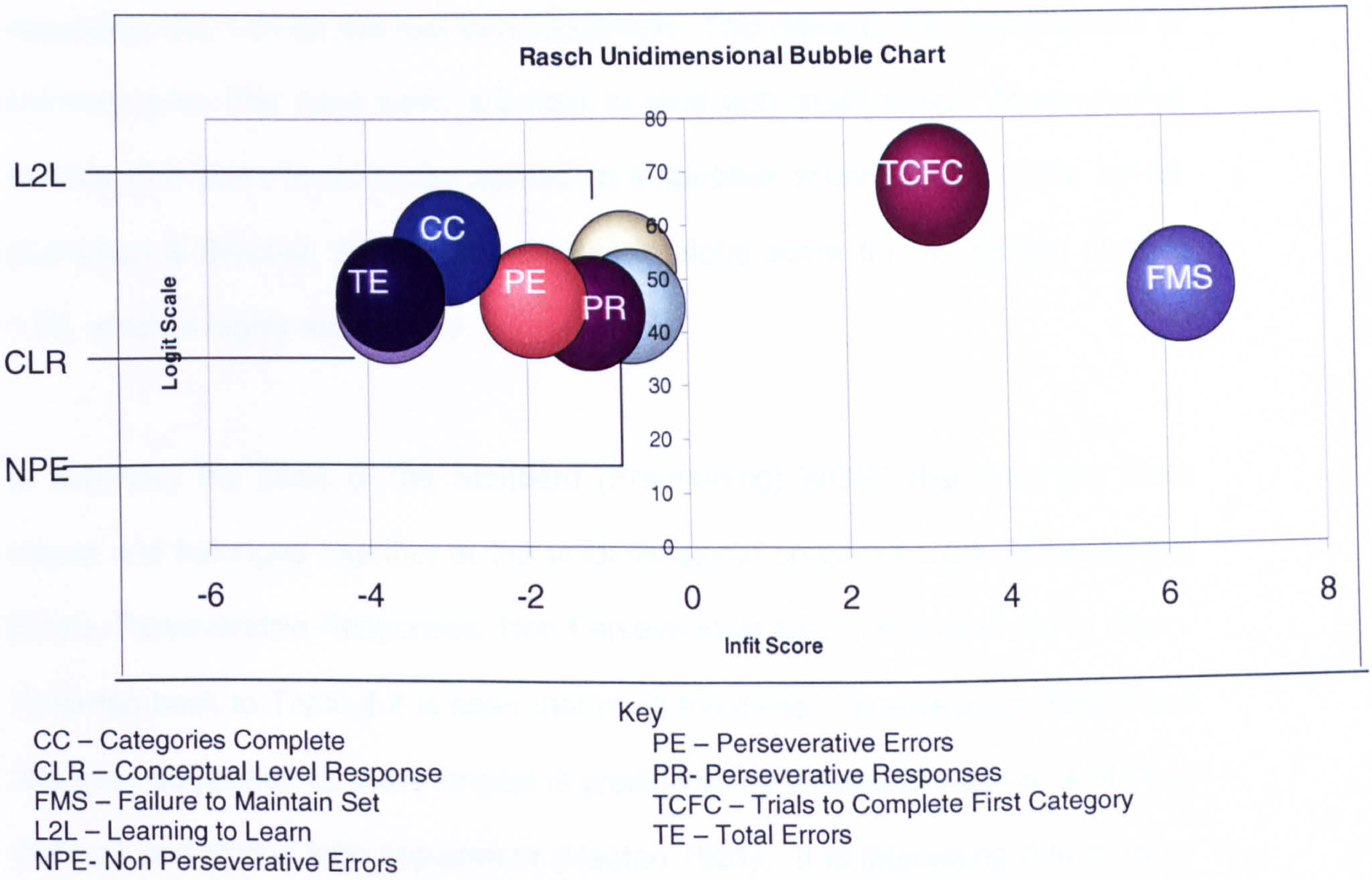


Figure 16: A Bubble Chart Representing the Rasch Model for the Standard WCST Using 16th Percentile Norms

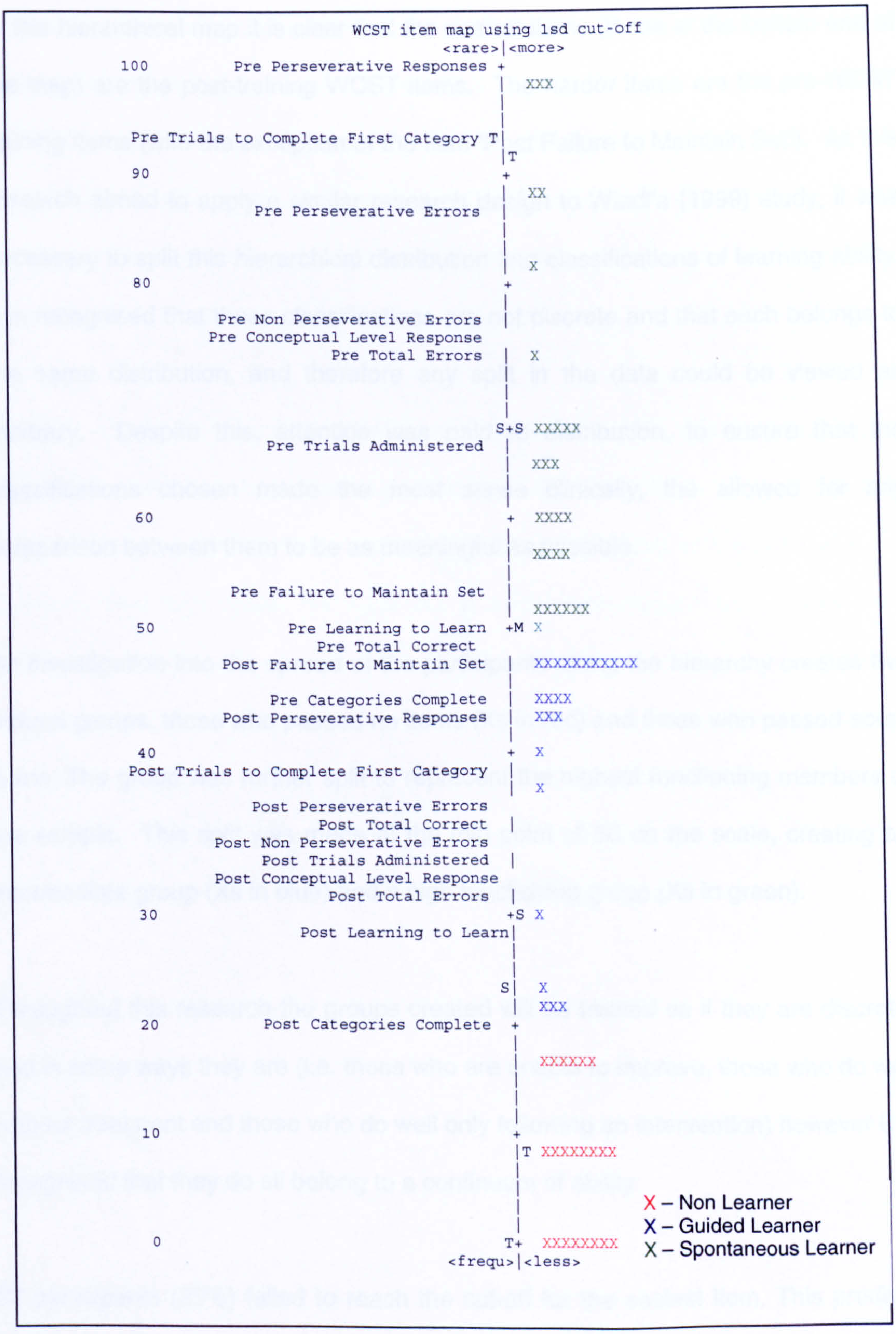
The three items on the left hand side are the items that do not fit the model; Total Errors (TE), Conceptual Level Response (CLR) and Categories Complete (CC). An Infit score greater than -2 indicates that these have less variation than the model would have predicted (they are more like the Guttman scaling model). The two items on the right of the map; Failure to Maintain Set (FMS) and Trials to Complete First Category (TCFC); are greater than +2, which indicates that they have more variance in the scores than the model would have predicted (they are less like the Guttman scaling model). The overlap of the items indicates that there is some imprecision in terms of accuracy of placement in the model of these items for this population.

The Separation scores for the normative WCST are 1.45 for the real person separation and 1.51 for the real item separation. This refers to the overall scores of standard error that have been adjusted to deal with misfit data. These scores indicate that there is adequate spread (a separation score of one is the cut-off (Sampson & Bradley, 2005)). The Cronbach alpha score for the person plots is 0.89, which is highly respectable.

In summary the items of the Standard (Pre-training) WCST that were the most robust and belonged together in the unidimensional construct were Perseverative Errors, Perseverative Responses, Non Perseverative Errors and Learning to Learn. Referring back to Table 4 it is seen that of all the items, Perseverative Responses has been suggested as the strongest in predicting the presence or absence of brain damage and frontal lobe impairment (Heaton 1981). It is interesting that three of the items (Perseverative Errors, Perseverative Responses and Non Perseverative Errors) are all related, in that they reflect a person's performance in terms of perseveration. In many ways, the Learning to Learn item could also be seen as reflecting perseveration (i.e. it is impossible to show learning if you continue to perseverate). In fact the 'Learning to Learn' item is created by measuring the reduction of errors in each grouping category. Perhaps the similarities between these four items, as well as the fact that they are all related in terms of performance, is why they reflect the overall construct.

Rasch for the Dynamic WCST

This item map (Figure 17) represents the hierarchy of difficulty for the items of the WCST (both pre and post-training administrations) and the hierarchy of achievement for each individual in the research sample. As with the first Rasch analysis each X on the right hand side of the map represents a participant. The items and the participants are plotted along an interval logarithm of odds scale, which has been shown as a percentage. The higher up the scale an item is the more difficult it is to reach the cut-off for and the higher up an 'X' is on the scale the higher that individual's level of achievement.



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                                    WCST item map using 1sd cut-off
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        100          Pre Perseverative Responses +
                                                 | XXX
                                                 |
                                                 |
       Pre Trials to Complete First Category T|
                                                 |T
        90                                       +
                                                 | XX
                       Pre Perseverative Errors |
                                                 |
                                                 |
                                                 |  X
        80                                       +
                                                 |
                  Pre Non Perseverative Errors |
                 Pre Conceptual Level Response
                               Pre Total Errors |  X
                                                 |
                                                 |
                                               S+S XXXXX
                       Pre Trials Administered |
                                                 | XXX
                                                 |
        60                                       + XXXX
                                                 |
                                                 | XXXX
                                                 |
                    Pre Failure to Maintain Set |
                                                 | XXXXXX
        50                Pre Learning to Learn +M X
                            Pre Total Correct
                   Post Failure to Maintain Set | XXXXXXXXXXX
                                                 |
                        Pre Categories Complete | XXXX
                   Post Perseverative Responses | XXX
                                                 |
        40                                       + X
       Post Trials to Complete First Category |
                                                 | X
                      Post Perseverative Errors
                             Post Total Correct |
                  Post Non Perseverative Errors
                      Post Trials Administered |
                 Post Conceptual Level Response
                              Post Total Errors |
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X – Non Learner
X – Guided Learner
X – Spontaneous Learner

Figure 17: Item Map Representing the Hierarchy of Difficulty for the Items of the WCST (Both Pre and Post-Training Administrations)

In this hierarchical map it is clear that the easiest items (those at the bottom end of the map) are the post-training WCST items. The harder items are the pre-WCST training items (with the exception of the item 'Post Failure to Maintain Set'). As this research aimed to apply a similar research design to Wiedl's (1999) study, it was necessary to split this hierarchical distribution into classifications of learning ability. It is recognised that these classifications are not discrete and that each belongs to the same distribution, and therefore any split in the data could be viewed as arbitrary. Despite this, attention was paid to distribution, to ensure that the classifications chosen made the most sense clinically, the allowed for any comparison between them to be as meaningful as possible.

An investigation into the spread of the participants along the hierarchy creates two natural groups, those who passed no items (Xs in red) and those who passed some items. The group was further split to represent the highest functioning members of the sample. This split was made at the mid point of 50 on the scale, creating an intermediate group (Xs in blue) and a high functioning group (Xs in green).

Throughout this research the groups created will be treated as if they are discrete, and in some ways they are (i.e. those who are unable to improve, those who do well without treatment and those who do well only following an intervention) however it is recognised that they do all belong to a continuum of ability.

22 participants (29%) failed to reach the cut-off for the easiest item. This predicts that it is unlikely they reached the cut-off for any of the items; this group were labelled Non Learners. No participants reached the cut-off for the hardest item but 30 (39%) were grouped into the highest scoring category. As these participants

showed evidence of passing some of the items in the Pre administration they were labelled Spontaneous Learners. Of the remaining, 25 individuals (32%) passed the cut-off for some of the items throughout the lower half of the item map (ranging from Post Categories Complete, to Post Failure to Maintain Set). As these individuals showed evidence of passing the items following training they were labelled Guided Learners.

Item fit is represented using the bubble chart (Figure 18). To aid interpretation, the post item measures have been plotted in a different colour to the pre item measures. As with the previous bubble chart, the items are plotted along a hierarchy (the logit scale) although this is better represented on the item map above.

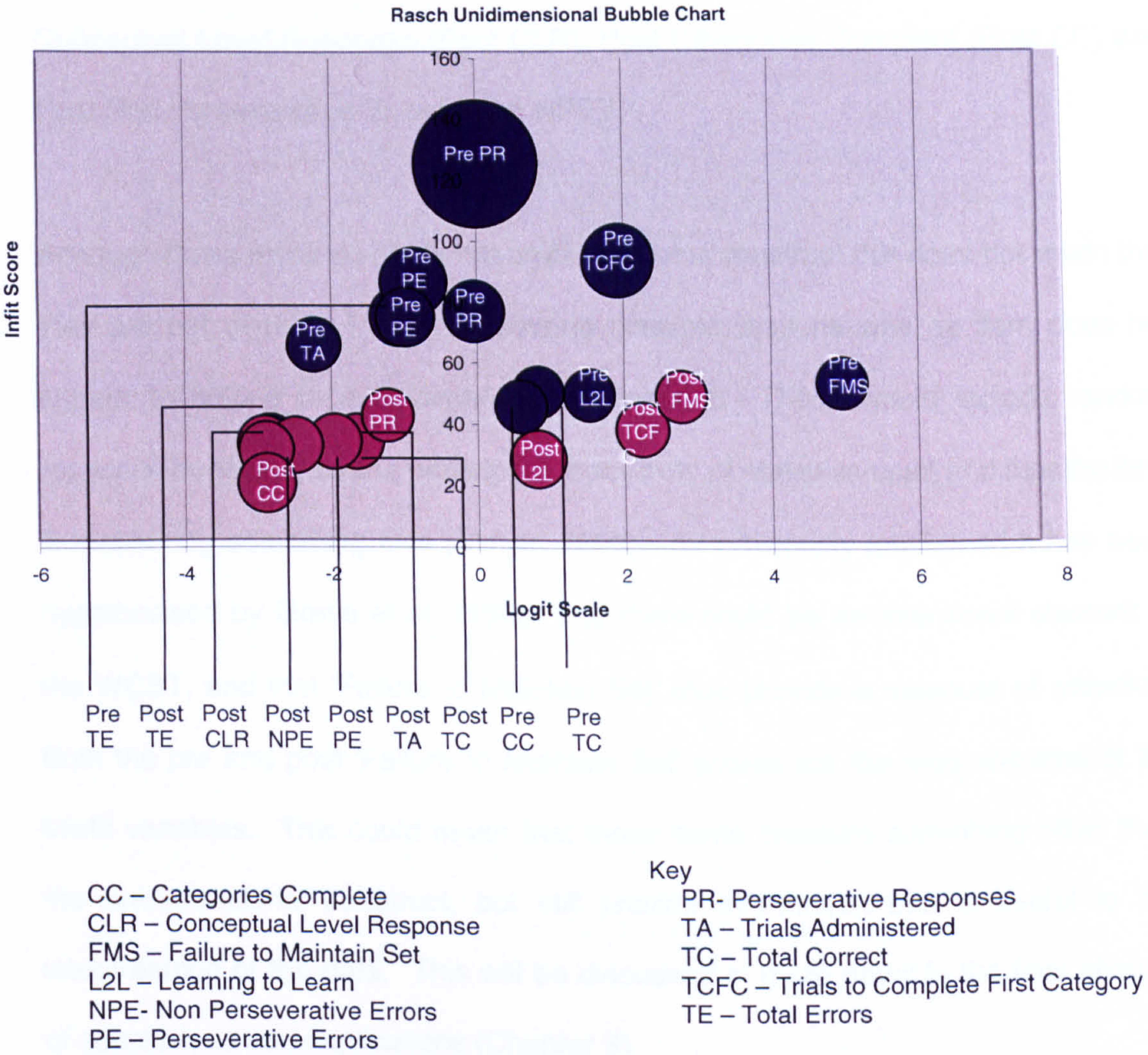


Figure 18: A Bubble Chart Representing the Rasch Model for the Dynamic WCST Using the One Standard Deviation Cut-Off

This map is best used in understanding the item fit and the error of the variables. In terms of item fit, the bubble chart shows that 14 of the 22 items belong to a unidimensional construct on the basis that they fall within the range of -2 and +2 standardised Z scores (Bond et al 2001). Of those that do not fit, three have more variance than the model would have predicted (Pre Failure to Maintain Set (Pre FMS), Post Failure to Maintain Set (Post FMS) and Post Trials to Complete First Category (Post TCFC)). Five have less variance than the model would have predicted (Pre Trials Administered (TA), Post Total Errors (Post TA), Post Conceptual Level Response (Post CLR), Post Categories Complete (Post CC) and Post Non Perseverative Errors (Post NPE)).

Although these items do not fit the unidimensional construct this does not mean that they are not useful. There are several possible reasons why an item does not appear to belong to a unidimensional construct. These would include random response behaviour by the participant, sensitivity of statistics used and that the item is measuring something else (Meijer, 2003). As previously mentioned it has been hypothesised by Greve et al (1996) that there could be an attentional element to the WCST, and that 'Failure to Maintain Set' may provide a measure of attention. Both the pre and post 'Failure to Maintain Set' scores are the most extreme of the Misfit variables. This could mean that these items measure something other than the unidimensional construct, but still provide information that is useful to the interpretation of the data. This will be discussed in more detail in the final chapter of conclusions and implications (Chapter 9).

The remaining items are those which fit within the construct, and these have been listed in order with the first as the highest ranked, in terms of difficulty, and the last as the lowest ranked.

- Pre Perseverative Responses
- Pre Trials to Complete First Category
- Pre Perseverative Errors
- Pre Non Perseverative Errors
- Pre Total Errors
- Pre Conceptual Level Response
- Pre Total Correct
- Pre Learning to Learn
- Pre Categories Complete
- Post Perseverative Responses
- Post Total Correct
- Post Trials Administered
- Post Perseverative Errors
- Post Learning to Learn

The size of the bubble indicates that the majority of the items are relative in terms of their error (zone of imprecision); however the Pre Perseverative Responses item (Pre PR) has a large zone of imprecision. This means that participants scored unexpectedly on this item (e.g. as it is the hardest item to pass it would be unexpected for participants lower down the scale to pass it, however some will have). The potential reasons for this will be explored in the discussion section.

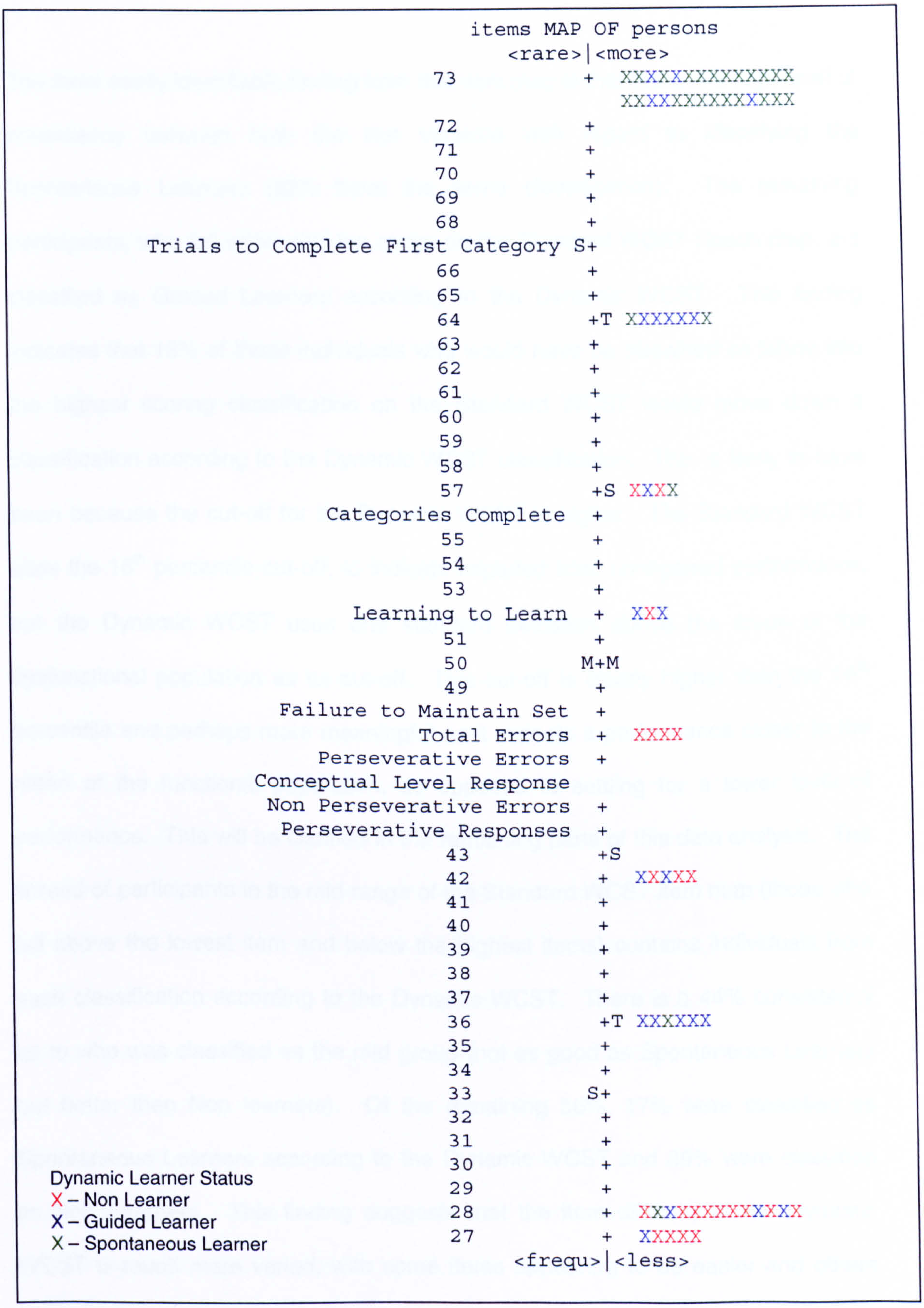
The Separation scores for the pre and post Rasch analysis are 2.64 for the real person separation and 4.28 for the real item separation. As these scores are larger than the scores created by the Standard WCST (Pre-train Rasch model) it indicates that the Dynamic WCST Rasch analysis creates a better spread of the individuals and that the items are better at discriminating between them than by using the Standard WCST alone. Cronbach alpha score for the person plots is 0.93, which is excellent.

The items on the dynamic Rasch map that separated the participants into three groups were ‘Post Categories Complete’ (separating Guided Learners from Non

Learners) and 'Pre Failure to Maintain Set' (separating Guided Learners from Spontaneous Learners). Interestingly these items have relatively good accuracy but do not belong to the unidimensional construct.

As previously discussed it is recognised that there are potential difficulties in using the cut-off score employed for this analysis. However this has been shown to create better spread that discriminates between participants more effectively than using the 16th percentile.

Having created two Rasch item maps it is important to compare the classifications that both created for each participant. Everyone in the sample now has two learner status classifications (one for the Standard WCST and one for the Dynamic WCST). To illustrate whether or not each individual has the same or different classifications for each test they will be plotted on an item map (Figure 19), according to where they fell on the 16th percentile cut-off, but will be colour coded according to how they were classified according to the Dynamic WCST (red for Non Learners, Blue for Guided Learners and Green for Spontaneous Learners). This map will indicate what consistencies and inconsistencies there are between the two maps.



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                                        items MAP OF persons
                                           <rare>|<more>
                                   73           +  XXXXXXXXXXXXXX
                                                   XXXXXXXXXXXXXX
                                   72           +
                                   71           +
                                   70           +
                                   69           +
                                   68           +
         Trials to Complete First Category     S+
                                   66           +
                                   65           +
                                   64           +T XXXXXXX
                                   63           +
                                   62           +
                                   61           +
                                   60           +
                                   59           +
                                   58           +
                                   57           +S XXXX
                         Categories Complete    +
                                   55           +
                                   54           +
                                   53           +
                           Learning to Learn    +  XXX
                                   51           +
                                   50          M+M
                                   49           +
                       Failure to Maintain Set  +
                                Total Errors    +  XXXX
                        Perseverative Errors    +
                   Conceptual Level Response
                    Non Perseverative Errors    +
                     Perseverative Responses    +
                                   43           +S
                                   42           +  XXXXX
                                   41           +
                                   40           +
                                   39           +
                                   38           +
                                   37           +
                                   36           +T XXXXXX
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                                   33          S+
                                   32           +
                                   31           +
                                   30           +
                                   29           +
                                   28           +  XXXXXXXXXXXXXXX
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Dynamic Learner Status
X – Non Learner
X – Guided Learner
X – Spontaneous Learner

Figure 19: Item Map Representing the Hierarchy of Difficulty for the Items of the Standard WCST with Participants Colour Coded To Dynamic Learner Status

The most easily identifiable finding from this item map is that there is a high level of consistency between both the test versions with regard to identifying the Spontaneous Learners (82% have the same classification). The remaining participants, who fall within this top range on the Standard WCST Rasch map, are classified as Guided Learners according to the Dynamic WCST. This finding indicates that 18% of those individuals who would have be classified as falling into the highest scoring classification on the Standard WCST would move down a classification according to the Dynamic WCST classification. This is likely to have been because the cut-off for the Dynamic WCST is higher. The Standard WCST uses the 16th percentile cut-off, to indicate impaired from unimpaired performance, but the Dynamic WCST uses one standard deviation above the mean of the dysfunctional population as its cut-off. This cut-off is clearly higher than the 16th percentile and perhaps more meaningful as it expects a performance closer to the mean of the functional population, as opposed to settling for a lower level of performance. This will be clarified in the remaining parts of this data analysis. The spread of participants in the mid range of the Standard WCST item map (those who fall above the lowest item and below the highest items) contains individuals from each classification according to the Dynamic WCST. There is a 44% consistency as to who was classified as the mid group (not as good as Spontaneous Learners but better than Non learners). Of the remaining 56%, 17% were classified as Spontaneous Learners according to the Dynamic WCST and 39% were classified as Non Learners. This finding suggests that the item difficulty of the Dynamic WCST is much more varied, with some items appearing to be easier and others harder. The individuals placed at the bottom end of this map, and who were classified as Non Learners according to the Standard WCST, showed a 55% consistency in terms of classification according to the Dynamic WCST. This is perhaps the most important finding as it suggests that only 55% of those individuals who fall into the impaired range on all of the items of the Standard WCST have no potential to benefit from guidance. Of the remaining 45%, 38% showed evidence of benefiting from guidance according to the Dynamic WCST and 7% were classified as Spontaneous Learners. A potential reason to explain why Spontaneous Learners according to the Dynamic WCST might be classified as Non Learners according to the Standard WCST will be explored in the discussion section of this Chapter (5.4).

This item map illustrates how the Standard WCST (pre-Train) is capable of providing accurate information about those individuals who are high functioning, passing the clinical cut-offs for most of the items of this test (Spontaneous Learners). It also illustrates how there is not enough 'separation' in this map to discriminate between the Guided Learners and the Non Learners. If learner status was being established using the item map created by the Standard WCST alone then it would be possible to establish who the Spontaneous Learners are, but the majority of the remaining individuals would appear to be incapable of learning how to complete this task. This is accurate as they do not have the capacity to pass the test independently, whilst relying on their impaired cognitive function, but they are not necessarily incapable of learning to pass it with guidance. This map therefore illustrates that the static assessment is adequately discriminating those who can and cannot learn independently but that there is no capability of separating out those individuals who have learning potential. Instead it classifies the remaining majority as those who fail most of items of the task. The Dynamic WCST, however, can create a better spread of ability, though it remains untested with regard to whether that is useful or not.

5.3.2 Traditional Statistical Analyses: Dynamic WCST investigation

The second part of this analysis investigates the learner status groups that were developed by the Dynamic WCST Rasch model in order to establish what variables may predict learner status and whether it can predict outcome following an acquired brain injury. These results will then be discussed in relation to the groups created by the Standard WCST, in order to compare which analysis (static versus dynamic) has better predictive value (part three of the data analysis). The research questions which were outlined originally in Chapter 3, section 3.5, concerning the extent and consequence of learning impairment and the variables which might impact learning ability will be examined here.

Question 1: To what extent do people with brain injuries have difficulty learning?

The Dynamic Training Rasch Map created three, relatively even learner status categories. 29% of the participants were classified as Non Learners because they could not pass any of the items according to the allocated cut-off. 32% passed some of the items (mainly those from the WCST in the post-training administration), and 39% of the participants passed some of the harder Pre-training items (see Figure 17).

This suggests that roughly a third had problems learning with guidance, a third had no difficulty learning the skills that were required to pass the test independently, and the final third had difficulty learning independently but could utilise a strategy to help them learn a different way.

	Count	Percentage
Non learner	22	29
Learner	25	32
Spontaneous Learner	30	39

Table 5: Number and Percentage of Participants in Each Learner Status Category, As Identified By the Dynamic Training Rasch Map

Question 2: Does intellectual ability impact learning?

In order to investigate this question the three learner status classifications (Spontaneous Learners, Guided Learners and Non Learners) were subjected to a one-way analysis of variance. Separate ANOVAs were conducted, one with the dependent variable as pre-injury intelligence and one with current intellectual ability as the dependent variable. Pre-injury intelligence was estimated using the Vanderploeg et al (1995a) algorithm using a WAIS-R or WASI subscale score[3], years of education, and socio-economic status.

Pre-injury IQ

The ANOVA found a significant main effect of learner status; F(2,68) = 3.95, p=0.02. A post hoc Scheffe analysis found a significant difference between the mean of the Non Learner group (M=92.12, sd=15.08) and the mean of the Spontaneous Learner group (M=103.26, sd=14.90) (p=0.03), but there were no other significant differences involving the Guided Learner Group (mean 95.09, sd=14.11).

These findings indicate that pre-injury cognitive ability clearly influences learner status. According to the learner status classifications created by the Dynamic

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[3] Estimation was enhanced as described in Chapter 3 section 3.1.5

WCST, pre-injury intellectual function has a significant influence, particularly in determining Spontaneous Learners and Non Learners, but it cannot account for who has potential to be a Guided Learner. This suggests that pre-injury intellectual functioning may not be sufficiently adequate as a guide to learning potential; however there is a risk of a Type II error having an effect here. This issue will be considered in more detail in the discussion section of this Chapter (section 5.4).

Current IQ

An analysis of variance (ANOVA) using current IQ as the dependent variable (measured using the FSIQ of either the WAIS or WASI) found that the effect of learner status was highly significant (F (2, 59) =10.52, $p<0.0001$). As with the pre-injury IQ a Scheffe test found a significant difference between Non Learners (mean= 79.47, sd=13.49) and Spontaneous Learners (mean = 99.20, sd=12.76), ($p<0.001$) but no significant differences involving Guided Learners (mean = 90.22, sd=16.45).

The pattern for this ANOVA was similar to that of the pre-injury IQ, with Non Learners having a significantly lower current IQ than the Spontaneous Learners. Again the Guided Learners followed this direction (having a higher current IQ than Non Learner and a lower current IQ than Spontaneous Learners) but there was no significant difference. Again these findings suggest that current intellectual function is related to learning ability, but that IQ alone cannot determine who has the potential to be a Guided Learner. The potential reasons as to why IQ might be able to predict Spontaneous and Non Learner statuses will be explored in the discussion, with particular emphasis on the role that cognitive reserve might play in this.

Question 3: Does severity of injury impact learning?

To answer this question the learner status scores were subjected to a one-way ANOVA, applying the Glasgow Coma Scale score at onset of injury as the dependent variable. The main effect yielded an F ratio of F(2,50) =3.68, P=0.03. Post hoc Scheffe analysis identified that the significant differences were between Non Learners (mean = 7.47, sd=4.17) and Spontaneous Learners (mean = 11.18, sd=3.97) (p=0.04). The Guided Learner Group was not significantly different to any of the other groups (mean = 9.00, sd=4.93).

Once again the same pattern was identified by the ANOVA, with significant differences found between Non Learners and Spontaneous Learners, with the Guided Learner group fitting the trend but not reaching significance. Before this is interpreted any further it is important to note that despite small sample size (N= 44) for GCS collected, the ANOVA was still significant. Because the sample size fell considerably short of the power criteria it was felt that another analysis indicating severity of injury with a higher N should be included based on the description of injury made at referral. Individuals were therefore categorised into severe (e.g. unresponsive, eyes not opening and non-vocalising) or mild/moderate injury (awake and alert but confused etc.). A chi-square test of goodness of fit was performed to determine whether the three learner status groups were equally distributed (Table 6). The 3x2 Chi Square analysis with Yates correction revealed that there was a significant difference (χ^2= 13.14 (df=2) (p<0.01).

	Non Learner	Guided Learner	Spontaneous Learner
Severe Brain Injury	15 (44%)	13 (38%)	6 (18%)
Mild/Moderate Brain Injury	7 (19%)	8 (22%)	22 (59%)

Table 6: Frequency of Individuals According To WCST Dynamic Learner Status and Severity of Injury According To GCS Categories

In an attempt to answer the question it appears that severity of injury does have an effect on learner status. In observing the distribution rates of the Chi Square it is noted that 44% of the severe group were Non Learners and 59% of the Mild/Moderate Group were Spontaneous Learners, suggesting that Severity of Injury Does influence learner status. Whilst the Chi Square was significant, the Guided Learner group shows an interesting pattern. Of the Severe Brain Injury Category, 38% were Guided Learners. This indicates that, although overall severity has an impact on learner status, it appears that again this Guided Learner classification (or the group that is only able to show its potential through interaction) cannot be predicted by severity, as was reinforced by the post hoc Scheffe analysis of the ANOVA. This is an important finding, emphasising the amount of information missed in traditional prognostic appraisal, and it will be discussed in greater details in Chapter 9, section 9.4.2.

Question 4: Does age have an impact on learning ability?

For this question the learner status classifications were conducted with two separate ANOVAs, one investigating the mean age when the injury was acquired as the dependent variable and the other using the mean age at time of testing. Both analyses had no significant main effect, F(2,71)=1.99, p=0.14 (for age at injury) and F(2,58)=0.95, p=0.39 (for age at testing). This implies that according to this learner status classification, the age of an individual when an injury is acquired and age at the time of testing has no impact on ability to learn. Investigation into the mean scores for these two ANOVAs suggests that for the variable 'age at injury' the difference between mean ages for the Guided Learners and High Scorers was small (29.26 versus 28.97), although the Non learners did appear to have a higher mean age at onset (35.45). For the variable 'age at testing' there appeared to be a more even distribution between the items. The mean age for Spontaneous Learners was 31.36 years, for Non Learners is was 33.5 years and for Guided Learners it was 28.9 years. The analysis identified that this was not a significant finding but it is possible that an inadequate sample size may have contributed to a Type II error having occurred in this situation.

Question 5: Does time since injury have an impact on learning ability?

An investigation into the normal distribution of the time since injury revealed three scores that fell greater than three standard deviations above the mean. The procedure originally outlined (section 4.2) was applied here. Analyses of Variance were conducted with and without these outliers included. These were initially removed, and an ANOVA was conducted to investigate whether the time that has passed (in months) since the individual suffered the ABI impacts upon learning. The results were not significant F(2,55)= 2.09, p=0.13, indicating that there were no significant differences between the learner status classifications in the time since their injury. An investigation into the analysis of variance with the outliers included yielded a significant F ratio; F(2,59)=3.39, p=0.04. An investigation into the homogeneity of variance using the Brown-Forsythe test, however, found a significant effect (F= 3.47, p=0.04), meaning that there was uneven variance between groups. This would suggest that parametric assessment is not appropriate. Investigation into the variance for each group found that Spontaneous

Learners had significantly less variance and Guided Learners had the largest variance.

As originally outlined, a comparison between the two ANOVAs (including and excluding outliers) creates a significant and non significant finding (please refer to Appendices section 11 for means etc. for both these ANOVAs). Whilst this research prefers not to exclude outliers, these appear to be skewing the data, as the Brown-Forsythe test identified an uneven variance, breaking the assumption of homogeneity of variance. Therefore the ANOVA that excludes the outliers will be chosen and the non significant finding will be applied.

An interesting observation of the results so far is that despite following the trend of results, the Guided Learner group has not been significantly distinguishable from either of the other two learner groups (Non learners or Spontaneous Learners). This could indicate that this classification is weak and does not have enough sensitivity to differentiate between the others categories. Alternatively, this latent ability learner group cannot be determined by current predictive measures such as IQ and severity of injury etc, but is a measure of some kind of adaptive ability which anyone could have, and may be more dependent on mindset and pre-injury personality characteristics than any variables currently measured. If this hypothesis has any weight it will be seen in the outcome measure of the CIQ, with the Guided Learner group having a significantly different outcome to the other categories.

Question 6: What impact does learning have on outcome?

The Community Integration Questionnaire (CIQ) was used to reflect recovery levels (see Chapter 1, section 1.3.1 for more detail on this test and the reasons it was chosen). Learner status classifications (Guided, Spontaneous and Non Learner) were subjected to a one-way ANOVA using three perspectives of Community Integration. These were community integration at the time of testing, community integration levels pre-injury and change in integration levels as a result of the injury (suggested by Dijkers 1997). For each of the ANOVAs the four measures of the CIQ were the dependent variables (Home, Social, Productive Activity and Total).

Pre-injury Community Integration

An ANOVA for pre-injury integration showed no significant effect between groups (F(8,134)=0.87; p=0.53). This implies that current learner status has no relationship with levels of community integration prior to accident. This is logical as there is now evidence to support that at its extreme end, learning ability is influenced by severity of injury, suggesting that pre-injury learner status would be different to post-injury learner status. It is possible that a measure of pre-injury learner status would be related to pre-injury integration; but that question is beyond the scope of this research.

Current Community Integration

An ANOVA assessing for the impact of learner status on levels of Current Community Integration found a significant main effect, F(8,134)=2.41; p=0.02. The scores are represented in Figure 20. Spontaneous Learners were shown to enjoy greater levels of community integration when compared to the other learner status categories.

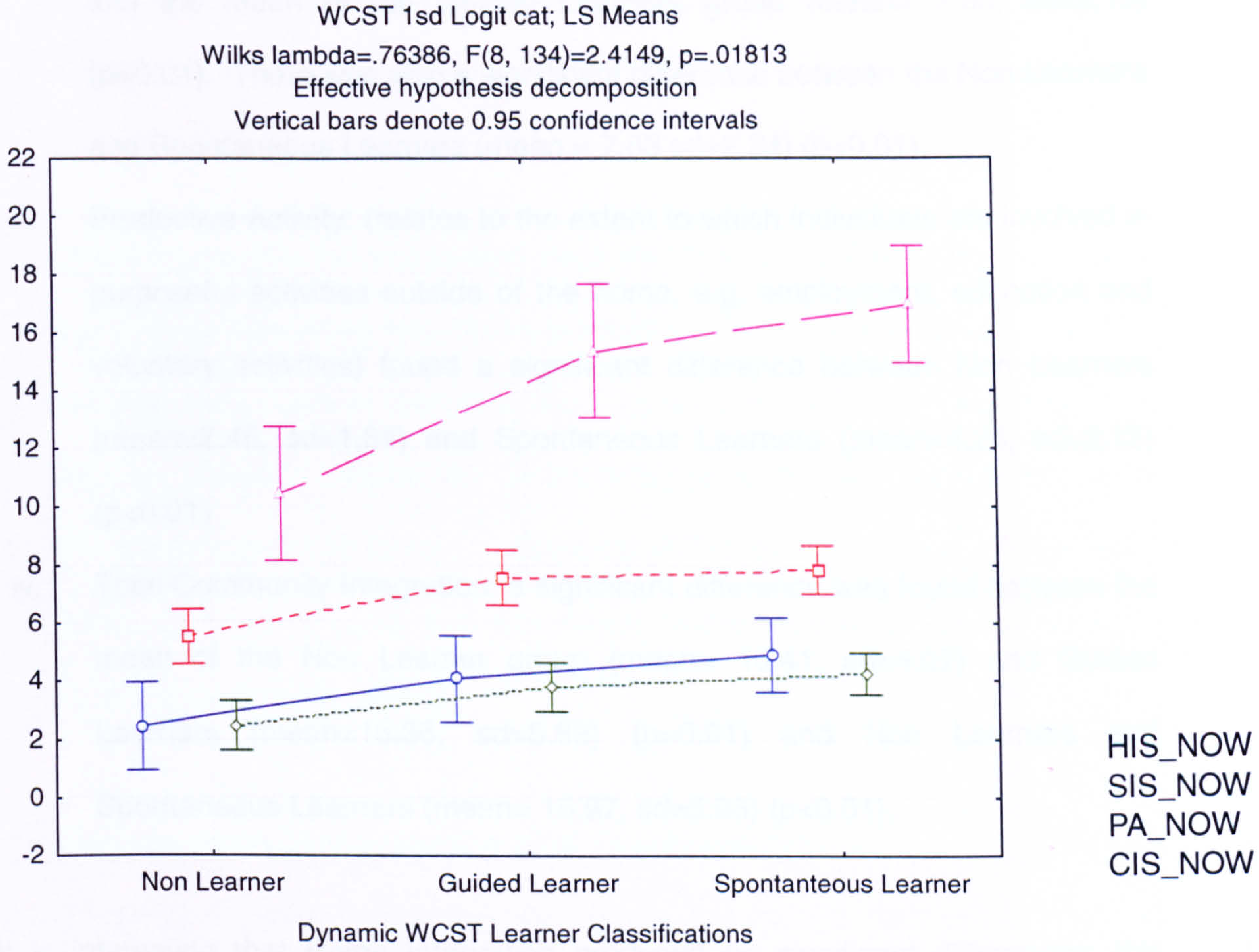

Figure 20: ANOVA with Mean Scores of Measures of Current Community Integration for Dynamic WCST Learner Status Classifications

Significant Post Hoc Scheffe relationships are listed below.

i. Home Integration: (participation in activities related to operation of the home, e.g. shopping for groceries, preparing meals, doing housework, caring for children and planning social gatherings) had no significant difference between the three levels of learning ability created by the dynamic WCST.

ii. Social Integration: (relates to activities associated with outside of the home (e.g. going shopping, leisure activities, visiting friends) found a significant difference between the mean of the Non Learners (mean =5.50, sd=2.35) and the mean of the Guided Learners group (mean= 7.55, sd=2.15) (p=0.01). There was also a significant difference between the Non Learners and Spontaneous Learners (mean = 7.83 sd=2.24) (p<0.01).

iii. Productive Activity: (relates to the extent to which individuals are involved in purposeful activities outside of the home, e.g. employment, education and voluntary activities) found a significant difference between Non Learners (mean=2.45, sd=1.84) and Spontaneous Learners (mean=4.24, sd=2.13) (p<0.01)

iv. Total Community Integration: a significant difference was found between the mean of the Non Learner group (mean= 10.41, sd=4.07) and Guided Learners (mean=15.36, sd=5.89) (p=0.01) and Non Learners and Spontaneous Learners (mean= 16.97, sd=5.93) (p<0.01).

It is interesting that Home Integration produced no significant differences; this suggests that the roles within the home environment do not change to a great degree following a brain injury, but they do in all the other aspects of community integration. One factor that could be contributing to this is a lack of homogeneity of variance, with the Brown-Forsythe test yielding a significant F ratio (F=5.02, p<0.001). These will be explored in the discussion.

In this ANOVA there are significant differences in Social Integration and the Total Community Integration between Non Learners and Guided Learners, and also Non Learners and Spontaneous Learners. There is no significant difference between Guided Learners and Spontaneous Learners. This implies that the further separation in person ability, which the Dynamic WCST was able to highlight, identifying those who would have failed the Standard WCST but were able to learn to pass the dynamic one is important. This group of Guided Learners have a significantly better outcome compared to Non Learners but not a significantly worse outcome compared to Spontaneous Learners.

This ANOVA supports the suggestion made earlier that latent learning ability does not appear to be something that can be predicted by IQ or severity of injury, but that it is a quality that influences outcome. It is suggested that latent learning ability may therefore be related to adaptability. In the final part of the data analysis this same ANOVA will be conducted using the Standard WCST Learner Groups. If this is not significant, it would suggest that this latent learner status group can only be measured using dynamic testing.

Difference between Current and Pre-injury Community Integration

The analysis of variance for the final outcome measure (change in levels of community integration) was also significant. (F (8,134)=2.30, P=0.02). For this graph (see Figure 21), the larger the difference the larger the level of change in community integration from pre-injury to current integration.

The significant post hoc Scheffe tests are listed below.

i. Change in Home Integration showed no significant differences between classifications.
ii. Change in Social Integration had a significant difference between Non Learners (mean=-4.73 sd=3.18) and Guided Learners (mean = -2.55, sd=2.63), (p=0.03) and also Non Learners and Spontaneous Learners (Mean=-2.76, sd =2.25) (p=0.04)

iii. Change in Productive Activity had a significant difference between Non Learners (mean = -3.18, sd=1.71) and Spontaneous Learners (mean = -1.52, sd=1.86) (p=0.01).

iv. Change in Community Integration Total had a significant difference between Non Learners (mean = -10.14, sd=6.02) and Spontaneous Learners (mean = -5.24, sd=4.39) (p=0.01).

Once again, no significant differences were observed between Guided Learners and Spontaneous Learners.

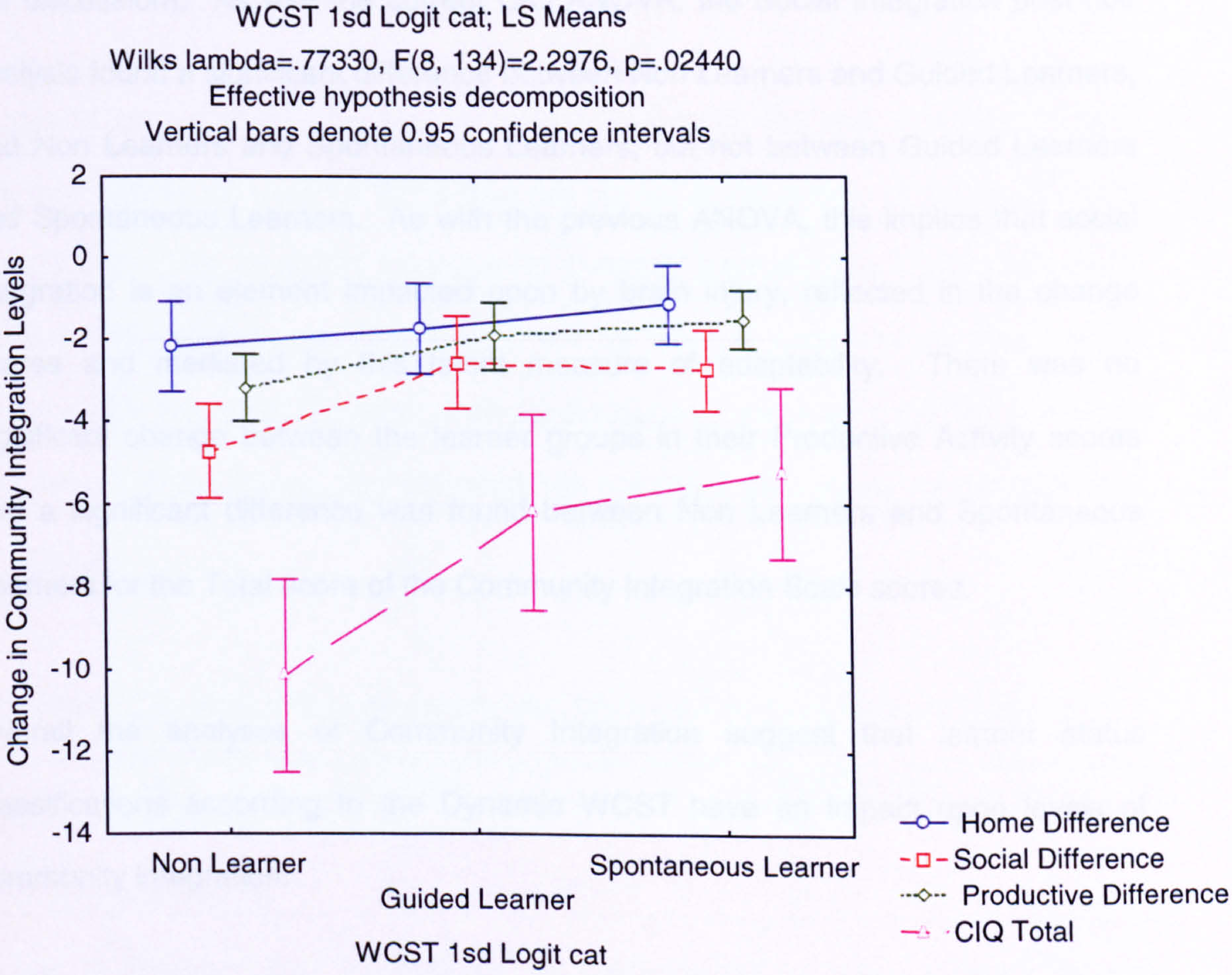

Figure 21: ANOVA for Dynamic WCST Learner Status Groups and Change in Community Integration Levels.

This ANOVA investigated whether there were significant differences between the groups in the degree to which their community integration scores changed following an ABI. The results found that there were no significant differences between the change scores in the Home Integration scale. This is understandable as there appears to be very little impact on the levels of home integration for each of the learner classifications. This could be because the activities measured by the Home Integration scale are routine and automatic and not impacted on as much by an ABI. Alternatively, it could be that the individuals did not have a big role in home integration activities and so there was little change (this will be further considered in the discussion). As with the current CIQ ANOVA, the Social Integration post hoc analysis found a significant difference between Non Learners and Guided Learners, and Non Learners and Spontaneous Learners, but not between Guided Learners and Spontaneous Learners. As with the previous ANOVA, this implies that social integration is an element impacted upon by brain injury, reflected in the change scores and mediated by this latent measure of adaptability. There was no significant change between the learner groups in their Productive Activity scores and a significant difference was found between Non Learners and Spontaneous Learners for the Total score of the Community Integration Scale scores.

Overall the analyses of Community Integration suggest that learner status classifications according to the Dynamic WCST have an impact upon levels of community integration.

5.3.3 Traditional Statistical Analyses: Standard WCST investigation

The results from the investigation into the Dynamic WCST learner Status classifications are encouraging but it is important to consider whether these results are different to the pattern of results created using the Standard WCST. If this was not the case, then the more time consuming Dynamic WCST would be redundant. In order to investigate this, the participants' classifications according to their placement on the Standard WCST Rasch map (see figure 15) were applied to the research questions and thus underwent the same analysis as the Dynamic WCST learner status groups.

It should be noted that for the Standard versions of the test, the term 'Guided Learner' will not be used for those who are placed at the middle of the range of the Rasch map. This is simply because no dynamic assessments have been used. Instead the middle-range classification will be labelled 'Learners' as they passed some of the items and therefore showed evidence of learning at the 16th percentile but not all of the items, and therefore did not meet the criteria for Spontaneous Learning.

Question 1: To what extent do people with brain injuries have difficulty learning?

	Count	Percentage
Non learner	29	39
Learner	18	24
Spontaneous Learner	28	37

Table 7: Number and Percentage of Participants in Each Learner Status Category, As Identified By the Standard WCST Rasch Map

The spread illustrated in Table 7 is not as even as the one created by the Dynamic

WCST and results in a larger proportion of ceiling and basement effects – there are fewer individuals who fall into the middle classification of learners. According to the learner classifications created by the Standard WCST a large proportion of this brain injury population are unable to learn (39%), 24% showed some evidence of learning and 37% showed evidence of learning spontaneously.

Question 2: Does intellectual ability impact learning?

An ANOVA was conducted for the Standard WCST learner groups for pre-injury and current IQs.

Pre-injury IQ

A one-way analysis of variance was applied to the three levels of learner status (Non Learner, Learner and Spontaneous Learner) using pre-injury IQ as the dependent variable. The ANOVA found no significant main effect F(2,67) = 2.30, p=0.11. This is quite a difference compared to the highly significant Dynamic WCST ANOVA results (F(2,68) = 3.95, p=0.02) and suggests that pre-injury intelligence is not related to post-injury learner status as classified by the Standard WCST.

Current IQ

The ANOVA investigating the relationship between current IQ and Standard learner status found a significant effect and yielded an F ratio of F(2,58)=9.65, p<0.001, with post hoc differences found between the Spontaneous Learners (mean=100.48, sd=13.17) and Non Learners (mean=82.30, sd=16.09) (p<0.001). This finding is similar to that of the Dynamic WCST ANOVA, which was also significant (F (2, 59) =10.52, p<0.001).

Questions 3: Does severity of injury impact learning?

The ANOVA completed for the Standard WCST learner groups investigating severity of injury and learner status found no significant main effect, F(2,49)=2.24, p=0.11. This is unlike the Dynamic WCST ANOVA, which was significant (F(2,44) =3.68, P=0.03). Again, as N was low for the ANOVAs, a Chi Square goodness of fit was performed with Yates correction to determine whether the severity of injury was equally distributed throughout the three learner status classifications (Table 8 includes the distribution and row percentages). The results revealed that there was a significant variance between groups $\chi^2= 9.63$ (df=2) (p=0.01).

	Non Learner	Learner	Spontaneous Learner
Severe Brain Injury	14 (41%)	13 (38%)	7 (21%)
Mild/Moderate Brain Injury	13 (37%)	4 (11%)	18 (51%)

Table 8: Frequency of Individuals According To Standard WCST Learner Status and Severity

Similar to the Dynamic WCST Chi square, this Chi square found a significant difference between categories. It is interesting to note that the Dynamic WCST was powerful enough to have a significant ANOVA despite having the same problem with low numbers. This spread indicates how the majority of the mild/moderate brain injury cases were Spontaneous Learners and the majority of severe brain injury cases were Non Learners. It is worth nothing that there is nearly an equal split between severe and mild/moderate injury and the Non Learner classifications suggesting that a severe injury is not the only factor that predicts poor performance on the Standard WCST. This finding suggests that severity of injury does impact learning ability but its clearest discrimination lies in determining Spontaneous Learners.

Question 4: Does age have an impact on learning ability?

Unlike the Dynamic WCST, the main effect of the ANOVA for Standard WCST learner status on the measure of 'age-at-onset' found a significant effect, F(2,70)=3.49, p=0.04. No specific differences were found through post hoc analysis (Non Learner mean age=35.52, sd=15.06, Learner mean age=26.78, sd=9.78, Spontaneous Learner mean age= 28.58, sd=10.37). This distribution suggests that the older the individual was when the injury was acquired, the more likely they would be to try to continue to use the same (now impaired) strategies to complete the WCST, thus increasing their chances of failing the test. This is an interesting finding as it suggests that age can have an impact on learning ability when an individual is required to rely on their own initiative, rather than benefit from guidance.

The ANOVA for age at time of testing, however, found no significant main effect F(2, 57)=0.60, p=0.55. Like the Dynamic WCST ANOVA this finding indicates that learner status is not affected or influenced by current age.

Question 5: Does time since injury have an impact on learning ability?

As with the Dynamic WCST learner groups, the Standard WCST learner group ANOVA measuring for significance between learner status and time (in months) since injury was also not significant, F(2,58)= 0.40, p=0.67. This result suggests that time since injury does not have an impact on learning ability as identified by the Standard WCST. On this occasion the assumption of homogeneity of variance was not compromised.

Question 6: What impact does learning have on outcome?

Pre-injury Integration

As with the Dynamic WCST (F (8,134) =0.87; p=0.53), the Standard WCST ANOVA found no significant main effect between learner groups, F(8,130)=0.84, =0.57. This indicates that there is no relationship between learner status as measured by the Standard WCST and pre-injury integration levels.

Current Integration

The ANOVA for the Standard WCST for current integration found no significant main effect, F(8,130) =1.83, p=0.08. This suggests that the learner status groups as allocated by the Standard WCST are not able to predict levels of community integration. A comparison with the results of the Dynamic WCST learner groups (F (8,134)=2.14; p=0.02) suggests the Standard WCST is less useful in terms of ecologically predictive power. It confirms the hypothesis that the groups created according to performance on the Dynamic WCST are better able to predict recovery levels. It further suggests that the measure of latent ability which distinguishes between learner status groups for social and total integration can only be identified through dynamic testing.

Difference between Current and Pre-injury Community Integration

The main effect for the analysis of variance investigating the degree of change of community integration scores following an ABI found no significant differences (F(8,130)=1.93, p=0.06). This indicates that the Standard WCST is again a weaker tool in predicting outcome or degree of change between classifications in community integration when compared with the Dynamic WCST learner groups (F (8,134)=2.29, P=0.02).

5.4 *Discussion*

This section will begin by analysing in detail the distribution of both the Standard and Dynamic WCST Rasch item maps and then move on to compare the significant relationships found for both, with reference to the clinical implications these findings may have.

5.4.1 Hierarchical Distribution for the Standard WCST

On the Standard WCST the item that was found to be the easiest to score above cut-off for was 'Perseverative Responses.' 61% of the group were likely to have passed the cut-off for this item and so were functioning above the impaired range. As this item measures the ability to utilise feedback, it suggests that the majority of the participants were able to work out either the original concept, or to recognise that a change in the rules had occurred, to a point that is considered above an impaired level of function (i.e. the 16th percentile). The remaining 39% were unable to recognise the shift, which meant that they were unable to progress further in the assessment. This item suggests that the foremost ability which is required for independent verbal deductive reasoning is the ability to recognise and respond to feedback. The fact that this item is the easiest to pass is an interesting and surprising finding as this item has been proposed as the most sensitive measure of predicting the presence or absence of brain damage and frontal lobe involvement (Heaton, 1981) – please refer back to Table 4 for more detail. This item separated 39% of the population, who were unable to pass this item at the 16th percentile. This suggests that the item Perseverative Responses does not have good discriminatory power in terms of predicting the presence or absence of brain damage (as everyone in this sample has experienced a brain injury). Perhaps, however, this simply means that the cut-off was too low or that this measure is sensitive only to those who have experienced severe brain injury. The next three items, which were placed above the Perseverative Responses item on the hierarchical scale, were Non Perseverative Errors, Conceptual Level Response and Perseverative Errors. These items are very closely related and they share similar traits with regard to what they measure, i.e. the ability to conceptualise and adhere to the rule. These items failed to separate out any of the participants in this sample, making them clinically weaker and practically meaningless with regard to interpretation of performance. The next item on the hierarchical scale is Total Errors; this item was able to separate out four individuals, predicting that they had a 50% chance of scoring within the average range on that item, and a 75% chance on the items below it. After that is the Learning to Learn item followed by Categories Complete; these two items separated three individuals' ability levels, suggesting that they were powerful within the analysis. This Rasch model suggests that the most difficult item to pass is the Trials to Complete First Category, which reflects how long it took the individual to work out the first rule. This provides a measure of an individual's initial 'concept attainment' ability, and it reflects the individual's ability to think flexibly as well as to receive and use feedback when the rules of the test are unknown. In between these last two items were eleven individuals, and above the hardest item were 29 individuals. In terms of utility, the Trials to Complete First Category item has a lot of uses: if a person shows evidence of performing above the 16th percentile there is a good probability that they are a Spontaneous Learner (82%), suggesting that how quickly a person can begin to use feedback on the original trial reflects a speed of processing which impacts overall performance. As mentioned in the Results section, the Standard WCST created a large ceiling and basement effect, indicating that a large proportion of the population passed the cut-off too easily, and some could not pass it at all. This is an interesting predicament; if only a ceiling or floor effect was found, then the cut-off could be raised or lowered to account for the grouping, and create a better spread of ability. This cannot be done however, because a large proportion of the sample had a chance of not passing any item (39%) and a large proportion had a high chance of passing every item (37%). This lack of spread suggests that the test is measuring something quite specific that many brain injured participants find hard, but many do not.

Investigation into the construct of the test shows that Learning to Learn, Perseverative Errors, Non Perseverative Errors and Perseverative Responses are the only items that belong to the same construct. This would support Greve et al (1996) and Sullivan et al's (1993) view that the WCST is multi factorial as well as finding support for Goldman et al's (1996) view that factors may be defined by the population.

It is also worth noting that the bubble chart (Figure 16) indicates that although all the items have a similar sized standard error, they are all large, suggesting that there was a lot of variability of responses within the items, which indicates that the model could not precisely place the items on the logit scale. This suggests that although the Standard WCST using the 16th percentile created an adequate spread of distribution for the participants and the items, as a cut-off, it is quite weak in terms of predicting the hierarchy of the items, and it certainly breaks the assumption of unidimensionality.

5.4.2 Hierarchical Distribution for the Dynamic WCST

The Dynamic Rasch using the WCST to reflect learning potential via the verbal processing system applies a different cut-off. This uses one standard deviation above the mean of the population (taken from the static, pre-training performance) and applies it to both the first and second (pre/post-training) trials.

As was expected, the Dynamic Rasch map (Figure 17) shows that the easiest items were those from the post-training administration. The first ten items were in fact post-training items, followed by one pre-training item and then the remaining post-training item. This indicates that all the items of the post-test, with the exception of Post Failure to Maintain set, were easier than the easiest item of the Pre-administration, which was Pre Categories Complete. It is interesting to note that whilst in the Standard version of the test, Failure to Maintain Set (which is thought to be a measure of attention (Greve et al 1996) was placed in the middle of the hierarchy, adding a training element has moved it to the hardest items of the post administration. This implies that training individuals how to pass a test, with several strands of information to be retained and manipulated, requires them to have to concentrate more. This supports Greve's (1996) hypothesis that adding a training intervention removes the problem solving element and makes the test more a measure of attention (or perhaps more accurately, working memory). This does not imply that it is no longer useful; perhaps it is now more representative of a measure of working memory, and as such more meaningful clinically.

Again, as may be expected, having trained a participant to complete a test means that those items that best reflect learning, or concept formation become the easiest items (Post Categories Complete, Post Learning To Learn, Post Conceptual Level

Response). A significant reduction in errors and the number of cards required to pass the test (Total Errors and Trials Administered) might also be expected. It was interesting that the Perseverative Errors and Responses were the hardest – this suggests that for this population, inhibiting a Perseverative Response (responding incorrectly before the first category is complete or before feedback is given after a rule change) is difficult to do, even if you know what you are supposed to do. It is possible that the reason that Post Trials to Complete First Category was one of the hardest items in the post-test administration, was related to the fact that individuals may have forgotten the item they were first supposed to match to (i.e. colour) or that they were continuing to perseverate from the last sort they used in the errorless training trial (i.e. number).

The easiest item of the pre-training test was Categories Complete (this is different to the 16th percentile cut-off which was Perseverative Responses), followed by Total Correct and Learning to Learn. This implies that the one standard deviation cut-off has significantly altered the difficulty ranking when compared to the item map created by the 16th percentile cut-off (Figure 15). This shift in order suggests that for the majority of individuals who have been trained on how to pass the test it will not be hard to complete all the categories of the test, but it will be difficult for them to minimise perseverative responses.

What is particularly interesting now is that the most difficult item of the Dynamic WCST is the Pre Perseverative Responses item. This has moved from being the easiest item to the most difficult after training. As mentioned earlier on, this item was identified by Heaton (1981) as the best in predicting the presence or absence of brain damage. Its position on this hierarchy using a higher cut-off means that it is such a difficult item that no one in the population was predicted to pass it. This means that with this cut-off it could now be seen again as discriminating between the brain injured and non brain-injured population. One factor that will have influenced this is the change in cut-off, moving from the 16th percentile to one standard deviation above the mean of the dysfunctional population. This is likely to have raised expectations in performance; setting the standard of performance considerably higher. It is possible that other factors that could have altered the difficulty are related to what the test item measures (i.e. sorting according to a previous rule, prior to feedback being given, or sorting prior to the first category being correct).

The next most difficult items on the scale were Trials to Complete First Category and Perseverative Errors. Within the Dynamic WCST scale these are in the same order for both the pre and post-trials and were among the hardest for both versions of the test. This suggests that they are related in some way. Perhaps the reason the Trials to Complete First Category is hard is because the individual continues to perseverate the same response, making it another measure of perseveration and therefore as hard as the Perseverative Response item. It is possible that perseveration is a problem for the majority of the sample in the Pre-WCST trial.

As can be seen from Figure 18, which illustrates the fit of the items of the Pre and Post-training test administrations, three of the included items did not fit the model because there was too much variance in relation to belonging to the construct. These were 'Pre Failure to Maintain Set', 'Post Failure to Maintain Set', and 'Post Trials to Complete First Category'. As both pre and post Failure to Maintain Set do not seem to fit the model, it suggests that the underlying construct of the test is not one related to attention; this suggests that the majority of the items are measuring something other than attention.

The items listed below were found to have less variance than the Rasch model would have predicted. These fell outside of the -2 range and so do not fit the unidimensional construct, and were ‘Pre Trials Administered’, ‘Post Total Errors’, ‘Post Conceptual Level Response’, ‘Post Categories Complete’ and ‘Post Non Perseverative Errors’. It is likely that the post items had such little variance on these scores because the training meant that the majority of people had reached the cut-off for these items on the Post-WCST. These items are thought to tap into the learning element of the test (which the training removed). The only item of the pre-WCST which had too little variance was ‘Pre Trials Administered’. This item is an interesting one as the number of trials administered does not represent whether the person has completed the test successfully or learnt the strategies, but is more likely a representation of the learning or poor retention/attention of rules. This therefore provides an indication of how quickly the individual picked up the rules of the test, if they did at all. This may explain why it did not fit into the same construct as the other items.

The remaining items that did belong to the unidimensional construct were primarily from the pre-administration; ‘Pre Perseverative Response’, ‘Pre Perseverative Errors’, ‘Pre Trials to Complete First Category’, ‘Pre Total Errors’, ‘Pre Conceptual Level Response’, ‘Pre Non Perseverative Errors’, ‘Pre Total Correct’, ‘Pre Learning to Learn’, ‘Pre Categories Complete’. Those from the post-administration were: ‘Post Perseverative Errors’, ‘Post Perseverative Responses’, ‘Post Total Correct’ and ‘Post Learning to Learn’.

If the unidimensional construct was to be labelled, taking into account the items that do not belong, it would be a test of executive function. More specifically it could be seen to indicate perseveration and concept attainment.

As mentioned in the results section, most of the items in Figure 18 had a similar sized 'zone of imprecision'. The one exception to this was the item 'Pre Perseverative Responses'. In one sense, this is confirmed because it was the hardest item of the test (using the one standard deviation cut-off). However, it had a significantly larger zone of imprecision, which implies that it was the weakest item in terms of predicting the precision of the item's location on the item map. As it was the hardest item this indicates that some participants who were not expected to reach the cut-off did so. This could suggest that they had less impaired perseverative abilities than predicted.

Figure 19 shows the discrepancy between the two items in terms of predicting placement along the hierarchy of the Dynamic and Standard item maps. The map shows that the Standard WCST had an 82% consistency with the Dynamic WCST in classifying Spontaneous Learners. There was a 44% consistency in predicting Learners/Guided Learners, and 56% consistency in predicting Non Learners. As expected, adding the dynamic training intervention created a better spread among the participants. This means that all the participants who were plotted at the lower end of the map on the Standard WCST were spread out more, to highlight those who were still unable to learn and those who had potential to move up the map following training.

The Standard WCST can predict those who perform well on the first administration. It is unable to provide information about a person's ability to benefit from guidance, or to learn with assistance. Instead, the majority of those remaining were classified as Non Learners, reflecting that they were unable to learn how to pass the test. This finding is not unexpected and reflects that the reason a measure of learning potential is being sought is because it would be incredibly helpful in clinical terms to predict who can, and perhaps more importantly who cannot, benefit from instruction. This could be seen as being more ecologically valid because following a brain injury, people rarely have to rehabilitate themselves or do not get the opportunity to benefit from any form of intervention from a peer.

The comparison of the different learner groups has yielded some interesting results. Firstly it was interesting to find that only the Dynamic WCST learner status showed a significant relationship with pre-injury IQ. This indicates that a measure of learning ability as classified by the dynamic assessment is related to pre-injury functioning, whereas performance on the Standard WCST is not. Within this ANOVA there was a significant difference between Non Learners and Spontaneous Learners. This could be interpreted as indicating that pre-injury intelligence has some influence at either end of the extremes, influencing those who can improve independently (Spontaneous Learners), and those who cannot adapt at all (Non Learners). It is possible that the Guided Learner group would also have been significantly differentiated by the pre-injury intelligence had the sample size been larger.

The Standard WCST seems not to reflect learning, but function limited by impairment. Perhaps because the cut-off was at the 16th percentile it was too low to be a challenge for many and therefore was not overtly related to pre-injury intelligence levels.

The findings that Current IQ levels were significantly related to learner status for both the Dynamic and Standard WCST are not unexpected. Intelligence measures tap into a range of functions, many of which would be involved in both the Standard and Dynamic WCST performance. It was interesting again to see that the significant differences were found between Non Learners and Spontaneous Learners; this could be interpreted as evidence that a higher IQ influences independent learning ability and a lower IQ prevents the ability to learn with or without guidance (Non Learners), but it cannot predict who has learning potential.

Similar conclusions could be drawn from the findings that severity of injury was significantly related to learner status from both Standard and Dynamic tests. Trends on the Standard WCST indicate that severity of injury has an influence on learning ability at the mild/moderate end of the range. On the Dynamic WCST severity of injury has an influence on the extreme ends of learning potential (Spontaneous Learners and Non Learners), but the measure of severity was unable to distinguish the ecologically valid classification of the Guided Learning Potential.

An interesting and unexpected result was found in relation to the impact of age on learning ability. Whilst the learner classifications found no significant main effect on age for the Dynamic WCST, one was found for the learner classifications from the Standard WCST. This implies that that the older a person is when they acquire their injury the more likely they are to try to continue to use the same (now impaired) strategies to complete the WCST, increasing their chances of failing the test. Perhaps a reason that the Dynamic WCST did not find any significance here is because once taught new strategies people can adapt and use them. This suggests that you can 'teach an old dog new tricks', and perhaps highlights the importance of adding the dynamic training; as the standard version suggests an individual is inflexible when working on their own

Neither dynamic nor standard tests found a significant relationship between learner status and age at time of testing. This is interesting because it implies that current age is irrelevant but age at onset is more important. Perhaps this means that the age when developmental processes were affected (blunted/impacted) is an important factor, and that age at time of testing does not pick this up because everyone was affected at different times.

All of the analyses above have found significant differences between only the Non Learner and Spontaneous Learner Groups (but not the Guided Learner Groups). There are two potential explanations for this. The first is that the Guided Learner Classification is statistically weaker than the other two categories and so is unable to differentiate itself. This could be caused because there is too high a variance with too much overlapping between the categories. The second explanation is that those factors that are known to predict outcome (i.e. pre-injury IQ, current cognitive ability and severity of injury) are able to find significant differences between the extreme ends of the scale (so finding significant differences between the pre-injury IQ of those who are unable to learn and those who are able to learn independently), but those who have learning potential (with guidance) cannot be determined by the predictive factors. This suggests that Learning Potential is not determined by pre-injury IQ, current IQ or severity of injury, and that some other factors are related to determining who will have learning potential and who would not. This research suggests that this Guided Learner Group reflects a measure of adaptability where, with guidance, compensation skills can be used to overcome difficulties. Obviously because Non Learners have been found to have significantly more severe injuries and significantly lower pre-injury and current IQs than Spontaneous Learners, it is clear that these factors do play a part. Some injuries will be so extreme and cognitive reserve so limited that an individual will be unable to learn with guidance. This research emphasises the importance of differentiating those individuals who unfortunately struggle to learn from those who have potential to. To confirm whether this second explanation was right it was expected that significant differences between all three of the learner status groups would be seen in the outcome. This would indicate that the Guided Learner Group is not so weak that it cannot differentiate anything significantly; but instead suggests that the only measure it is able to produce significant differences between is the person's level of recovery, which is the most clinically meaningful measure.

Neither the Standard nor the Dynamic WCST learner classifications were related to pre-injury community integration levels. This is not an unexpected result. However, it was felt necessary to investigate further whether learner status was innate and could be reflected through lifestyle prior to injury.

Only the Dynamic WCST showed a significant relationship with current community integration levels. The ANOVA found no significant differences learner status classifications on the 'Home Integration' scale. 'Social Integration' and 'Total Integration' found the most significant differences in the post hoc analyses. Both found significant differences between Non Learners and Guided Learners and Non

Learners and Spontaneous Learners. This is the first ANOVA to distinguish the Guided Learners from another group and suggests that there is a fundamental difference between those who can be taught strategies and those that cannot in relation to their recovery. This is support for the hypothesis that the Guided Learner Group is important as it distinguishes outcome, but that it is not found as being significantly different in the ANOVAs investigating predictive variables such as IQ, and severity of injury because the group of individuals who belong to this classification have a large variance (some will have experienced severe injury and some will have low pre and current IQ levels). This suggests that other factors are contributing to determine who has potential to learn.

The ANVOA for learner status and change in integration levels since injury was significant for the Dynamic WCST but not for the Standard WCST learner status. Again, significant differences were not found for the 'Home Integration' scale, but were found between Non learners and Spontaneous Learners on the other three scales and between Non Learners and Guided Learners for the 'Social Integration' scale.

Figure 21 illustrates that there was little difference between groups for the 'Home Integration' scale. A possible explanation, other than that of the problems with homogeneity of variance, comes from an investigation of mean scores for this variable (see Appendices Section 11 for all WCST statistical analyses significances, Means, N's etc.). Investigation into the means show that the pre-injury mean score for Spontaneous Learners was six. This suggests that individuals shared household activities with whomever they lived with. Current Integration for Spontaneous Learners was five suggesting that overall individuals still shared responsibility for household activities. For Guided Learners the score moves from six to four, suggesting that some responsibility was lost. Non Learners saw a move from five to three. Overall in comparison there were no significant differences between groups, because each lost a similar amount of responsibility. However, an investigation of the means shows that although in terms of points they were about the same, where they were in terms of function at home could be quite different. 'Productive Activity' differences showed the next smallest amount of change (this was surprising as it was expected to be the biggest difference due to the fact that a lot of people stop working post-injury), but this could be a reflection of the socioeconomic status of this population. Non Learners had the biggest decrease in productive activity; there was minimal difference between the Guided Learners and Spontaneous Learners.

Social integration had an interesting distribution. Non learners had the biggest change, followed by Spontaneous Learners; Guided Learners had the least amount of change but the difference between Guided Learners and Spontaneous Learners was miniscule and certainly not significant.

Obviously the largest difference was overall Community Integration, with Non Learners having the most change, followed by Guided Learners and finally Spontaneous Learners.

Overall this study has found that Dynamic learning utilising the Verbal Learning system, using the WCST, creates a better understanding of learning ability and learning potential in a population of brain injury individuals. These learner classifications have a more significant relationship with recovery than the information collected using a Standard WCST. It appears that learner status is influenced by pre-injury intelligence levels, the impact of the injury on cognitive function, the severity of the injury and the age at the time of the injury. These factors can differentiate those who can learn independently and those who are unable to learn, but cannot distinguish who from the Non Learner groups have potential to learn with guidance. As this Guided Learner Group has been found to have a significantly better recovery (Community Integration) than the Non Learner Group, but not a significantly worse outcome than the Spontaneous Learners, then it appears that it is important to be able to identify them.

Chapter 6 : Study Two: Investigation into Non-Verbal Learning Using the Ruff Light Trail Learning Test

The previous study used the Standard WCST and adapted it by sandwiching a training element in-between two administrations of the test to create a dynamic assessment of Explicit Verbal Learning potential. This investigation concluded that the 'Dynamic WCST' created a better spread of person performance which was more meaningful clinically than the Standard version of the WCST.

This second study aimed to investigate whether a measure of learning potential using a different processing system could also produce more clinically meaningful information when compared to its 'Standard' equivalent. This second test will utilise the Non-Verbal/Visuospatial processing system. As previously outlined in section 3.1 to aid further comparison between the studies at a later stage, a test was chosen which taps into many of the same properties of executive function as that used in Study One

As previously mentioned, the test chosen was the Ruff Light Trail Learning Test (RULIT) (Ruff et al., 1996), which taps into the explicit, Visuospatial Learning system.

Methodology

Please refer to Chapter 3 for overall research design, methodology and information regarding the assessments completed.

Assessments Completed

The Standard RULIT

Dynamic RULIT

Neuropsychological Battery (see Chapter 3, section 3.1.5 for details)

The RULIT requires an individual to learn a 15 step route through a group of connected circles. Participants are told that they will be asked to learn a route that the examiner has memorised, it is not the shortest route nor can they see it, instead they will be taught it and they will be given feedback (see Appendices 12, for the RULIT Standard and Dynamic scripts). The participant's first trial is all guess work; they then have up to ten trials to complete the route with no mistakes. Successful completion requires them to complete the route error free twice.

It is felt important to clarify that the RULIT was chosen because it is more than simply a test of visual memory. It also provides an insight into the process of learning (i.e. as opposed to producing a measure of how much someone can remember after one instance, it measures the learning over a number of instances with feedback being given at every stage thereby establishing a learning curve). In this way it is similar to the WCST.

The Standard RULIT has seven measures, which are, 'Total Correct', 'Total Step Errors', 'Trials to Completion', 'Trial Two Correct', 'Trial Two Errors', 'Delayed Correct' and 'Delayed Errors'. Of these measures 'Total Correct', 'Total Step Errors' and 'Trials to Completion' are measures of Learning; 'Trial Two Correct and Trial Two Errors' are measures of Immediate Memory; and 'Delayed Correct' and 'Delayed Errors' are measures of Delayed Memory.

The authors felt their test had to incorporate certain characteristics, e.g. 1) it could not rely on drawing ability, 2) good performance was not dependent on keen eyesight, 3) good performance was not reliant on good motor control, 4) good performance was not reliant on refined visuospatial integration (i.e. the visuospatial content was at a level where the pattern and connections between dots could be understood by all), 5) recall did not rely on recognition (e.g. having to recognise which was the correct path).

The RULIT was developed as there were few available assessments of visuospatial learning, even though there were equal chances of developing right hemisphere damage following neuropathology, and subsequently equal chances of impairments of visuospatial processing or verbal processing abilities (Ruff et al., 1996).

In the primary analysis of the test, strong evidence was found to suggest that planning was necessary for successful completion of the test. The authors concluded from this that the test was therefore more than just one of memory. Further analysis (Allen & Ruff, 1999) confirmed that the RULIT scores were empirically distinct from verbal learning and memory. The authors argued that this is a relatively unique quality in the assessment; their hypothesis was that this additional measure was due to the relative difficulty of the test, even for the normal population, and that verbal mediation is impractical if not impossible.

Like the WCST, evaluation of this assessment found that it was possible to differentiate errors and their causes, e.g. it is possible to distinguish problems with attention or short term memory (through observation of someone repeating the same error on the same spot on the same trial). In addition, problems with learning could be highlighted through observation over trials (an error made on a point in the trail that had not been made there before) and problems with perseveration (illustrated when an individual made the same error on the same point of the trail over several trials). This evidence emphasises similarities between the WCST and the RULIT but distinguishes them by their systems of processing.

Having established that the RULIT is a comprehensive measure of visuospatial learning and memory, which requires many of the skills that are often referred to as executive functioning, the next stage for this research is to implement a dynamic, errorless learning intervention to sandwich the pre and post administrations of the test.

Whist the emphasis during the errorless training for Study One was on verbal instruction and verbal reinforcement as well as the role of the examiner preventing errors being made, this study will minimise verbal involvement to avoid the participant verbalising the assessment.

6.1 Procedure

Participants were tested using Form 1 of RULIT to establish a baseline in performance (see Appendices 13), and following this they were tested using an alternate version of the test and provided with an overlay highlighting the route they were required to learn (see Appendices 14 and 15). The experimenter ensured that the participant understood the route by facilitating them in their initial journey over the route. They were then informed that after ten attempts of practising the route, they would be asked to remember the route without the overlay. The participant was then encouraged if necessary to trace the route over ten trials. Ten attempts were allowed as this is the number of trials that an individual has on the standard assessment to learn the route.

After the ten trials the overlay with the route was removed and the participant was asked to show the administrator the route they had learnt. The participant was given feedback at each step (as per the standard administration) and allowed up to ten attempts to pass the test (by completing the route twice in a row, making no errors).

Both the standard and the dynamic administrations also measured delayed recall.

Scoring

In order to compare whether this information is better than the information gained from the Standard RULIT, a clinical cut-off was utilised for the standard model, which was the 16th percentile. See Chapter 5, section 5.2.1 for details about choice of this cut-off.

6.2 Data Conceptualisation and Analysis

As in Study One, two Rasch analyses were conducted. The first Rasch Analysis explores the hierarchy and fit of the items as they are commonly used in a clinical setting. This Rasch model provides information about how the Standard RULIT currently defines an ABI population in terms of performance on the test and will provide information about whether the five items of the Standard RULIT belong to a unidimensional construct or if the different scores are measuring different skills.

The second Rasch analysis considers the pre and post-training items of the RULIT in the same construct. This will inform us of whether dynamic training has an impact on the scores that the RULIT provides and whether it impacts upon the construct validity of the test. The only efficient way to explore the impact of dynamic training on the post-administration of the RULIT is to count both administrations (pre and post) separately (doubling the number of items of the RULIT and considering the pre and post items as two unique contributions to the model). As with Study One, categorical data was required. This was then converted into interval data using a logarithm of odds algorithm. The chosen cut-off was one standard deviation above the mean of the dysfunctional population (at the time of the standard performance). The reasons for this choice and the limitations of it have been discussed in detail in Chapter 2, section 2.2.3 and 2.3.

The second part of the data analysis investigates the efficiency of the dynamic Rasch Model in separating out and classifying the participants based on their learning potential. These groups will then be tested using more conventional statistics (primarily ANOVAs) and will attempt to find answers to the following questions:

1. To what extent do people with brain injuries have difficulty learning?
2. Does intellectual ability impact learning?
3. Does Severity of Injury impact learning?
4. Does age have an impact on learning ability?
5. Does time since injury have an impact on learning ability?
6. What impact does learning have on outcome?

These questions will also be applied to the classifications of learning ability as determined by the Standard RULIT Rasch model. The study will conclude by comparing the information gained from these two classifications of learning in order to appreciate whether a dynamic test of Non-Verbal Learning Potential provides more clinically meaningful information than a standard version with regard to person ability.

6.3 Results

See Chapter 4, section 4.2 for a detailed description of the primary analysis.

6.3.1 Part One of the Data Analyses: Rasch for the Standard and Dynamic RULIT

The initial analysis will build an understanding of how an acquired brain injury population is defined in terms of the interpretation of their performance on the Standard RULIT. This is achieved by representing the hierarchical spread of person ability and item difficulty. As in Study One, the results of the RULIT were split according to the normative data, using the 16th percentile as the cut-off. Within the RULIT's seven items of measurement, five of the items had percentile scores that could be applied ('Total Correct', 'Total Step Errors', Trial Two Correct', 'Delayed Correct' and 'Delayed Errors').

These items were split at the 16th percentile and represented in a Rasch Item Map below (Figure 22).

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                           <rare>|<more>
73          Delayed Correct      +  XXXXXXXXXXXXXXXXXXXXX
72                               +
71                               +
70                               +
69                               +
68                               +  XXXXXXXXXXXX
67                               +
66                               +
65                               +
64                               +
63                              S+S
62                               +
61                               +
60                               +
59                               +
58                               +
57                               +
56                               +
55                               +  XXXXXX
54          Total Correct        +
53                               +
52                               +
51                               +
50                               +M
49                               +
48                              M+
47                               +
46                               +
45             Delayed Errors    +
44          Trials 2 Correct     +  XXXXXX
43                               +
42                               +
41                               +
40                               +
39                               +
38                               +
37                               +S
36                               +  X
35          Total Step Errors    +
34                               +
33                               +
32                              S+  XXXXXXXXXXXXXXXXX
31                               +  XXXX
                          <frequ>|<less>
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Figure 22: Item Map Representing the Hierarchy of Difficulty for the Standard RULIT Administration Using the 16th Percentile Cut-Off

This map shows the hierarchy of the items of the Standard RULIT (see section 5.3.1 for explanation of how to interpret the results). This analysis found that the most difficult item to pass was 'Delayed Correct' and the easiest item to pass was 'Total Step Errors'. This suggests that overall learning ability is easier for the participants whereas delayed memory is considerably more challenging.

21 participants (31%) failed to reach the clinical cut-off for the easiest item. This indicates that it is unlikely they scored at greater than the 16th percentile for any of the items of the RULIT and so were scoring in the impaired range for every item of the test. 21 participants (31%) were plotted above the hardest item on the item map, indicating that they are likely to have scored within the normal range (greater than the 16th percentile) for every item of the RULIT. The remaining 25 (38%) are spread amongst the map.

As in Study One, a Bubble chart has been used to represent the logit plot and the error and unidimensional construct fit for each item on the scale. This is found in Figure 23.

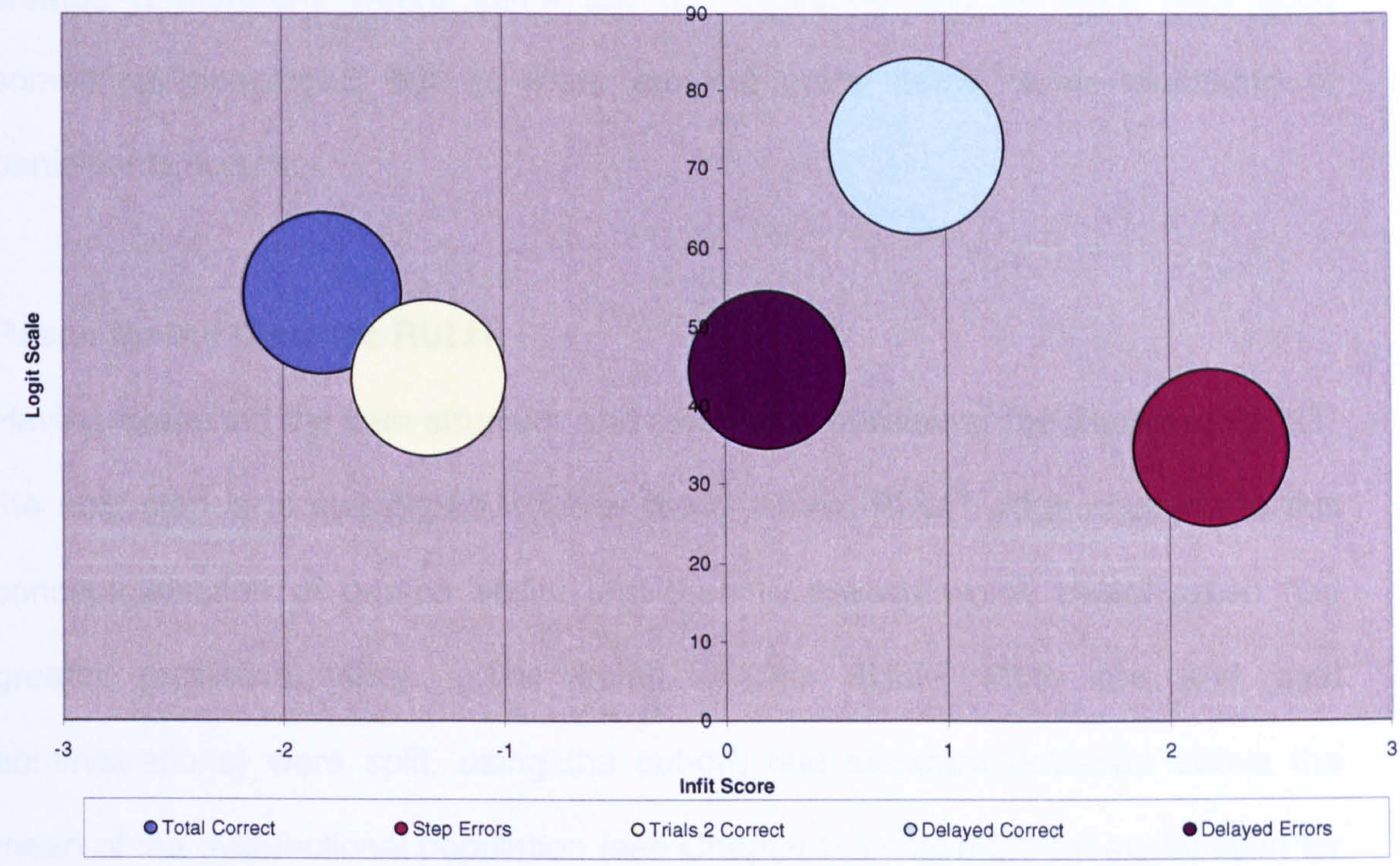

Figure 23: A Bubble Chart Representing the Rasch Model for the Standard RULIT Using 16th Percentile Norms

The chart illustrates that the only item that does not belong to the unidimensional construct is 'Step Errors'. This suggests that this item has more variance than the model would have predicted. The items have a relatively similar amount of error, suggesting some imprecision with regard to predicting their position on the hierarchical scale, but there is little overlap of the items, which indicates that although the precision of the plot is not accurate, this is unlikely to affect the hierarchical order of the items.

This model has created a Real Person Separation Score of 1.07, which, according to Sampson & Bradley's (2005) guidelines (≥1), suggests that the model was able to adequately spread individuals along the scale. The Real Item Separation Score was 2.8, which indicates that the items had more than adequate spread along the scale. These findings indicate that the Rasch Model for the Standard RULIT created a hierarchy where items are not clustering and so each item adds something meaningful, but as there are not many items, some clustering of participants occurs.

Rasch for the Dynamic RULIT

Having examined the item structure and separation abilities of the Standard RULIT, the next step is to investigate whether the Dynamic RULIT adds anything to this conceptualisation of person ability and then to assess which classification has greater predictive utility. The items of the RULIT (both pre and post administrations) were split, using the cut-off, one standard deviation above the mean of the dysfunctional population (see Chapter 2, section 2.3 for explanation for this choice of cut-off) and applied to the Rasch Model to create an item map. This has been included below in Figure 24.

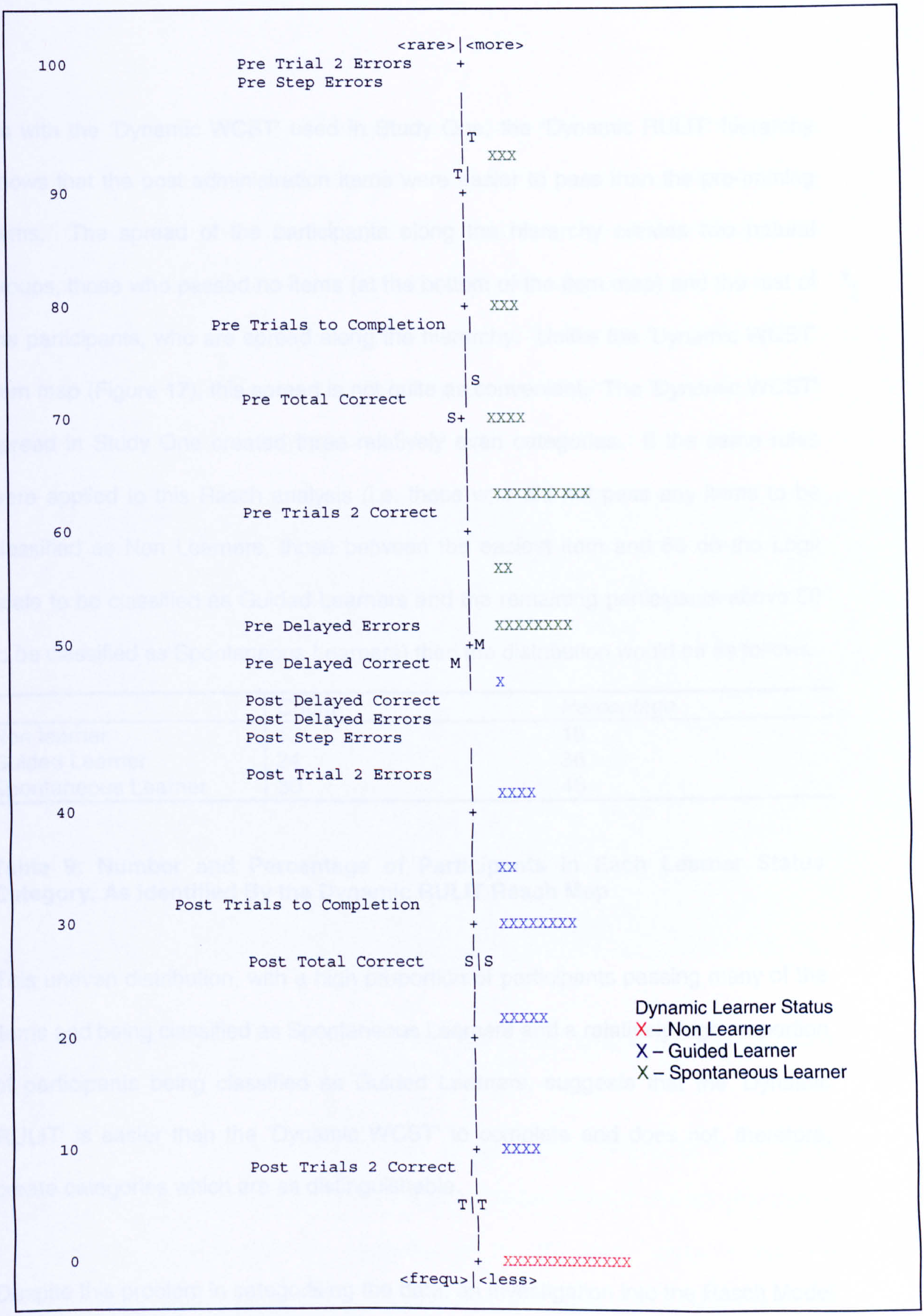

Figure 24: Item Map Representing the Hierarchy of Difficulty for the Items of the Dynamic RULIT (Both Pre and Post-Training Administrations)

As with the 'Dynamic WCST' used in Study One, the 'Dynamic RULIT' hierarchy shows that the post administration items were easier to pass than the pre-training items. The spread of the participants along the hierarchy creates two natural groups, those who passed no items (at the bottom of the item map) and the rest of the participants, who are spread along the hierarchy. Unlike the 'Dynamic WCST' item map (Figure 17), this spread is not quite as convenient. The 'Dynamic WCST' spread in Study One created three relatively even categories. If the same rules were applied to this Rasch analysis (i.e. those who did not pass any items to be classified as Non Learners, those between the easiest item and 50 on the Logit scale to be classified as Guided Learners and the remaining participants above 50 to be classified as Spontaneous Learners) then the distribution would be as follows.

	Count	*Percentage*
Non learner	13	19
Guided Learner	24	36
Spontaneous Learner	30	45

Table 9: Number and Percentage of Participants in Each Learner Status Category, As Identified By the Dynamic RULIT Rasch Map

This uneven distribution, with a high proportion of participants passing many of the items and being classified as Spontaneous Learners and a relatively high proportion of participants being classified as Guided Learners, suggests that the 'Dynamic RULIT' is easier than the 'Dynamic WCST' to complete and does not, therefore, create categories which are as distinguishable.

Despite this problem in categorising the data, an investigation into the Rasch Model (refer to Figure 25), found that every item of both the pre and post-training tests fitted the unidimensional construct and the model created a good spread of participants along the hierarchy (real person separation = 2.25). The spread of the items was also very good (Real Item Separation = 4.19), indicating that there was little clustering and the items each added value. These scores are likely to be influenced by the fact that the items all fitted within one construct.

The information regarding the fit, hierarchy and error of the items has been represented on the bubble chart below (Figure 25)

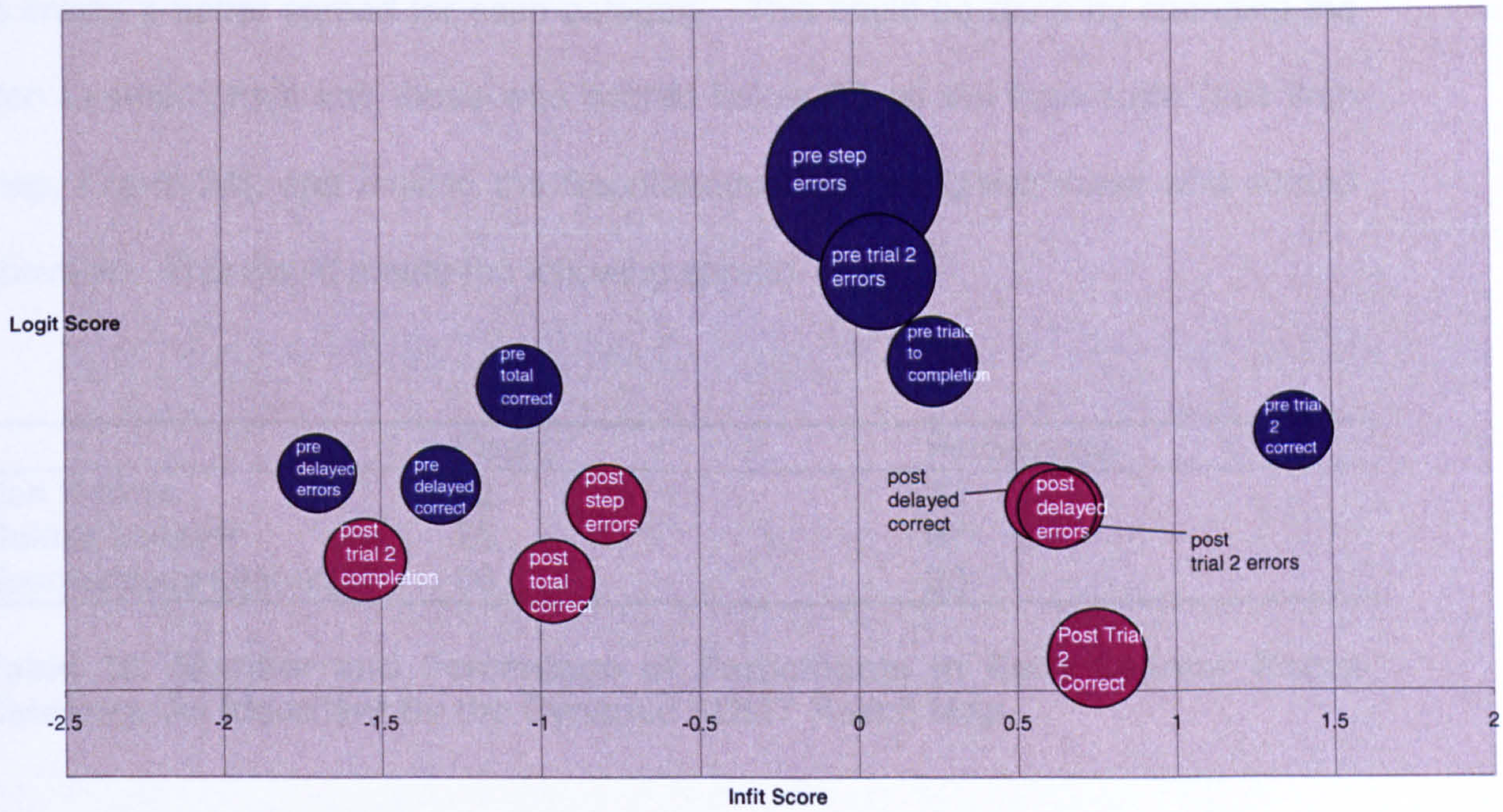

Figure 25: A Bubble Chart Representing the Rasch Model for the Dynamic RULIT Using the One Standard Deviation Cut-Off

This bubble chart highlights that as well as every item belonging to the same unidimensional construct, all the items are proportional in terms of error (the size of the bubble). This is with the exception of the top item, which is the pre-administration 'Step Errors'. This implies that this item has a larger zone of imprecision in terms of predicting its place in the hierarchy, indicating that participants are likely to have more varied responses to this item than the model would have predicted (e.g. against the model's predictions the Non Learners may have reached the cut-off unexpectedly, or Spontaneous Learners may not have reached the cut-off).

In creating the groups, it is tempting to adjust the original grouping criteria on the Rasch hierarchy (i.e. Non Learners are those who did not pass any items, Spontaneous Learners are those above 50, the rest are Guided Learners) in order to create a better spread for each category. This could be done by changing the Non Learner group into those who scored below 20 on the logit scale (see item map, Figure 24), and making the Spontaneous Learner group those who scored above 60. This would create the following spread.

	Count	Percentage
Non learner	22	33
Guided Learner	25	37
Spontaneous Learner	20	30

Table 10: Number and Percentage of Participants in Each Learner Status Category, As Identified By the Dynamic RULIT Rasch Map

Using this sorting method enables the power criterion to be met for the ANOVA's in part two of the data analysis. However, it was felt that consistency between investigations was important for several reasons, including a fair comparison between studies, as well as the fact that this uneven distribution provides important information about how difficult the test was in relation to the other studies. Therefore, despite the sample for the 'Non Learners' being low the original classification system was maintained[4].

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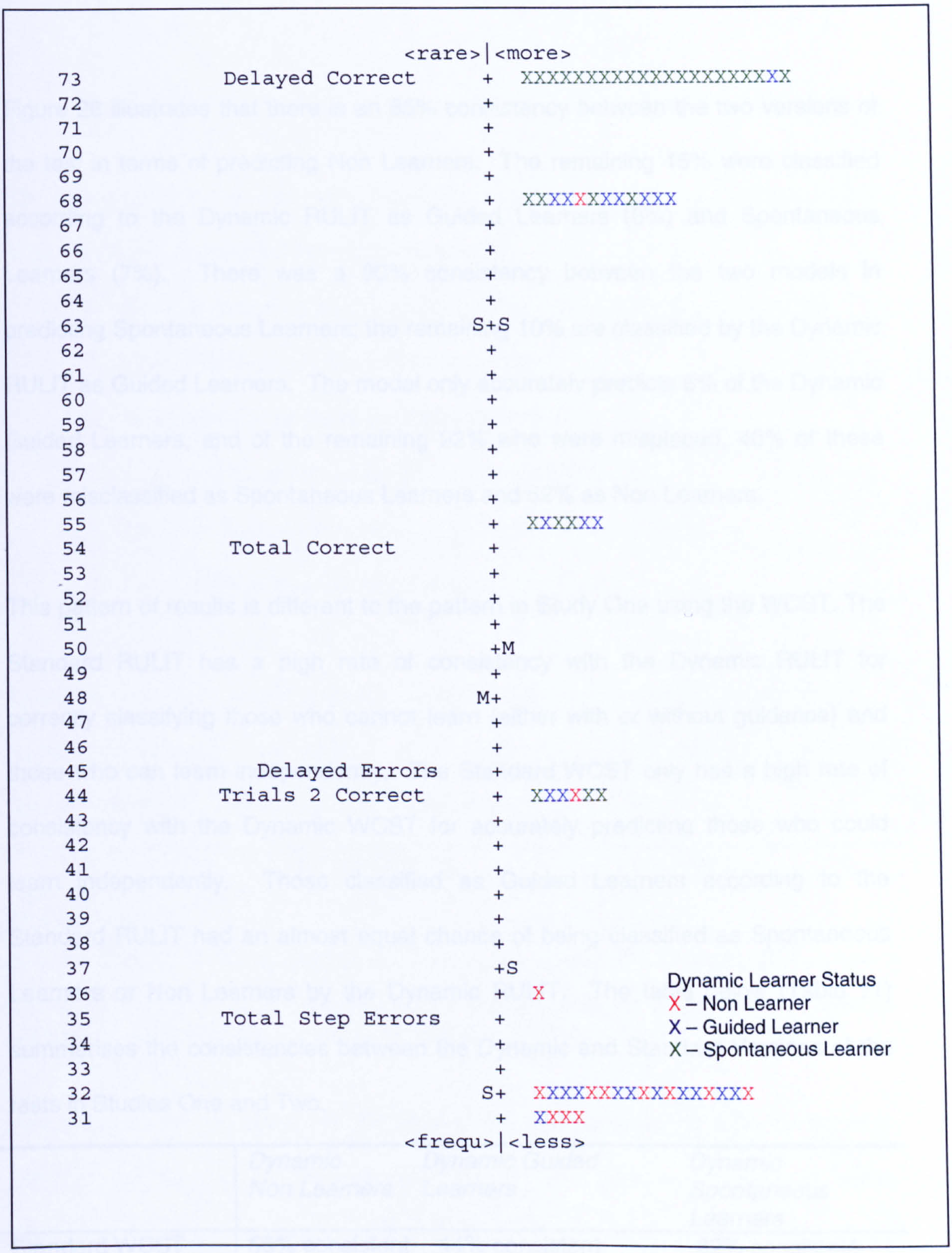
[4] Although these alternative categories were not applied to this research, they were created and will be referred to if it is thought that Type II errors have occurred due to the power criteria not being met. Please see Appendix14 for details.

As with the analyses in the previous study, the next stage of this investigation is to compare the classifications of learning ability created by the Standard RULIT to the classifications of learning potential created by the Dynamic RULIT. Again the two learner status classifications created by both versions will be represented on one map (Figure 26). Each individual has been plotted according to where they fell on the 16th percentile cut-off, but will be colour coded according to how they were placed according to the Dynamic RULIT classifications (red for Non Learners, Blue for Guided Learners and Green for Spontaneous Learners). This map will indicate what consistencies and inconsistencies there are between the two maps.



```
                        <rare>|<more>
 73          Delayed Correct     +  XXXXXXXXXXXXXXXXXXXXX
 72                              +
 71                              +
 70                              +
 69                              +
 68                              +  XXXXXXXXXXXX
 67                              +
 66                              +
 65                              +
 64                              +
 63                             S+S
 62                              +
 61                              +
 60                              +
 59                              +
 58                              +
 57                              +
 56                              +
 55                              +  XXXXXX
 54          Total Correct       +
 53                              +
 52                              +
 51                              +
 50                              +M
 49                              +
 48                             M+
 47                              +
 46                              +
 45            Delayed Errors    +
 44          Trials 2 Correct    +  XXXXXX
 43                              +
 42                              +
 41                              +
 40                              +
 39                              +
 38                              +
 37                              +S
 36                              +  X
 35          Total Step Errors   +
 34                              +
 33                              +
 32                             S+  XXXXXXXXXXXXXXXXX
 31                              +  XXXX
                        <frequ>|<less>
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Figure 26: A Rasch Item Map Showing the Hierarchy of Difficultly For the Items of the Standard RULIT with Participants Colour Coded According To the Dynamic RULIT

Figure 26 illustrates that there is an 85% consistency between the two versions of the test in terms of predicting Non Learners. The remaining 15% were classified according to the Dynamic RULIT as Guided Learners (8%) and Spontaneous Learners (7%). There was a 90% consistency between the two models in predicting Spontaneous Learners; the remaining 10% are classified by the Dynamic RULIT as Guided Learners. The model only accurately predicts 8% of the Dynamic Guided Learners, and of the remaining 92% who were misplaced, 40% of these were misclassified as Spontaneous Learners and 52% as Non Learners.

This pattern of results is different to the pattern in Study One using the WCST. The Standard RULIT has a high rate of consistency with the Dynamic RULIT for correctly classifying those who cannot learn (either with or without guidance) and those who can learn independently. The Standard WCST only has a high rate of consistency with the Dynamic WCST for accurately predicting those who could learn independently. Those classified as Guided Learners according to the Standard RULIT had an almost equal chance of being classified as Spontaneous Learners or Non Learners by the Dynamic RULIT. The table below (Table 11) summarises the consistencies between the Dynamic and Standard Versions of the tests in Studies One and Two.

	Dynamic Non Learners	*Dynamic Guided Learners*	*Dynamic Spontaneous Learners*
Standard WCST	55% consistent	44% consistent	82% consistent
Standard RULIT	85% consistent	8% consistent	90% consistent

Table 11: Consistency in Learner Status Classifications between the Standard and Dynamic Tests of Studies One and Two

6.3.2 Traditional Statistical Analyses: the Dynamic RULIT Investigation

The second part of this analysis will use the groups created by the Dynamic RULIT Rasch Model to answer the research questions;

1. To what extent do people with brain injuries have difficulty learning?
2. Does intellectual ability impact learning?
3. Does Severity of Injury impact learning?
4. Does age have an impact on learning ability?
5. Does time since injury have an impact learning ability?
6. What impact does learning have on outcome?

Question 1: To what extent do people with brain injuries have difficulty learning?

Table 12 highlights the number of participants that fall into each category (determined by the Rasch logit scale categories).

	Count	*Percentage*
Non learner	13	19
Guided Learner	24	36
Spontaneous Learner	30	45

Table 12: Number and Percentage of Participants in Each Learner Status Category, As Identified By the Dynamic RULIT Rasch Map

According to the 'Dynamic RULIT' 19% of the participants had difficulty learning, 36% of the participants had difficulty learning independently but could utilise strategies provided to enable them to learn after intervention and 45% of the participants could master the test independently. Compared to the Dynamic WCST in Study One (section 5.3.2) this dynamic assessment appears to be easier and so according to this learning classification, the majority of participants did not have difficulty learning visuospatially following a brain injury.

Question 2: Does intellectual ability impact learning?

To investigate the relationship between learning status and intellectual ability, the learner status classifications were subjected to an analysis of variance using current and pre-injury IQs as the dependent variables.

Pre-injury IQ

The ANOVA for pre-injury IQ was not significantly related to learner status, F(2,59)=0.63; p=0.53). This result could have been influenced by the inadequate power for one of the categories which had a smaller than ideal sample size. To examine whether this finding was in fact a false negative, an investigation of the means was conducted and a comparison of the findings using the alternative learner status classification (with a better distribution between each of the three categories) was made. The mean pre-injury IQ scores showed that the average Non Learner pre-injury IQ was 94.03, for the Guided Learners it was 97.76 and for the Spontaneous Learners it was 99.97. This has a maximum of only three IQ points between the categories, (for the significant pre-injury Dynamic WCST the Non Learners' mean score was 92.12, Guided Learner's was 95.09 and for Spontaneous Learners it was 103.26). The ANOVA using the alternative learner status in Appendices 16 was also not significant. This would suggest that even if the power was adequate, the differences might not be significant, and that this finding is not the result of a Type II error. These results suggest that this test does not tap into the same abilities as the WCST and they are not influenced by pre-injury abilities.

Current IQ

The ANOVA for current IQ (using WAIS or WASI FSIQ), was highly significant, F(2,54)=8.44, $p<0.0001$. A Post hoc Scheffe analysis found a significant difference between Non Learners and Guided Learners ($p=0.03$) and Non Learners and Spontaneous Learners ($p<0.001$).

This ANOVA finds that the Non Learner group's current IQ (mean = 73.67, sd =14.53) is significantly lower than those in the Guided Learner group (mean = 90.00, sd=14.91) and the Spontaneous Learner group (mean = 97.07, sd=14.81), but that the current IQ of Guided Learners and Spontaneous Learners was not significantly discriminative (despite following the trend). This suggests that Non-Verbal / Visuospatial Learning is predominantly influenced by current intellectual abilities, which would indicate that the impact of the injury could also have a significant impact.

Question 3: Does Severity of Injury impact learning?

ANOVA for Glasgow Coma Scale score at onset of injury found a main effect of learner status categories in relation to severity of injury, F(2,41)=6.43, $p=0.001$). Post hoc investigation found a significant difference between Non Learners (mean = 5.63, sd= 4.17) and Spontaneous Learners (mean=11.52, sd= 4.00) ($p=0.01$) only. Again it is recognised that the number in this analysis is too small (N=41) to obtain effective power, but that despite this the ANOVA was still significant, suggesting a strong relationship.

Question 4: Does age have an impact on learning ability?

An analysis of variance showed that the effect of learner status on age at onset of injury and age at time of testing was not significant (F(2,62)=3.04, p=0.06 and F2,52)=2.77, p=0.07 respectively). As with the Dynamic WCST it appears that age does not influence Dynamic RULIT learner status.

Question 5: Does time since injury have an impact on learning?

The analysis of variance investigating the relationship of time since injury with learner status found a non significant main effect (F (2,53)= 1.64, p= 0.20). This has a low N so a comparison of the same analysis was conducted using the Alternative Dynamic RULIT classifications (Figure 27). This yielded a significant F ratio, F(2,52)= 3.83, p= 0.03. It is interesting to note here that this second ANOVA had the same number of participants as the first, but the spread was a little more even. The post hoc analysis of this AVOVA found significant differences between the mean of the Non Learner Group (mean= 68.06, standard deviation = 74.68), and the mean of the Spontaneous Learner Group (mean = 13.68, sd = 15.59).

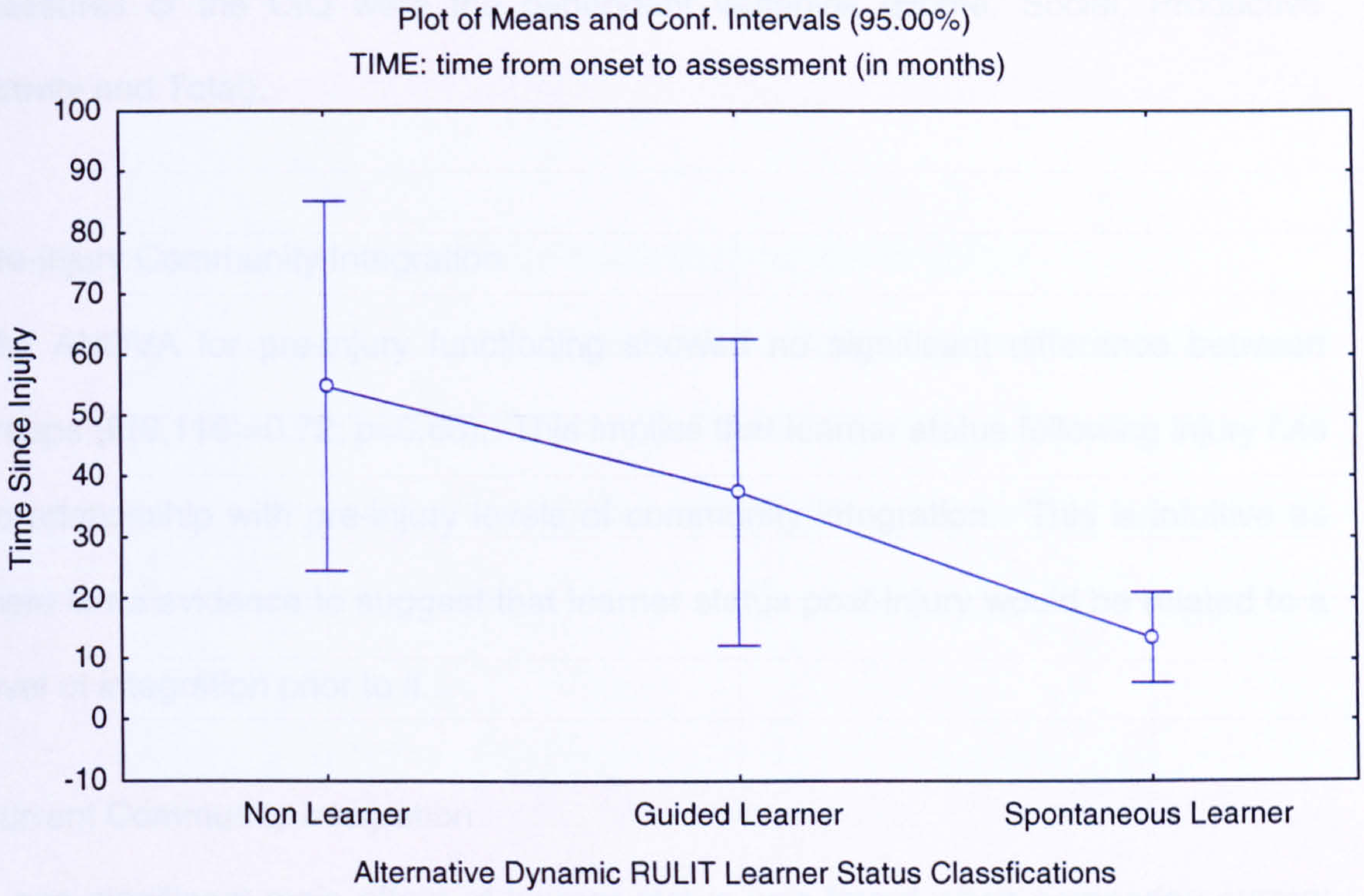

Figure 27: ANOVA for the Alternative Dynamic RULIT Learner Status Groups and Mean Time in Months since Injury

This ANOVA appears to suggest that time since injury does affect learner status. However, it is unclear as to whether time is affecting learner status or reflecting that learner status is unchangeable. This result appears to indicate that Non Learners are an unchanging group and that Spontaneous Learners are likely to be able to be identified earlier on in recovery.

Question 6: What impact does learning have on outcome?

As with Study One, the Community Integration Questionnaire was used to reflect recovery. Learner classifications were subjected to analysis of variance using three perspectives of Community Integration (i.e. current and pre-injury levels of integration and change in integrations). For each of the ANOVAs the four measures of the CIQ were the dependent variables (Home, Social, Productive Activity and Total).

Pre-injury Community Integration

The ANOVA for pre-injury functioning showed no significant difference between groups (F(8,116)=0.72; p=0.68). This implies that learner status following injury has no relationship with pre-injury levels of community integration. This is intuitive as there is no evidence to suggest that learner status post-injury would be related to a level of integration prior to it.

Current Community Integration

A non significant main effect of learner status was found when comparing current community integration levels, F(8,116)=1.95, p=0.06), but it is worth noting that the p value neared significance. An investigation into the mean scores for each of the scales across classifications found a very similar spread to that of the significant Dynamic WCST CIQ ANOVA. This would suggest that insufficient power due to inadequate sample size might be contributing to this non significant finding. The mean score distribution has been illustrated in Table 13.

	Dynamic RULIT			*Dynamic WCST*		
	NL	*GL*	*SL*	*NL*	*GL*	*SL*
Home	2.46	3.50	4.76	2.45	4.05	4.90
Social	5.54	6.40	8.03	5.50	7.55	7.83
Productive Activity	2.08	3.27	4.03	2.45	3.77	4.24
Total	10.08	13.18	16.83	10.40	15.36	16.97

Table 13: Comparison of Mean Scores for the Dynamic RULIT and Dynamic WCST ANOVA for Current Community Integration

The alternative learner status ANOVA (Appendix 16) for current CIQ was significant, which provides additional support that this non significant finding is a false negative. An alternate possibility, however, is that these classifications simply do not have enough sensitivity to predict an ecologically valid outcome.

Difference between Current and Pre-injury Community Integration

The analysis of variance investigating the relationship between learner status and change in integration levels was not significant. (F(8.116)=1.70, p=0.11). This result is not a surprise considering the fact that the current and pre-injury IQ ANOVAs were also not significant.

6.3.3 Traditional Statistical Analyses: the Standard RULIT Investigation

The next stage of this investigation will investigate the learner classifications created by the Standard RULIT. This will facilitate a comparison in the discussion section of the efficacy of each of the learner classifications created by the two assessments.

As it was in Study One, the term Guided Learner will not be applied to those individuals who were placed in the middle range of the Rasch map (and therefore who passed some items and not others). This has been done because there has been no errorless learning intervention and no guidance was provided. Instead this group will be labelled as 'Learners' as they passed some of the items, thus showing evidence of learning at or above the 16th percentile but not all of the items, and therefore did not meet the criteria for Spontaneous Learning.

Once again the research questions were answered according to the learning classification created by performance on the standard version of the test.

Question 1: To what extent do people with brain injuries have difficulty learning?

Table 14 summaries the distribution and overall percentage of each of the Standard RULIT learner status classifications, Table 15 compares the difference in distribution between the Standard and Dynamic RULIT groups.

	Count	*Percentage*
Non learner	21	31
Learner	25	38
Spontaneous Learner	21	31

Table 14: Number and Percentage of Participants in Each Learner Status Category, As Identified By the Standard RULIT Rasch Map

	Non Learner	*Guided Learner/Learner*	*Spontaneous Learner*
Dynamic RULIT	13 (19)	24 (36)	30 (45)
Standard RULIT	21 (31)	25 (38)	21 (31)

Table 15: A Comparison of the Distribution between the Standard and Dynamic Learner Status Categories

The comparison between the Standard and the Dynamic RULIT illustrates how the Dynamic RULIT created a more uneven distribution in performance, with less Non Learners and more Spontaneous Learners when compared to the Standard RULIT. This suggests that the Dynamic RULIT might be too easy, creating a ceiling effect of performance.

For the Standard RULIT it can be observed that 31% of this brain injury population have difficulty learning, 31% have no problems learning on every item of the test, and 38% have difficulty passing all the items, but are able to learn enough to pass some.

Question 2: Does intellectual ability impact learning?

Two analyses of variances were conducted to investigate the main effect of Standard RULIT learner status on pre-injury and current IQs.

Pre-injury IQ

The ANOVA investigating the main effect of learner status on pre-injury IQ yielded a significant F ratio, F(2,59)=3.33, p=0.043. Post hoc analysis found a significant difference between Non Learners (mean= 91.58, sd=14.14) and Learners (mean= 103.64 sd=16.13) p=0.04. This ANOVA is interesting because it places the Learner group as the highest for IQ (refer to graph in Figure 30). This implies that Spontaneous Learners (those who passed the majority all of the items) had a lower IQ pre-injury (mean = 97.64, sd =14.08) when compared to the Learners (who only passed some of the items). The reasons for this are unclear.

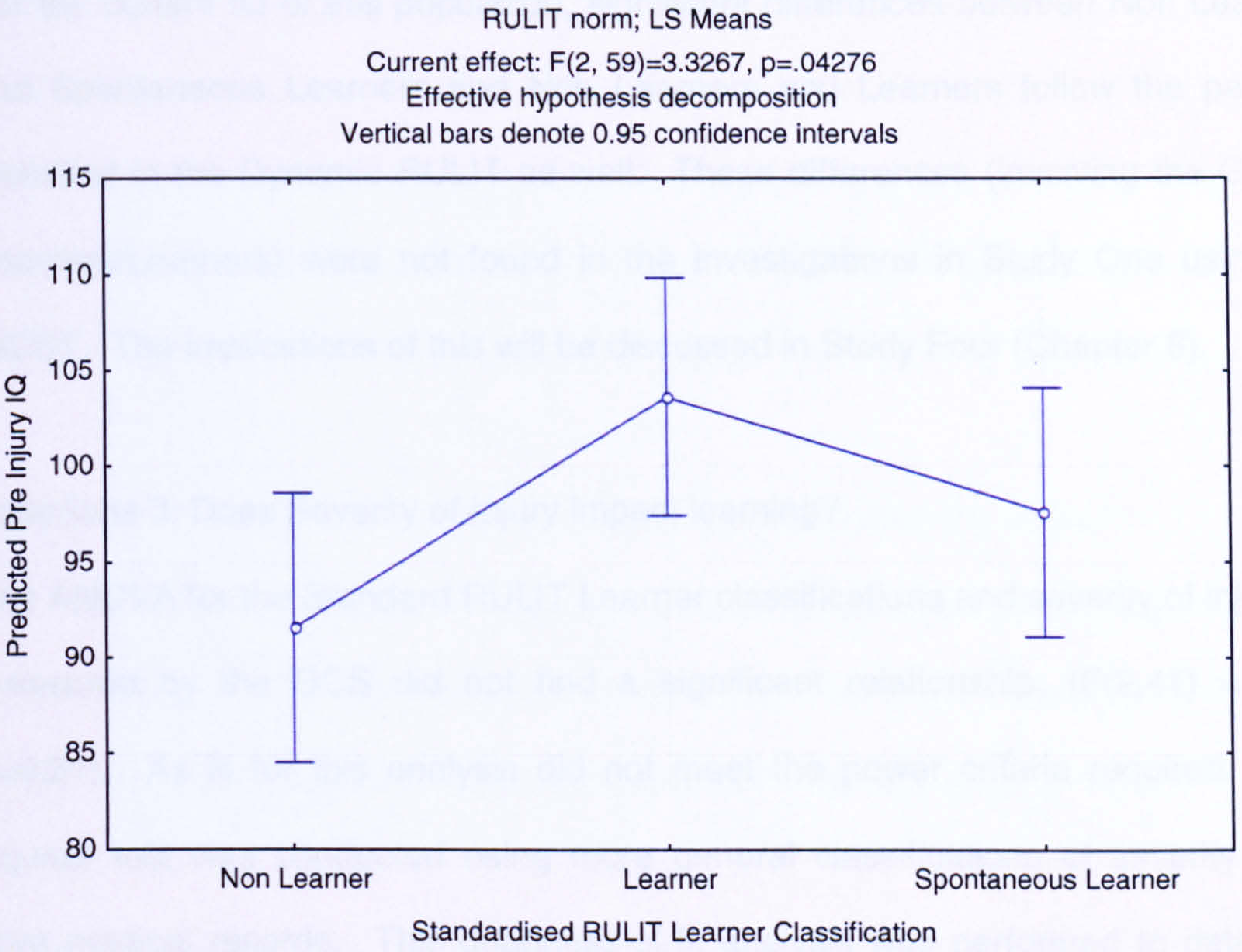

Figure 28: ANOVA for the Standard RULIT Learner Groups and Pre-Injury IQ.

Current IQ

The main effect of the Standard RULIT learner status classifications on current IQ yielded an F ratio of F (2,54)=6.95, $p<0.001$; this was a similar finding to that of the Dynamic RULIT ANOVA, (F(2,54)=8.44, $p<0.001$). For the Standard RULIT ANOVA, post hoc analysis found significant differences between Non Learners (mean = 79.82, sd= 12.78) and Learners (mean= 92.90, sd =15.19), (p=0.03) and also Non Learners and Spontaneous Learners (mean= 98.21 sd=16.90) ($p<0.001$).

These investigations indicate that intellectual ability (both pre-injury and current measures) have an impact on learning ability as determined by the Standard RULIT. The patterns of this influence were not always as predicted (with Learners having a higher predicted pre-injury learning ability than Spontaneous Learners).

For the current IQ of this population, significant differences between Non Learners and Spontaneous Learners and Non Learners and Learners follow the patterns identified in the Dynamic RULIT as well. These differences (involving the Guided Learners/Learners) were not found in the investigations in Study One using the WCST. The implications of this will be discussed in Study Four (Chapter 8).

Questions 3: Does Severity of Injury impact learning?

The ANOVA for the Standard RULIT Learner classifications and severity of injury as measured by the GCS did not find a significant relationship, (F(2,41) = 1.63, p=0.21). As N for this analysis did not meet the power criteria required, a Chi Square test was conducted using more general classifications of severity taken from medical records. This goodness-of-fit analysis was performed to determine whether the three learner status classifications were equally distributed. The analysis with Yates correction was not significant (χ^2= 1.62 (df=2) (p=0.44)). The distribution has been outlined in Table 16.

	Non Learner	*Learner*	*Spontaneous Learner*
Severe Brain Injury	10(37%)	10 (37%)	7 (26%)
Mild/Moderate Brain Injury	8(24%)	12 (36%)	13 (40%)

Table 16: Frequency of Severity Distributed across Standard RULIT Learner Status Classifications

This Chi Square indicates that learner status as determined by the Standard RULIT is not affected by severity of injury.

Question 4: Does Age have an impact on learning ability?

Like the Dynamic RULIT learner groups, the ANOVAs investigating age (both at onset and at testing) for the Standard RULIT groups were not significant (F(2,62)=1.95, p=0.15) and (F(2,52)=2.17, p=0.12) respectively. Again this infers that age does not influence learning ability.

Question 5: Does time since injury have an impact on learning ability?

The ANOVA for time since injury and standard RULIT learner groups was not significant; (F(2,53)= 0.43, p= 0.65) indicating that for the Standard RULIT learner groups there is no significant relationship with time since injury.

Question 6: What impact does learning have on outcome?

Pre-injury Integration

As with the Dynamic RULIT (F(8.116)= 0.72, p=.0.68), the Standard RULIT ANOVA found no significant differences between learner groups (F(8, 116)= 1.29, p=0.25). Once again this confirms that pre-injury integration levels are not related to learning ability.

Current Integration

Unlike the Dynamic RULIT, which was not significant (F(8,116)=1.95, p=0.06), the Standard RULIT ANOVA did find a significant relationship between current Integration and learning ability (F(8,116)=2.58, p=0.01). Significant post hoc Scheffe analyses have been laid out below.

Social Integration

- Spontaneous Learners (mean = 5.60, sd=2.01) and Non Learners (mean = 8.35, sd=2.58) (p=0.001)

Total Community Integration

- Spontaneous Learners (mean = 17.00, sd=6.08) and Non Learners (mean = 10.70, sd=4.22) (p=0.003).

This significant ANOVA suggests that the Standard RULIT has more ecologically predictive utility than the Dynamic RULIT. Despite this it is interesting to note that the significant differences were only found between the extreme ends of learning ability (i.e. no significant differences were found that involved the middle Learner group). This indicates that perhaps the Standard RULIT classifications are not as valuable as the Dynamic WCST test, which was able to distinguish a significantly different recovery level for each of the three learning classifications.

Change in levels of community Integration

The analysis of variance applied to the Standard RULIT learning classifications to investigate the impact on change of community integration levels yielded a non significant F ratio, (F(8,116)= 1.72, p=0.10).

The implications of these results will be discussed in the following section.

6.4 Discussion

The conclusions that can be drawn from this investigation are almost the reverse of those drawn from Study One. This study found that adapting a test of visuospatial learning by adding an errorless learning training intervention to it did not increase its utility in predicting recovery levels. There may be several explanations for this. The first is related to the fact that the power criterion was not met; the distribution of the groups was grossly uneven with 45% of the population having a high likelihood of passing every item (compared to 31% of the Standard RULIT). This suggests that there was a ceiling effect and that the training on the test made it too easy to pass. With only 13 participants classified as Non Learners it is clear that each of the analyses would have one category which had significantly less participants than the power criteria required. This means that any non significant findings should be viewed tentatively as there is an increased risk for Type II errors being the reason for this. In actual fact, despite this problem with power, several of the ANOVAs did find significant main effects of learner status (i.e. current IQ, Severity of Injury), suggesting that the effect size must be large. To investigate whether the non significant findings were a result of inadequate power an alternative learner status classification was made on the Dynamic RULIT map. This involved moving the grouping criteria for Non Learners from below the easiest item to those who were plotted below 20 on the scale. This increases the number of people who would be placed in this Non Learner category. Throughout this study, when an unexpected non-significant finding occurred with the Dynamic RULIT investigation, this was compared to the new alternative RULIT category ANOVA to see if a significant finding occurred. This would indicate if the non significances were related to power, rather than lack of effect. When these new ANOVAs were done the only differences that were found were in the relationship with the Current Community Integration Scores and Time since Injury. This suggests that the non-significances are likely to be related to issues of power.

An alternative explanation, which could account for why the Dynamic RULIT was not a better predictor of recovery than the Standard RULIT, is that it was not an effective measure of learning ability. Before a possible explanation is given regarding why the RULIT does not appear to lend itself well to dynamic assessment the different Rasch item maps and their properties will be explored.

Hierarchical Distribution for the Standard RULIT

Within the Standard RULIT only five of the items had normative data to allow a split at the 16th percentile. Unlike the WCST, the majority of this test was found to belong to a unidimensional construct. The only item that was found to be a misfit was the 'Total Step Errors' item. This measure reflects any error that a person makes during the initial encoding trials, with no consideration of what might be influencing that error. Interestingly it is also the easiest item to pass and only 30% of the population performed below the 16th percentile cut-off on it. The other items belonging to the construct were 'Total Correct', 'Trial Two Correct', 'Delayed Correct' and 'Delayed Errors'. These items could be seen as reflecting the process of learning and retrieval of learnt information, whereas Step Errors could be seen as reflecting the difficulties that interfere with the encoding process. The fact that it is the easiest is only a reflection of the low 16th percentile cut-off which has been applied.

Hierarchical Distribution for the Dynamic RULIT

It was not unexpected that the Post Training items of the Dynamic RULIT were found at the bottom of the hierarchical map, and were therefore the easiest items to pass. The lowest item and therefore the easiest to pass was 'Post Trial Two Correct'. This measure probably taps into immediate memory, as people were told what the route was, so their first attempt without the route would have been their best, whilst it was fresh in their mind. The second easiest item was 'Post Total Correct'; again this is now a measure of memory as opposed to learning, as people are simply recalling what they have learnt over the errorless training trial. The hardest items to pass were 'Pre Trial Two Correct' and 'Pre Step Errors'. The 'Post-Training Delayed Recall' was hardest of all the post-training items, but within the pre-training items the 'Delayed Recall' was the easiest. It is possible that the errorless learning intervention has played a role in this. On the initial trial-and-error task learning over several trials has been effortful and has encouraged a deeper level of processing (Craik et al., 1972). However, the errorless training intervention has perhaps been less effortful. This finding replicates that of Evans et al (2000), who concluded that trial and error was the more efficient means of learning a route. It also provides support to Squires et al's (1997) research, which found evidence that the benefits of errorless learning are not always maintained over a delay.

With regard to the construct and error properties of the Dynamic RULIT (please refer to Figure 25), it was interesting to observe that all of the items belong to the same construct as opposed to the static assessment's 16th Percentile cut-off. The fact that the 'Pre Step Errors' now belonged must have been related to the change in cut-off. This 16th percentile cut-off, which made it the easiest item to pass, also meant that it was not sensitive enough – this somehow meant that it created too much variance with regard to what the model predicted. Now that the cut-off is one standard deviation above the mean of the population it has made the item harder to pass and, as a result, part of the construct. If the Standard RULIT construct was suggested as one of encoding and retaining information and to which the Post-Training items also belong then it is felt that this label might still apply. However, it does not appear to reflect learning potential, only the individual's ability to learn through trial and error or through errorless learning technique. On reflection, minimising the verbal element and therefore the interaction has probably had an effect on whether it can now be seen as a measure of learning potential because learning potential is thought to come about through interaction with a more experienced peer, and this has not occurred here. The Standard Error of these items shows that the majority of them have a similar and relatively small amount of imprecision; the only item that was significantly larger was the 'Pre Step Errors'. This is not unexpected when you consider that with a lower cut-off it was the easiest to pass, indicating that within this population there is a large spread of ability on this item. It is important to note that this item does not measure ability to learn the route (and therefore does not equate with failure or success of the test), e.g. you can have a huge number of errors for the first few trails and still complete the test successfully or very few number of errors and not complete the test (it only takes one error to prevent a successful trial).

When considering the differences between learner status classifications it was found that pre-injury IQ was significantly related to the Standard RULIT learner status classifications, and could differentiate significantly Non Learners from Learners, but not Non Learners from Spontaneous Learners or Learners from Spontaneous Learners. Learners in this classification were those that had passed some of the items. This group had the highest IQ (by an average of 6 IQ points). The fact that pre-injury IQ related to the Standard RULIT but not the Dynamic RULIT learner status suggests that either pre-injury ability is not related to visuospatial learning (but the Standard RULIT suggests it is), or that the Dynamic RULIT is no longer a test of learning, but a test of the product of learning (memory), and that pre-injury IQ is not related to that. This conclusion seems to be the most likely. The ANOVA investigating the relationship between current IQ and learner status showed the same significant pattern for both learner classification groups, with differences found between Non Learners and Learners/Guided Learners and also Non Learners and Spontaneous Learners. This suggests that current cognitive ability is related to learning, and that low IQ prevents an individual from using strategies to memorise the route (whether independently with trial-and-error or with errorless learning).

A very interesting finding was that severity of injury was not related to learner status classifications for the Standard RULIT. This is unlike the findings of the Dynamic RULIT and appears to suggest that learning visuospatially is not affected by severity of brain injury (at the 16th percentile), but that the dynamic test of learning and memory is.

Perhaps the most noteworthy finding of Study Two was that the Dynamic RULIT learner classifications had no significant main effect on levels of community integration (Pre-injury, Current or Change in Integration scores). This suggests that as a tool to predict recovery, dynamic testing using the RULIT is clinically meaningless. An investigation into the alternative classification of the Dynamic RULIT suggests that this is likely to be related to weak power as the ANOVA with a better spread, and therefore better power, produced significant results. The Standard RULIT ANOVA for current community integration levels was also significant; this suggests that even if the Dynamic RULIT had enough power, it might not be worth the additional time that the training intervention takes, as significant differences can be found with just the pre-administration. The post hoc analysis found significant differences for Social and Total categories (between Non Learners and Spontaneous Learners). This could mean that visuospatial learning relates to social and overall community outcome or that learning is a global measure as Feuerstein predicted and that this measure of visuospatial learning is a reflection of all modalities of learning. This will be assessed in Study Four, where each individual's learner statuses will be compared.

One reason the Standard RULIT proved itself a better measure of learning ability may be related to the complexity of the test. For the original version of the test the individual is required to problem solve and learn over several trials, utilising feedback and requiring the development of trial-and-error strategies. The training intervention provided the route and removed the need for progressive learning over trials; instead it required the person to remember the route as opposed to learn it. It is possible that the difference between the Dynamic WCST and the Dynamic RULIT is in the complexity of the test. In the post-training WCST the individual is still required to hold and manipulate information on-line, they are required to remember which rule they are currently using, as well as monitor the number of consecutive responses they have made and then choose the next rule at the right moment. The post-training RULIT simply requires the person to memorise a route and then reproduce it. The Dynamic WCST has quite a complex test construct, (as shown by the bubble chart Figure 18). The dynamic RULIT, on the other hand, does not have as complex a structure (Figure 25) and so the errorless training intervention is perhaps too much, in that it is not simply providing a strategy to be remembered and used, it is just teaching the person the answer. This therefore may be a test of the person's ability to remember the test, but not their ability to use a strategy to pass it.

Perhaps a failing of the test is that the feedback element of it is verbal, which perhaps makes the test more verbally explicit. It was observed that on the post-training administration of the test people began to spontaneously verbalise their thinking, perhaps suggesting that the post administration version had introduced a more overt verbal role.

Chapter 7 : Study Three: Investigation into Implicit Learning Using the Tower of Hanoi

This third study aims to add to our understanding about the clinical utility of a measure of a person's potential to learn. The first two studies investigated explicit learning systems (verbal and visuospatial). They investigated whether the provision of additional information to improve performance on a test was more clinically meaningful than the standard versions and whether it related better to individual levels of recovery. This third study is somewhat different, in that it will not add a dynamic training element to the test. Rather it will focus on the improvement an individual makes independently on their second attempt of the test (Trial Two). It will therefore not be measuring the individual's zone of proximal development as brought about by a third party, but their individual spontaneous improvement. In order to measure individual improvement or the practice effect in Trial Two, it was felt that the test chosen needed to be one where the rules for successful completion were not obvious or explicit, so that Trial Two was still a challenge intellectually. For this reason the third study was one which tapped into the implicit system of learning. Having an implicit test with complex rules ensures that the improvement made on the second trial will show whether an individual was able to take on information about their first performance and learn, or not.

In choosing an implicit test, to enable a comparison, it was again felt that it would be helpful if the test tapped into the same abilities as those measured in Study One and Two. Therefore a literature search was conducted on implicit tests of executive function; the test that was felt appropriate was the Tower of Hanoi.

The ToH was originally a puzzle from the 1800s, consisting of three pegs and a number of discs (three as a minimum) each one smaller than the previous. At the beginning of the test the discs are stacked on top of each other (largest at the bottom) on the peg at one end of the test. The participant is told that the aim is for all three discs to end up on the peg at the other end of the test in the same order as they are now. They are instructed that there are certain rules they must follow; (they cannot place a larger disc on top of a smaller one, they cannot move more than one disc at once, and the discs cannot be put anywhere other than on the pegs).

Research has identified that this test is a measure of problem solving ability (Goel & Grafman, 1995; Lezak, 2004a) and that success on the task was impaired by frontal lobe damage – which supports the executive function theory (Goel et al., 1995).

Goel et al's paper (1995) is instrumental in our understanding of the ToH. Their view is that it is not merely a test of planning but more accurately a measure of inhibitory ability, short term memory deficiencies and subgoal conflict resolution difficulties. Although the test is implicit (in that it is difficult to make explicit the rules necessary to pass the test), there are strategies used for completion, which have been outlined by Simon (2004b):

1. The goal recursion strategy involves transferring the pyramid of discs that are blocking the bottom disc to the spare peg and then transferring the bottom disc to the goal peg, etc (the obvious disadvantage to this is that there are no clear rules as to how to transfer the pyramid, which

means that it requires the concept to be developed and contained cognitively and has no perceptual strategy).

2. Move pattern strategy states that on odd numbered moves the participant must move the smallest disc and on even move the next smallest exposed disc. If the total number of discs included is odd, then the participant must move the smallest disc from the source to the target to other, if it is even, they must move the disc in the opposite direction (this rule is simple enough and easy to follow as long as the information can be retained in short-term memory).
3. Simple perceptual strategy: This is a simple strategy which requires the examinee to look at the test and establish if the largest disc is where it should be. If it is not they should move any discs on top of it and place the disc on the target peg, then start again. The simple perceptual strategy has an advantage that it can be applied at any stage of the test. A disadvantage is that, like the goal recursion strategy, there is no explicit rule to follow in order to achieve this. Also, if there are four or more discs in the test then inevitably the target peg will be blocked.
4. Sophisticated perceptual strategy: This strategy is more sophisticated than the simple perceptual strategy and provides a solution to the disadvantages in the simple perceptual strategy in that it identifies the need for subgoals to be identified and then created in order to decide how to move the discs that are obstructing the largest disc. These subgoals are temporary and can go against the principal goal (causing a conflict).

From observing the problem solving pathway, the authors identified that their participants (controls and frontal patients) used the perceptual strategy; this requires the use of subgoals in order to complete the task. Using this model to explain performance they concluded that failing the task was related to not being able to inhibit the temptation to stick to the principal goal, as opposed to putting the temporary and conflicting goal first.

Evidence for the use of subgoals has been supported in other research (Goel, Pullara, & Grafman, 2001; Handley et al., 2002a) and has identified the role of working memory in retaining these subgoals (Gilhooly et al., 2002; Zook et al., 2004). It seems that without the ability to construct goals and to follow goals that are counterintuitive to the end result, individuals are unable to succeed in the task. It follows that to keep all this information in mind working memory is an important variable in this equation.

Handley et al (2002a) investigated the role that working memory plays in the ToH. Their findings best fit a model which allows verbal and spatial factors to correlate but suggests that spatial working memory best predicts TOH performance. This is supported by Gilhooly et al (2002) in his work with the Tower of London (a similar but distinct assessment).

In the past the ToH was recognised as a test of implicit learning because observations have been made that amnesic participants who had no recollection of having seen the test showed evidence of learning over several trials (Handley, Capon, Copp, & Harper, 2002b). More recent research has questioned this however. For example, Winter et al (2001) and Xu & Corkin (2001) concluded that declarative rules can be used to complete this test that even amnesiac patients use. Despite this problem it appears to be the most suitable test available; in that on initial presentation a successful completion is difficult to verbalise or express explicitly and that first completion does not stop the test being a challenge on the second trial.

Despite the popularity of the ToH assessment a comprehensive literature search found no norms or specific methods for scoring the ToH. A suggested revision has been made by Ahonmiska et al (2000). They recognised that the test taps into a number of levels of executive functioning but that typically only one score is provided (time). Failure on the test could be due to poor planning or problems with inhibition or error correction or perseveration. They also explain that within a typical time score a lot of information could be missed (e.g. it does not discriminate between whether more time was spent before the task was begun or after). If less time was spent planning before the test is started it implies that either the individual is impulsive, or they are able to generate strategies quickly.

Ahonmiksa and colleagues focussed on the pause in time spent before the first, fifth and ninth moves in particular, which have been identified as being critical in the planning process (Welsh et al 1994). As well as this they investigated the utility of the measure of relative time scores (raw time scores divided by average move time). Their research suggested that the error patterns could reflect problem solving strategy impairments (like the RULIT and the WCST). They identified different kinds of errors which could be reflective of different processes, for example the self-correction score (when one disc was moved from one peg to another immediately), the almost performed move (when a disc was almost removed from a peg and then replaced) and the perseverative move (when a person repeated the same mistake at the beginning of a trial that they had done on the preceding trial). Errors made at the critical move were more serious as they had a bigger impact on the completion of the test; however their findings indicated that only the sum scores of serious errors correlated negatively with performance. They found that their relative time score correlated more with the achieved score than the raw planning time.

In order for the authors to conduct such a detailed scoring approach they used video equipment to record each individual's performance and were then able to go back over the tape to break the results down. Unfortunately this type of equipment was not available for this research and, as such, the two scores collected were the time to complete and the number of moves over trial one and two.

Methodology

Please refer to Chapter 3 for overall research design, methodology and information regarding the assessments completed.

Equipment Used

Tower of Hanoi

The ToH was purpose built by Remap for use by the Acquired Brain Injury Service. Remap are a nationwide registered charity who provide technical equipment for disabled people. This version was designed to be large enough so that it could be used by people with problems with fine motor control. Its dimensions are as follows:

Base Length:	45cm
Base Depth:	7cm
Peg height:	16cm
Disc 1 (Largest disc) Diameter:	14.2cm
Disc 2 diameter :	12.5cm
Disc 3 diameter:	10.7cm
Disc 4 diameter:	8.8cm
Disc 5 diameter:	6.9cm

7.1 Procedure

Participants had completed the neuropsychological battery as outlined in the research methodology chapter (Chapter 3, section 3.1.5) and were given instructions about the ToH (see Appendices 20).

Each participant was initially given the ToH task with three discs and, once the aims and rules were explained, they were asked to attempt the test. Once they had successfully completed this attempt (Trial One), they were asked to attempt to complete it again. If by the second administration (Trial Two) the participant had mastered the test in the minimum number of moves possible, another disc was added to the assessment. For this research each first attempt at a new level (i.e. three, four or five disc level) is classified as Trial One, the second attempt is Trial Two. The maximum number of discs was Five.

Scoring

Time in seconds to complete each trial and the number of moves to complete the trial were scored for each participant on both attempts.

7.2 Data Conceptualisation and Analysis

7.2.1 Trial One (Standard Trial)

Unlike Studies One and Two, which both had normative data for the Standard version of this assessment, the ToH has no means of assessing performance on the first trial by comparison to the 'Normal Population'. Whilst the cut-off for the Standard Versions of the WCST and the RULIT was the 16th Percentile, this study chose to apply a cut-off of one standard deviation above the mean of the population. This cut-off was chosen because the aim of the Standard tests in this research is to illustrate how participants' static performances are interpreted by comparing them to the 'Normal population'. As the average scores of this population are likely to reflect an impaired performance, compared to that of the general population, it was felt that one standard deviation above this mean would be more reflective of a 'normal' cut-off. Unfortunately a preliminary analysis of the data discovered that this cut-off would not be applicable for the 'Time Taken' measure. The range of time for each of the trials (three, four or five discs) produced a large number of outliers (for example the range in time to complete the TOH trial one with three discs ranged between 7 and 417 seconds – creating a standard deviation of 69 seconds, with a mean of 64 seconds. If this was the cut-off applied, then it would mean that to show improvement in performance, the test would have to be completed in less time (one standard deviation better than the mean of the population) and therefore that it would have to be completed in -5 seconds. An investigation into the reasons for such a high standard deviation indicated that 12 of the 62 participants had large enough scores to be skewing the data significantly. It was felt that these individuals could not be removed simply because they skew the data. These individuals represent one fifth of the sample and the large variance found in the measure was thought to be a reflection of its weakness as a measure of performance in discriminating abilities. A better alternative could have been to subdivide the measure of time taken prior to beginning and then the remainder of time spent.

This all suggests that the time taken to complete the ToH is clinically interesting but statistically meaningless due to high variance. As previous research has indicated that it is not unusual to employ only one measure for the ToH (Ahonmiska, Ahonen, Aro, & Lyytinen, 2000), a single measure was therefore used in the interpretation of the Standard ToH, i.e. 'Number of Moves'. One standard deviation above the mean of the population could be used for this measure, with one outlier that was skewing the mean and standard deviation scores removed for the four disc and two outliers removed from the five disc trial.

7.2.2 Trial Two (Latent Implicit Improvement)

Unlike Studies One and Two, this third study does not contain a training element that could interfere with the content and face validity of the test. This means that, if norms were available, a comparison could be made between time one and time two to see whether each individual improves their performance to cross the threshold between dysfunctional and functional performance; unfortunately, as previously mentioned, no norms are available for this population. The cut-off for the Standard ToH Rasch analysis (investigating performance on the first attempt for each level only and therefore not measuring the individuals' implicit improvement) was one standard deviation above the mean of the population. If the same methodology was to be applied to this study as was for Studies One and Two then the one standard deviation cut-off should be used for the second trial. Because this third study does not use a training element, however, there is no risk of altering the structure of the test, e.g. construct or face validity. As a result it is possible to focus more on levels of individual improvement. To assess whether any improvement was significant (both clinically and statistically) the reliable change method was used for measuring improvement of performance over test occasion (see Chapter 2, section, 2.2.4 for more detail on reliable change). Being able to focus on individual improvement, as opposed to looking at group means and group standard deviations, meant that for this version of the ToH it was again possible to include the measure 'Time Taken'. Each participant's scores at Trial One and Two would be compared and examined in relation to the reliable change cut-off to determine if enough change had occurred for it to be clinically and statistically significant.

As discussed previously (see section 2.2.4) one of the flaws of reliable change is that it fails to take into account a ceiling effect. To overcome this, the ceiling was taken into consideration when categorising the data. This meant that, instead of the data being dichotomous, three categories were created (those who did not meet the reliable change index, those who did – and therefore had statistically improved, and those who could not statistically improve because they were performing too well at time one – see Appendices 21 for calculations). The data was scored according to these categories with the same style of coding as is used for the dichotomous Rasch (e.g. 0 is lower than 1 and 1 is lower than 2; i.e. 0 is no change, 1 is change and 2 is could not change).

As with the previous two studies, adding a second trial to this assessment was expected to elicit a different measure of learning ability. For the Studies One and

Two the addition of a training element was expected to create a measure of learning potential as opposed to individual or actualised learning measured by the Standard test. In this study it is assumed that the first trial of the ToH provides a measure of Implicit learning, but that this second measure provides a reflection of the individual's 'Latent Implicit Learning Ability'.

Once again it is important to clarify how the individuals will be labelled. As this test does not involve any dynamic training intervention it is not felt appropriate to label those individuals in the Latent Implicit trial who are placed in the middle of the hierarchical map as Guided Learners. As they have shown some evidence of reaching a clinically and statistically significant change for some of the items they will be categorised as Learners. Those who have shown a clinically and statistically significant change for all or the majority of the items will be labelled Spontaneous Learners and those who do not show change on any item will be labelled Non Learners. These three labels will also be applied to the Standard ToH version.

7.3 Results

See Chapter 4 section 4.2 for a detailed description of the primary analysis.

7.3.1 Part One of the Data Analysis: Rasch for the Standard and Latent Implicit ToH

As discussed previously in this Chapter, performance on Trial One for the ToH will be measured using the cut-off at one standard deviation above the mean of the population. This cut-off was applied only to the 'Number of Moves' variable as there were problems with variance within the 'Time Taken' variable (please refer to section 7.2.1 for further information).

Having applied the one standard deviation cut-off to the participants' performance for Trial One of the ToH, this information was applied to the Rasch Model and the item map created has been included in Figure 29.

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Figure 29: Item Map Representing the Hierarchy of Difficulty for a Standard ToH Administration using the Cut-off One Standard Deviation above the Mean of the Population

It was expected that with only three items included in this Standard ToH assessment there would be considerable clustering in participant performance. It is also not a surprise that the three disc trial was found to be the easiest and the five disc trial the hardest. This item map indicates that ten people had a 75% chance of passing the five disc trial according to the one standard deviation above the mean cut-off (this is indicated as the participants, who are represented as Xs on the right of the map, are plotted above the five disc item on the left of the map, those below have a 25% chance of passing the item). Thirty one people from the sample had a 75% chance of passing the four disc trial (the group above the four disc item on the map, but below the five disc item). Seventeen participants were plotted as having a 75 % chance of passing the easiest item but only a 25% chance of passing the next item. Only five of the individuals had a 25% chance of passing the easiest item.

This type of hierarchy creates considerable grouping around the middle with minimum numbers of individuals falling at the bottom and top of the map. This suggests that the Standard ToH using one standard deviation above the mean of the population as a cut-off may not be sensitive enough to separate out individuals. This will be examined shortly. In order to compare this hierarchical distribution, it is necessary to categorise the participants into learner status groups. This item map creates some difficulty in deciding how to group the participants, principally because there is so much grouping in the middle of the map. If the map was split with Non Learners not passing the easiest item (as was used with the other studies) this would result in a limited number of Non Learners (five participants), with the vast majority of participants being classified as Learners (48). Figure 29 indicates that this model was not sensitive enough and that the cut-off was too easy for all but five of the participants. Therefore, a decision was made to raise the separating point to a logit score of 50, which includes the cluster of individuals who still showed a 25% chance of passing the next item but who were likely to pass the first item. It is understood that changing this cut-off has implications in terms of consistency between the tests. However this problem was not created by the other standard tests, suggesting it is not as easy, therefore the only option was to either change the one standard deviation cut-off or change the cut-off on the map. Other alternatives were considered (e.g. using the minimum number of moves as a cut-off, although this created the same dilemma but in reverse (only four Spontaneous Learners were created- see Appendices 23).

The next analysis investigated the fit and error of the items of the Standard ToH and is represented in Figure 30. The Logit scale is plotted on the Y axis and the Infit scale along the X axis. The error of each item is represented as the size of the item.

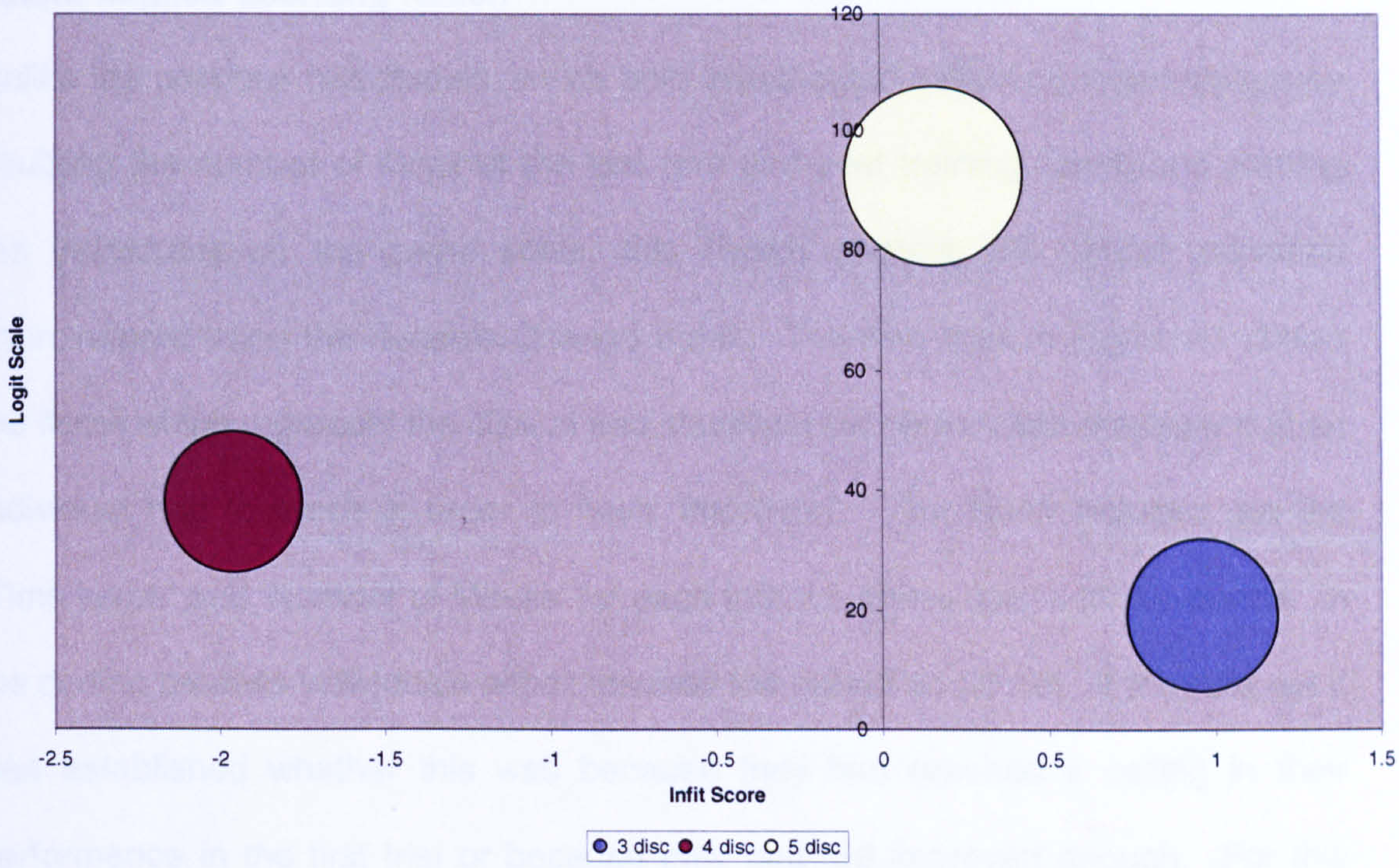


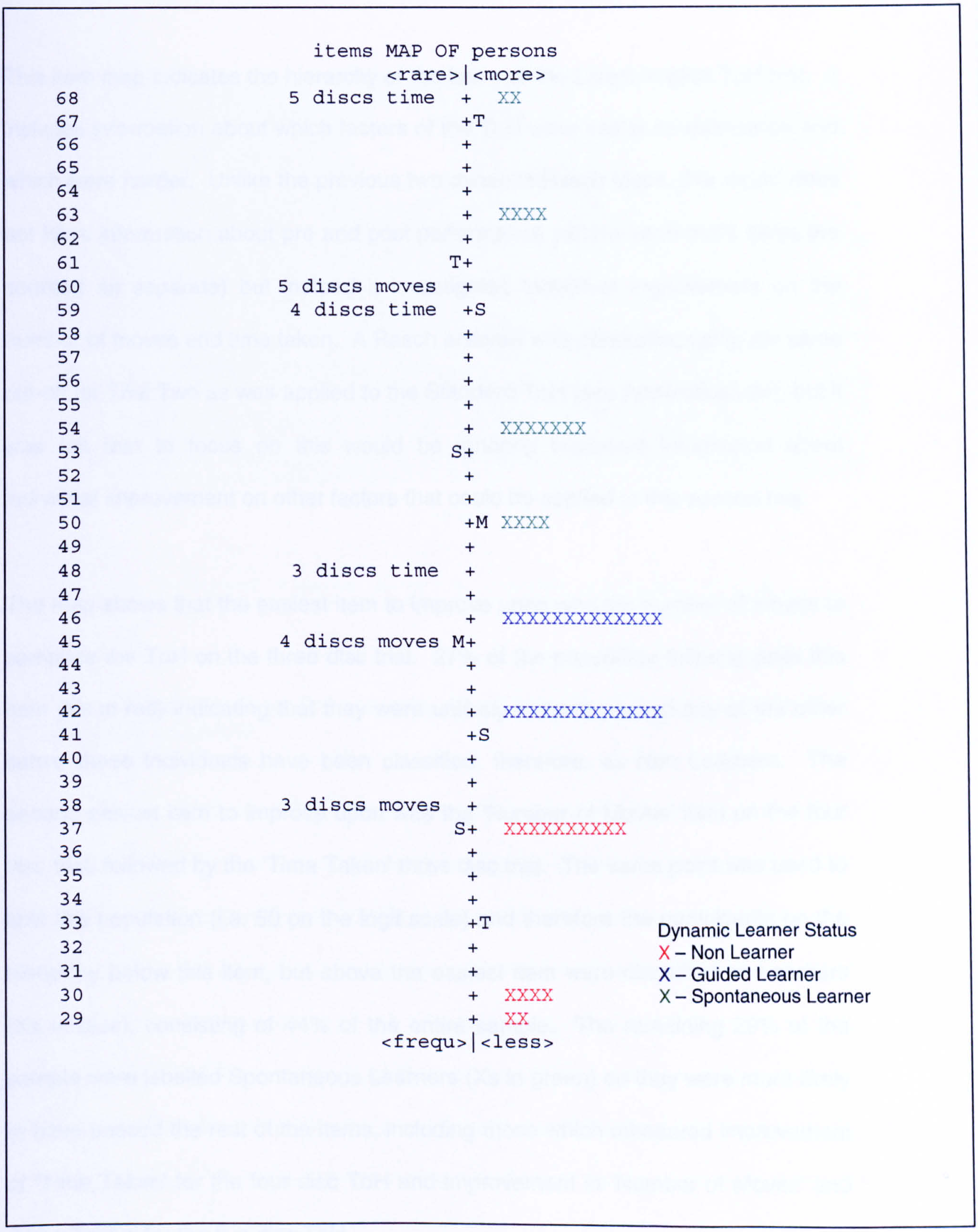
Figure 30: A Bubble Chart Representing the Rasch Model for the Standard ToH Administration One Standard Deviation above the Mean as the Cut-Off

This chart indicates that the three items of the ToH test all belong to the same unidimensional construct. All the items have a relatively comparative error size, indicating that they have an equivalent variance in predicted difficulty.

Figure 29 indicated that the items of the ToH created some clustering of participants. This is confirmed by the Real Person Separation Score of 0, which indicates that this model does not have an adequate ability to create a spread in the participants who completed the test. It is likely that the Real Person Separation Score was inadequate because there was an unbalanced ratio of items to participants. The Real Item Separation Score was 5.16, indicating that the items of the ToH were spread adequately throughout the map, which is understandable as there were only three items and they had no overlap in error.

Latent Implicit Learning Rasch

Unlike the previous two studies, which both investigated individual improvement by doubling the number of items of the test (pre and post training items) and plotting the individuals on the same scale, this Rasch analysis will reflect individual improvement using the Reliable Change Index. The item map in Figure 31 shows the items which represent the clinical and statistical cut-off for each measure that an individual had to reach in order to have 'improved'. The items included are the 'Time taken' and 'Number of Moves' for each trial (i.e. three, four and five discs). In the coding process individuals either reached the cut-off or did not. If they did not it was established whether this was because they had reached a ceiling in their performance in the first trial or because they had not improved enough. For this Rasch model, the coding process was therefore not dichotomous, but included three codes.



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 60                  5 discs moves   +
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 58                                  +
 57                                  +
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 49                                  +
 48                   3 discs time   +
 47                                  +
 46                                  +  XXXXXXXXXXXXX
 45                  4 discs moves  M+
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 42                                  +  XXXXXXXXXXXXX
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Dynamic Learner Status
X – Non Learner
X – Guided Learner
X – Spontaneous Learner

Figure 31: Item Map Representing the Hierarchy of Difficulty for the Items of the Latent Implicit ToH (Both Measures of Reliable Change for Number of Moves and Time)

This item map indicates the hierarchy of the items of the Latent Implicit ToH test. It includes information about which factors of the ToH were easier to improve on and which were harder. Unlike the previous two dynamic Rasch Maps, this model does not have information about pre and post performance (where each trial's items are counted as separate) but instead it investigates individual improvement on the number of moves and time taken. A Rasch analysis was conducted using the same cut-off for Trial Two as was applied to the Standard ToH (see Appendices 24), but it was felt that to focus on this would be ignoring important information about individual improvement on other factors that could be applied to this second trial.

The map shows that the easiest item to improve upon was the number of moves to complete the ToH on the three disc trial. 27% of the population failed to pass this item (Xs in red) indicating that they were unlikely to have passed any of the other items; these individuals have been classified, therefore, as Non Learners. The second easiest item to improve upon was the 'Number of Moves' item on the four disc trial, followed by the 'Time Taken' three disc trial. The same point was used to split this population (i.e. 50 on the logit scale) and therefore the participants on the hierarchy below this item, but above the easiest item were classified as Learners (Xs in blue), consisting of 44% of the entire sample. The remaining 29% of the sample were labelled Spontaneous Learners (Xs in green) as they were more likely to have passed the rest of the items, including those which measured improvement of 'Time Taken' for the four disc ToH and improvement in 'Number of Moves' and 'Time Taken' for the five disc ToH.

The Bubble chart below (Figure 32) is a visual representation of the misfit and error data for the implicit learning ToH test.

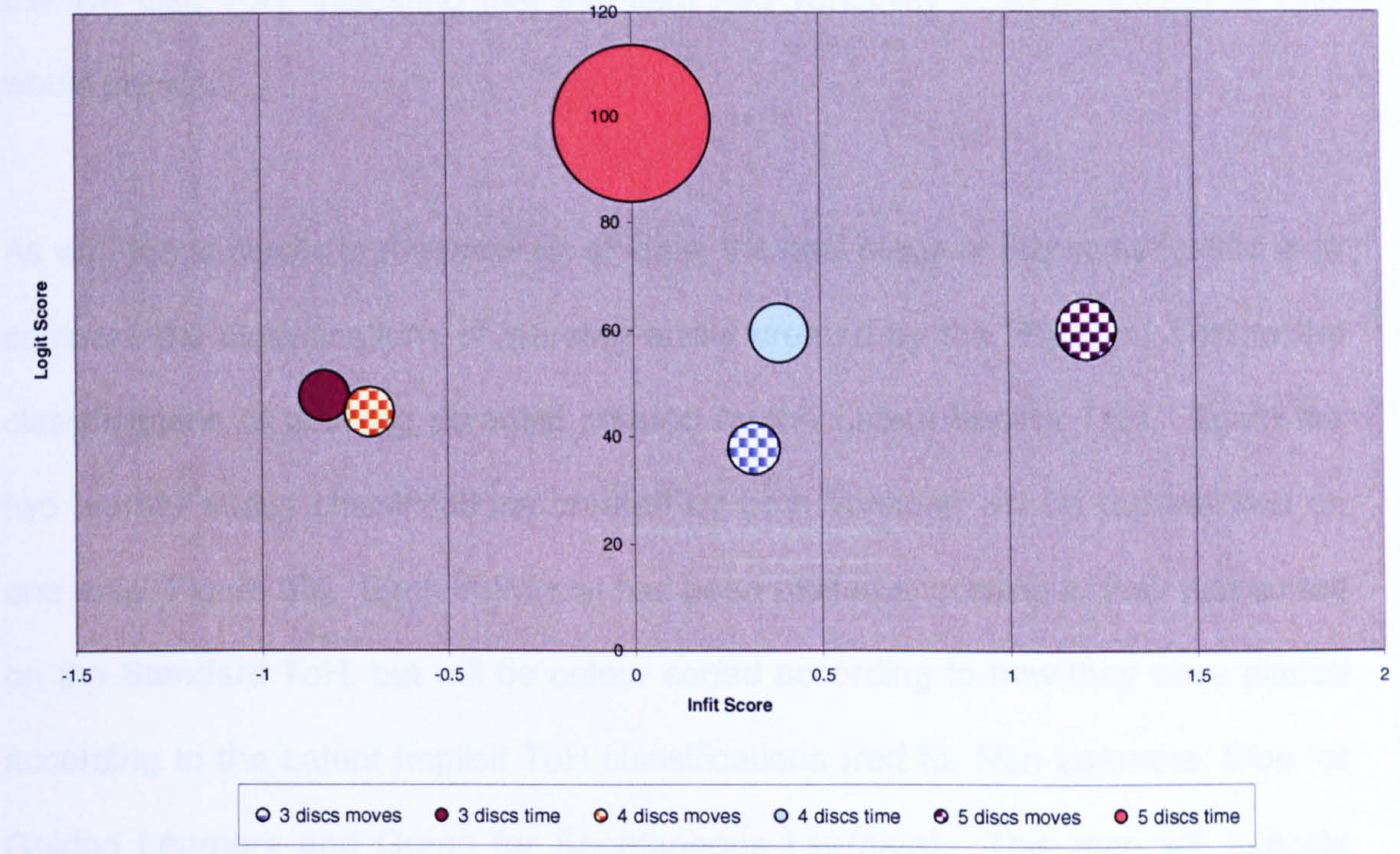

Figure 32: A Bubble Chart Representing the Rasch Model for the Implicit ToH Using RCI as a Cut-Off

An analysis of misfit data (Figure 32) concluded that all of the items of the ToH ('Time Taken' and 'Number of Moves') belonged to the same unidimensional construct, indicating that improvements in both of these measures reflect the same underlying ability. A possible interpretation of these results is that including both of these measures is unnecessary. An alternative explanation could be that both measures tap into different aspects of the same construct; one possibility is that the measure of improvement in the time taken reflects speed of information processing, and the measure of improvement in the number of moves taps into abstract reasoning or perhaps goal neglect.

Of the items included in Figure 32, all showed a relatively small amount of error with the exception of the item which measures improvement of time taken to complete the five disc ToH, indicating that this item had variability in its prediction of who would pass it.

As with the analyses in the previous studies, the next stage of this investigation is to compare the classifications of learning ability created by the Standard ToH to the classifications of learning potential created by the Latent Implicit ToH. Again the two learner status classifications created by both versions will be represented on one map (Figure 33). Each individual has been plotted according to their placement on the Standard ToH, but will be colour coded according to how they were placed according to the Latent Implicit ToH classifications (red for Non Learners, Blue for Guided Learners and Green for Spontaneous Learners). This map will indicate what consistencies and inconsistencies there are between the two classifications.

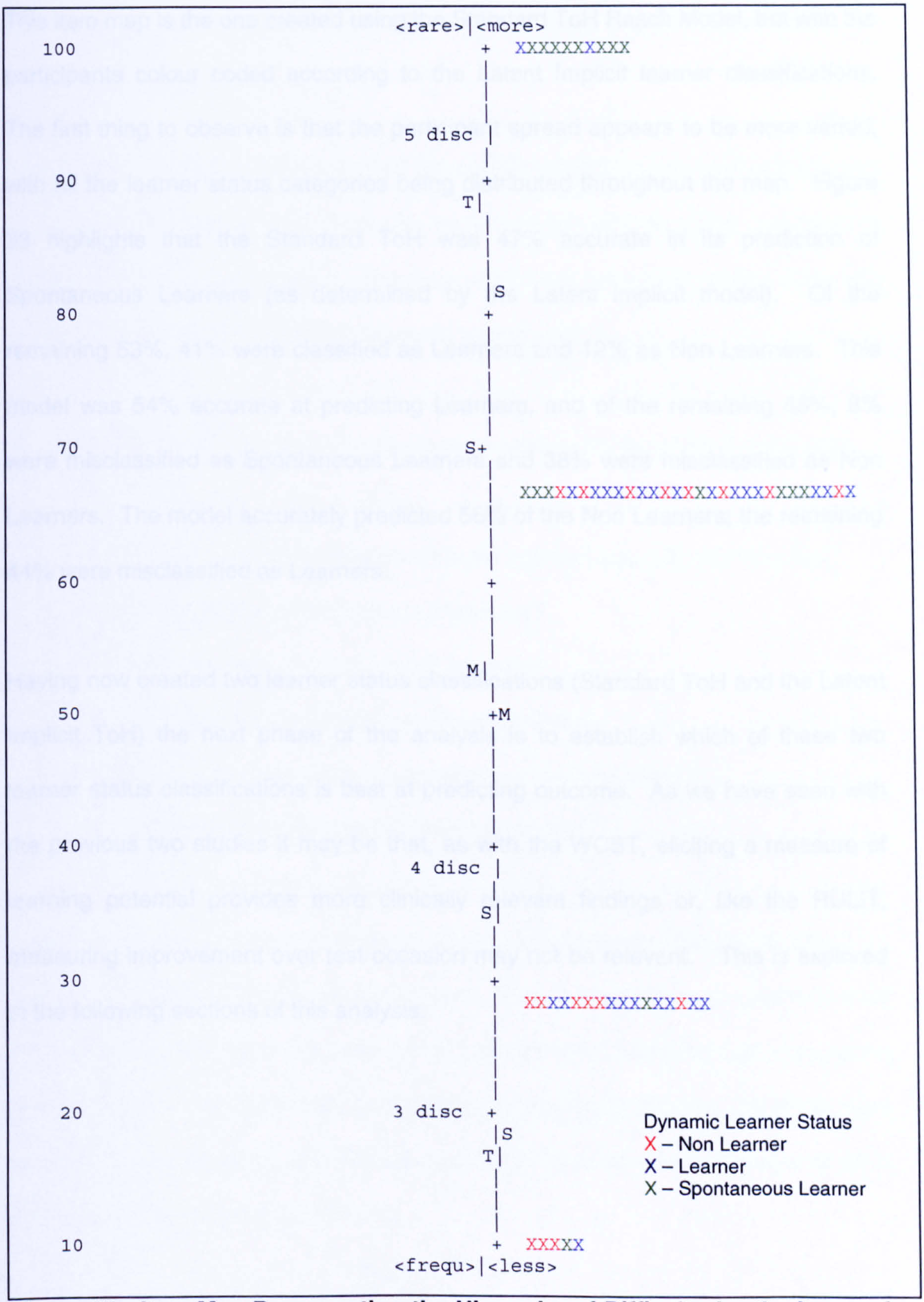

Figure 33: Item Map Representing the Hierarchy of Difficulty for the Items of the Standard ToH with Participants Colour Coded To the Latent Implicit Learner Status

This item map is the one created using the Standard ToH Rasch Model, but with the participants colour coded according to the Latent Implicit learner classifications. The first thing to observe is that the participant spread appears to be more varied, with all the learner status categories being distributed throughout the map. Figure 33 highlights that the Standard ToH was 47% accurate in its prediction of Spontaneous Learners (as determined by the Latent implicit model). Of the remaining 53%, 41% were classified as Learners and 12% as Non Learners. This model was 54% accurate at predicting Learners, and of the remaining 46%, 8% were misclassified as Spontaneous Learners and 38% were misclassified as Non Learners. The model accurately predicted 56% of the Non Learners; the remaining 44% were misclassified as Learners.

Having now created two learner status classifications (Standard ToH and the Latent Implicit ToH) the next phase of the analysis is to establish which of these two learner status classifications is best at predicting outcome. As we have seen with the previous two studies it may be that, as with the WCST, eliciting a measure of learning potential provides more clinically relevant findings or, like the RULIT, measuring improvement over test occasion may not be relevant. This is explored in the following sections of this analysis.

7.3.2 Traditional Statistical Analyses: the Latent Implicit ToH Investigation

Having established the Latent Implicit learner classifications the next section aims to explore what factors may determine an individual's learner status and whether learner status impacts outcome. These investigations have been broken down into research questions which will be answered individually.

As with studies one and two, these research questions will be applied to the data

1. To what extent do people with brain injuries have difficulty learning?
2. Does intellectual ability impact learning?
3. Does Severity of Injury impact learning?
4. Does age have an impact on learning ability?
5. Does time since injury have an impact learning ability?
6. What impact does learning have on outcome?

Question 1: To what extent do people with brain injuries have difficulty learning?
Table 17 indicates that of the 59 participants, 16 of them (27%) were unable to pass the RCI cut-off for any of the items of the Latent Implicit Learning ToH, suggesting they could not reach a clinically and statistically significant change. 26 (44%) were able to improve on some of the items, and 17 (29%) were able to improve on all of the items of the Latent implicit ToH.

	Count	*Percentage*
Non learner	16	27
Learner	26	44
Spontaneous Learner	17	29

Table 17: Number and Percentage of Participants in Each Learner Status Category, As Identified By the Latent Implicit ToH Rasch Map

Question 2: Does intellectual ability impact learning?

As with the previous studies, the main effect of the learner status classification was tested for significant differences with measures of pre-injury and current IQ as the dependent variables. Pre-injury functioning was estimated using the Vanderploeg's (1995) algorithm and current IQ was measured using the WAIS or WASI FSIQ score.

Pre-injury IQ

The analysis of variance found no significant main effect of learner status with pre-injury IQ as the dependent variable (F(2,52)=0.55, p=0.58), indicating that pre-injury intellectual ability might not play a role in determining learner status as defined by the Latent Implicit learning ToH model. It is worth noting that power may have been a factor here as the numbers for the Non Learners and Spontaneous Learners were lower than preferred.

Current IQ

The ANOVA for the current IQ yielded a significant F ratio; F(2, 47)=4.99, p=0.01. A post hoc analysis, using the Scheffe F Test, found significant differences between Non Learners (mean=85.69, sd=14.85) and Spontaneous Learners (mean=102.07, sd=12.52) (p=0.02) and also between Learners (mean=89.27, sd=16.20) and Spontaneous Learners (p=0.05). This indicates that IQ would be able to separate

Spontaneous Learners from Learners and Spontaneous Learners from Non Learners but is not sensitive enough to separate Non Learners from Learners; the reasons for this will be explored in the discussion section.

From these investigations it seems that current intellectual functioning does have an impact on Latent Implicit Learning, with a higher IQ correlating with more evidence of implicit learning potential. Pre-injury IQ does not appear to be related to this learning classification.

Question 3: Does Severity of Injury impact learning?

An ANOVA testing for overall difference between learner status and severity of injury found no significant main effect (F(2, 38)=2.63, p=0.09), but, once again power criteria were not met as there were low numbers for the Spontaneous Learner and Non Learner groups (see Appendices 25 for means of ANOVAs).

As the numbers for this ANOVA were particularly low (N=38) a Chi Square goodness-of-fit was performed to determine whether severity of injury was equally distributed amongst the three levels of learning. Using descriptions of injury made at referral, individuals were also categorised into severe (e.g. unresponsive, eyes not opening and non vocalising) or mild/moderate injury (awake but confused etc.). The analysis with Yates correction identified that there was an equal distribution and was therefore not significant $\chi^2 = 3.24$ (df=2) (p=0.20). The distribution amongst Learner Classifications has been summarised in Table 18.

	Non Learner	*Learner*	*Spontaneous Learner*
Severe Brain Injury	6	14	4
Mild/Moderate Brain Injury	8	10	10

Table 18: Frequency of Participants Found In Each ToH Implicit Learner Category Separated By Severity of Injury According To GCS Categories

This analysis suggests that the ANOVA was not significant for reasons other than power criteria not being met and, interestingly, suggests that Latent Implicit Learning Potential is not related to severity of injury.

Question 4: Does age have an impact on learning ability?

To answer this question two measures of age were investigated, both age when injury was acquired and age at time of testing. The ANOVA comparing the mean age at injury was not significant (F(2,55)=0.39, p=0.68), nor was the ANOVA comparing mean age at time of testing (F(2,44)=. 1.22, p=0.30). This indicates that age does not have an impact on implicit learning potential.

Question 5: Does time since injury have an impact on learning ability?

An ANOVA was conducted to investigate whether the stage that someone was in their recovery, i.e. the time since their injury, has an impact on their learning ability. An analysis of variance was conducted, which yielded a non significant F ratio, F(2,45)= 0.61, p=0.55

This finding is likely to have been affected by a low N but follows the non significant pattern which has been reflected in the other studies in connection to the relationship between time since injury and learning ability. It suggests that there is no relationship between the time since a person's injury and their latent implicit learning potential.

Question 6: What impact does learning have on outcome?

Once again the CIQ was used to reflect outcome and separate ANOVAs were completed for pre-injury and current community integration levels as well as one measuring the amount of change in community integration levels following acquired brain injury.

Pre-injury Community Integration

As with Study One and Two this ANOVA was not significant; (F(8, 98)=1.65, p=0.12) suggesting that Latent Implicit Learning on the ToH is not related to pre-injury levels of community integration. Again this is intuitive because performance on the ToH is likely to be different to how it would have been prior to the brain injury and therefore even if there was a strong relationship between current Community Integration and ToH performance, current ToH performance would not be related to pre-injury CIQ.

Current Community Integration

The ANOVA investigating the impact of latent implicit learning potential on recovery levels yielded a significant F ratio of F(8, 98)=2.151, p=0.04. The scores have been illustrated on Figure 34. Interestingly the only significant difference that the post hoc Scheffe analyses identified was on the Productive Activity scale between Learners (mean=2.88, sd=2.13) and Spontaneous Learners (mean=4.93, sd=1.69) (p= 0.01). The results for this ANOVA suggest the Latent Implicit ToH has relatively weak predictive ability in comparison to that of the Dynamic WCST in Study One, and the possible reasons for this result will be explored in more detail in the discussion section of Study Four (Chapter 8, section 8.4).

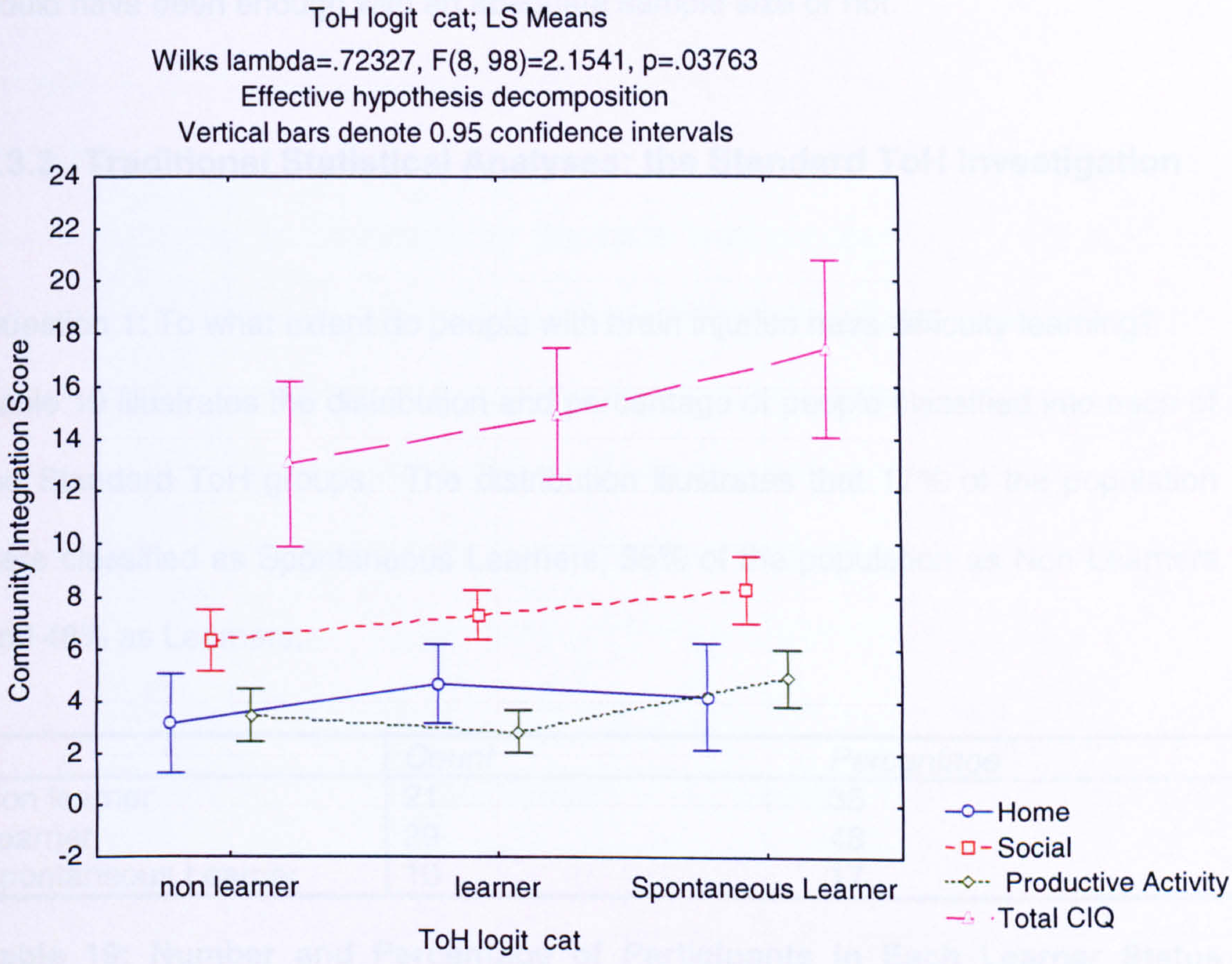

Figure 34: ANOVA for the Latent Implicit ToH Learner Status Groups and Levels of Community Integration

Difference between Current and Pre-injury Community Integration

The ANOVA measuring change in levels of community integration between learner status groups following an acquired brain injury was not significant; F(8, 98)=1.74, p=.10 indicating that the Latent Implicit ToH could not predict changes in levels of community integration following an ABI. Again, it is worth mentioning that numbers for Learners and Spontaneous Learners were lower than the power criterion demands and that the chance of this being a Type II error means that this interpretation is tentative. A cursory look at the differences in mean scores across learner classifications identified that the biggest difference between groups was less than two points for each subscale. It is still uncertain as to whether this difference would have been enough with an adequate sample size or not.

7.3.3 Traditional Statistical Analyses: the Standard ToH Investigation

Question 1: To what extent do people with brain injuries have difficulty learning?

Table 19 illustrates the distribution and percentage of people classified into each of the Standard ToH groups. The distribution illustrates that 17% of the population were classified as Spontaneous Learners, 35% of the population as Non Learners and 48% as Learners.

	Count	*Percentage*
Non learner	21	35
Learner	29	48
Spontaneous Learner	10	17

Table 19: Number and Percentage of Participants in Each Learner Status Category, As Identified By the Standard ToH Rasch Map

Question 2: To what extent do people with brain injuries have difficulty learning?

Pre-Injury IQ

Like the Latent Implicit ToH ANOVA, which found no significant main effect of learner status on pre-injury IQ, this ANOVA found no significant main effect of the Standard ToH learner status on pre-injury intellectual ability (F(2,55)=1.89, p=0.16).

Current IQ

Unlike the ANOVA for Latent Implicit Learner classifications and current IQ, this ANOVA was not significant (F(2,50)=2.48,p=0.09). This indicates that Latent implicit learning potential is influenced by intelligence but the implicit learning as measured by the Standard ToH performance is not.

Question 3: Does severity of Injury impact learning?

The ANOVA investigating the main effect of the Standard ToH learner status and severity of injury as measured by the GCS was not significant (F(2,38)=2.53, p=0.09). This again could have been influenced by a low N, so a Chi Square was used to classify the severity of injury. The analysis, with Yates correction, identified that there was an equal distribution and was therefore not significantly different between groups χ^2= 2.65 (df=2) (p=0.27). The distribution has been outlined in Table 20.

	Non Learner	*Learner*	*Spontaneous Learner*
Severe Brain Injury	11	11	3
Mild/Moderate Brain Injury	7	18	5

Table 20: Frequency of Individuals According To Standard ToH Learner Status and Severity

Again this indicates that severity of injury does not impact learning ability as defined by the Standard ToH.

Question 4: Does age have an impact on learning ability?

The analysis of variance investigating the main effect of learner status on the variable 'age at onset' found no significant difference between learner groups (F(2,58)=0.6, p=0.54). The ANOVA investigating age at time of testing was also not significant (F(2,47)=0.91, p=0.41). These findings suggest that age (either current or when the injury occurred) does not have an impact on learning ability as determined by the Standard ToH.

Question 5: Does time since injury have an impact on learning ability?

As with the Implicit learner status group the Standard ToH ANOVA for time since injury was not significant (F(2,48)= 0.56, p= 0.55) and suggests the time since injury is not related to implicit learning ability.

Question 6: What impact does learning have on outcome?

Pre-Injury Integration

Again this pre-injury ANOVA was not significant (F(8,106)=0.86, p=0.55). This finding suggests that current learning ability as identified by the Standard ToH is not related to pre-injury levels of community integration.

Current Community Integration

The ANOVA comparing the current Community Integration levels between standard ToH learner groups, was not significant, (F(8,106)=1.95, p=0.06). This is unlike the ANOVA that investigated the current community integration levels between the Latent Implicit learner status groups, which suggests that the Latent Implicit model is a more ecologically valid tool.

Difference between Current and Pre-Injury Community Integration

The ANOVA comparing change in levels of community integration after injury with the Standard ToH learner groups was also not significant (F(8,106)=1.27, p=0.26). As the Latent Implicit learner status group ANOVA was also not significant this indicates that the skills the test requires are not sensitive to measuring change in integration (regardless of whether the test is measuring the static or implicit learning skills).

7.4 Discussion

The first, and most obvious, observation to make from this study is that the Standard ToH analysis found no significant relationship with any of the variables investigated. There are several reasons that could be seen to contribute towards this finding. The first is that the ToH could be a weak tool for classifying learning ability and so, whereas in the previous studies learner status was able to discriminate between different factors known to relate to outcome, these classifications were not. The second possibility is that the tool is adequate but that the cut-off that was applied was too low and therefore was too easy for people to pass. The third potential contributing reason for the Standard ToH appearing to be a weak tool is that the criteria that were applied to the other studies for classifying learner states (e.g. a Non Learner is someone who does not reach the cut-off for any of the items) were not applied to this one. For this study the cut-off for Non Learners was raised to make the distribution more evenly spread, and perhaps this influenced the non significant findings (e.g. individuals who perhaps would have been classified as Learners were classified as Non Learners). A fourth reason is that there were only three measures included in the Rasch map and an inadequate spread of participants. These three items were well spread out themselves but they created a great deal of clustering of the participants. This meant that groups of people were plotted together who perhaps would have been spread further apart if there had been more items. A fifth reason is that, despite changing the cut-off to create a better spread, the distribution still resulted in one group only having ten people in it. This obviously affects power and means that the group needed 11 more people to reach the predetermined criteria. All in all this appears to be an ineffective measure of learning ability, but this is more likely to be affected by the criteria that were applied to the ToH as opposed to the ToH itself.

With regard to the hierarchy of items that belong to the Standard ToH the order is logical, the trial with the least number of discs was shown to be the easiest to pass the cut-off for followed by the trial with four then five discs. Only 5 people could not meet cut-off for the three disc trial, a further 17 people could not meet criteria for the four disc trial and 31 could not meet cut-off for the five disc trial. Only ten people passed the cut-off for the five disc trial of the Standard ToH.

This distribution does not create much separation among the individuals' performance (with only five people at the bottom of the map, ten at the top and everyone else in between). This is not just a reflection of the cut-off being inappropriate, but also having only three items in the test.

Creating the different criteria for classifying learners (i.e. at the 50th logit scale) included more people (22 in total) with 31 people as classified as Learners and ten as Spontaneous Learners. This is the best spread that could have been created but it is not ideal and does not create a good separation for the participants. This is reflected in the Real Person Separation Score of 0, which indicates that the model does not have adequate ability to separate out performance of individuals. This could also explain why the three test items (three, four, and five discs) all have a relatively large error score, suggesting that they had an equal but large zone of imprecision in predicting their place on the hierarchical scale.

These measures could be interpreted as indicating that when using the Tower of Hanoi as standard (and without Norms) using one measure only (as Ahonmiska et al (2000) reports occurs frequently) is not all that meaningful clinically. A better option would be to provide another measure that could be included, such as time taken. This was the original plan for this research but, as discussed in the results section (section 7.2.1), a preview of the distribution of the time taken amongst the sample, and of the means and standard deviations for each trial of the ToH (for the three, four and five disc trials) suggested that if the cut-off of one standard deviation was applied it would be so high that in order to improve you would have to complete the test in -5 seconds. This ruled out everyone. To make the standard deviation meaningful 12 outliers would have to be removed. This was felt unreasonable as it is often commented that the outliers are often the most interesting (Ahonmiska et al., 2000). Whilst it is the practice of this research to recognise anyone over three standard deviations from the mean as an outlier (section 4.2) it was felt that removing so many people was not clinically meaningful, as they represent approximately one fifth of the sample. It was therefore decided that using the time taken as a crude measure would not be clinically meaningful.

The Latent Implicit TOH created a much better spread; this is likely to have been influenced by it having twice as many items. Another benefit of this version was that the criteria for defining learner status could be reinstated here (i.e. a Non Learner is one that falls below the easiest item, a Learner is someone that falls between the first item and 50 on the logit scale and a Spontaneous Learner is anyone plotted above 50 on the scale).

Adding a second trial for the test meant that it was possible to measure individual improvement using the Reliable Change Index. This measured the improvement that each participant made, taking into consideration the standard error of measurement of the test. Because this method was utilised it was possible to then consider the number of moves as well as the time taken. Section 7.2.2 outlines the data conceptualisation of the Latent Implicit Learning ToH study.

The reliable change scores for the 'Time Taken' and 'Number of Moves' items created an interesting hierarchy. The easiest item to reach a clinically and statistically meaningful change score for was the 'Number of Moves' item for the three disc trial, followed by the four disc trial 'Number of Moves' item. The next item on the hierarchy was the 'Time Taken' for the three disc trial, followed by the four disc trial 'Time Taken' item. This implies that it is harder to improve on the time taken to complete a trial, as opposed to the number of moves taken to complete a trial. This finding was initially surprising as it was anticipated that improving on the time spent on the task would be the easier of the two. It is possible that the time taken to complete a trial more accurately reflects a planning element than the number of moves. Therefore, as planning is still required on the second trial, it is harder to improve enough on this measure to reach the cut-off. Perhaps a better measure would have been to observe time spent prior to the test (planning) and time spent during the test (problem solving).

An investigation of fit found that all the items belonged to the same construct. This implies that the measures of time taken to complete the test and the number of moves belong to the same unidimensional construct. The measures of error were all comparable, with the exception of the item measuring the improvement in moves for the five disc trial. This suggests that there was a larger zone of imprecision with regard to predicting placement on the hierarchical scale, indicating that either more or less of the participants who were expected to reach this cut-off did.

Figure 33 shows the distribution of the Latent Implicit Learner classifications plotted according to the hierarchy of the Standard TOH item map. This figure shows that the individual classifications between tests are very different. There was only a 47% consistency in predicting those who were Spontaneous Learners; a 54% consistency in identifying Learners and a 56% consistency in identifying Non Learners.

Having identified that both item maps create quite a different spread in performance it was then necessary to establish which is better in predicting outcome. This is easy to answer as the Standard ToH found no significant relationships with any of the variables for any of the questions asked, indicating that the learner status classifications were not significantly related to any of the factors known to influence outcome following ABI. Therefore, by default the Latent Implicit ToH learner status classifications appear to be the better of the two.

An interesting finding for the relationship between learner status and current IQ was that a significant main effect was only found for the Latent Implicit learner status, indicating that the performance on the Standard ToH was not affected by current IQ. An investigation into the means, however, observed that the distribution amongst learner groups followed a similar trend to the previous studies (with the High Scorer groups having a higher IQ than the Learners, who in turn had a higher IQ than the Non Learners). It is possible that that this is a Type II error caused by inadequate power. An alternative explanation is that adding a second trial allows the individual to use their intellectual abilities to improve their performance, whereas the initial trial is one of guess work and trial and error. The measure of improvement could therefore allow them the opportunity to learn from their mistakes. This is an interesting hypothesis particularly as the ToH is thought to be a measure of implicit ability and research has found that the implicit learning system does not deal well with errors. It is surprising that so large a proportion of the sample showed evidence of improving over only two trials, which could be seen as evidence of the involvement of the declarative system proposed by Winter et al (2001) and Xu & Corkin (2001).

It was interesting to see that neither of the ToH measures were significantly related to severity of injury. If this finding is valid it implies that whatever the ToH is measuring (either implicit improvement on frontal tasks or frontal functioning) is not determined by the severity of the injury.

Neither the Latent Implicit nor the Standard ToH was significantly related to pre-injury community integration. Once again, this is not unexpected as it implies the performance on either test was not related to how an individual was integrated into the community prior to their injury.

Only the Latent Implicit ToH was significantly related to current community function. The post hoc analysis revealed that the only significant difference was with the Productive Activity scale, where Learners were significantly less integrated than the Spontaneous Learner group. This is an unusual finding for this research and it is uncertain how to interpret it. It suggests that Learners (those who improve on some of the items of the ToH but not all) have the lowest productive activity levels (lower than Non Learners and Spontaneous Learners) and are therefore less involved in activities such as education and employment than the other groups.

Neither the Latent Implicit nor the Standard ToH learner classifications were significantly related to the degree of change in community integration levels. This is likely to reflect the fact that pre-injury there was no difference between groups on the community integration scores and that post-injury there was only a change in certain scores, e.g. productive activity and total CIQ. This meant that overall there would only have been an obvious change for CIQ Total and perhaps Productive Activity, with perhaps the largest change being evident for Non Learners and the lowest change for Spontaneous Learners. This would not have been a big enough difference for it to be significant.

In conclusion, the Tower of Hanoi test has not been found to be a good measure of clinically meaningful learning ability. The factors that have contributed to this have been related to the lack of normative data available, and subsequently the problems of choosing appropriate cut-offs to separate performance. For the Standard ToH this difficulty was exacerbated by a huge variance of performance creating such a high standard deviation. This meant it was impossible to include one of the measures ('Time Taken'). This had a knock on effect as it reduced the number of items in the Rasch map and made the spread of participants inadequate. For the Latent Implicit ToH it was fortunate that the reliable change index could be used for both the time and moves items, but this prevented an investigation into the first and second trials to see whether they had the same properties. Although the Latent Implicit ToH was found to relate to Community Integration, the post hoc analysis only found a significant difference between the Learners and Spontaneous Learners on the Productive Activity scale. This is unusual and it is unclear at this stage what would be contributing to this fact.

Having completed the individual investigations into each of the three studies, and into the comparison between the Standard and Dynamic/Latent Implicit measures of improvement, the next stage of this investigation will be to compare each of these three studies with each other.

Chapter 8 : Study Four: Comparative Investigation of the Classifications of Learning and the Clinical Utility of Learning Potential

Each of the previous three studies explored whether adding a dynamic element to a test of executive function added to our understanding of recovery following acquired brain injury. Study One concluded that using dynamic training utilising the Verbal Learning system was more useful than the static standard assessment. Study Two found that using dynamic training on a test which focuses on the Visuospatial Learning system was not more useful than the original Standard RULIT assessment. Study Three concluded that adding a second trial to a test of implicit learning, and therefore measuring Latent Implicit Learning Potential, was more helpful than the one off standard assessment.

The intention of this final part of the investigation is to compare the findings of the previous three studies. Attention has been paid to the significant and non-significant relationships that were found for each of the learner status categories created. To assist in the exploration of the results, a summary table (Table 21) has been created to provide a précis of all the significant findings of the standard and dynamic or implicit versions of the three tests. In Table 21, the post hoc analyses for ANOVAs were included with the significant differences between the groups highlighted in grey.

The first section of this chapter examines the results of the summary table, exploring similarities and differences that the Rasch models produced according to the types of learning being measured. In the second part the different learner status classifications that each participant was given (dependent upon what test was used) are collectively applied to a Rasch Model. This has allowed for an investigation into the hierarchy of test difficulty and an exploration into the dimensionality of the classifications (i.e. did each of the classifications belong to one construct or not?). This exploration leads to a conclusion on whether learner status is modality specific or not (i.e. are there differences found in learning ability dependent upon which processing system is being utilised or not?).

The information gained was used to make a choice on which learner status classification has the most clinical utility. Multiple regression analyses were applied to confirm the choice with regard to establishing the comparative power of the learner classifications in predicting recovery. This was followed by further analyses which added variables of known prognostic ability. This final part of this study consists of four multiple regressions (each one with one of the scales of the Community Integration Questionnaire as the dependent variable); the independent variables used consist of factors identified by the evidence base as predictors of outcome e.g. pre-injury IQ, Socioeconomic Status (SES), severity of injury, as well as the learner status test identified as the most clinically useful. The purpose of these regressions is to compare the predictive utility of each of these factors.

8.1 Review of Previous Studies

Table 21 provides a summary of statistical significance for each variable (e.g. pre-injury IQ, current IQ, severity of injury, etc.) that was explored in studies one, two and three, and for each learner status group produced (e.g. Dynamic WCST, Standard WCST, Dynamic RULIT, etc.). On examination of this table, the first thing which is noticeable is that three of the variables were not found to be significant for any of the tests, 'Age at Testing', 'Time Since Injury' and 'Pre-injury Levels of Community Integration'. This suggests that these factors are not related to learning ability or learning potential (however it was defined). It was also noted that 'Current Intellectual Ability' had a significant relationship with all the tests (with the exception of the Standard Tower of Hanoi). This suggests that current (and often impaired) intellectual functioning, and how an individual learns on the majority of these tests are closely related. Interestingly, the post hoc analysis on this variable may provide more information than the overall significance. For example, all the ANOVAs found significant differences between Non Learners and Spontaneous Learners, but only the Latent Implicit Tower of Hanoi found significant differences between Learners and Spontaneous Learners. The implications of this will be explored in the discussion section of this chapter (section 8.4).

An inspection of Table 21 to identify which of the learner status classifications is the most sensitive to the factors being investigated identifies the Dynamic WCST. This had the highest number of significant main effects of learner status on the dependent variables being measured (e.g. this was the only test to produce a significant main effect of Learner status on the dependent variable 'Change in Community Integration Levels'). Other tests that found significant relationships with 'Current Community Integration' were the Standard RULIT and the Latent Implicit ToH, but these tests found less significant differences at post hoc analysis. The only test to have found a significant relationship with 'Age at Onset of Injury' was the Standard WCST, although interestingly post hoc analyses found no specific significant differences between learner groups. An exploration into the distribution of means for 'Age at Onset' found that Non Learners had a higher mean score than the other groups, the Learners had the lowest mean age at the time of their injury whilst Spontaneous Learners were slightly older than them. This finding may suggest that poor performance on the test may be influenced by the age an individual is at the onset of their injury. Interestingly the learner classifications for the standard ToH found no significant relationships with any of the variables. It is possible that this could have been brought about by altering the criteria slightly for classifying the Non Learner group on the Rasch hierarchy to create a better spread between learner categories; altering this cut-off may have affected the true Non Learner classification, thus impacting the predictive ability of the groups. It is also possible that inadequate power played a significant role in weakening these analyses. Having identified the strengths and weaknesses of each of these learner status classifications it is thought important to compare these tests within the same context, investigating the hierarchical properties of difficulty and measuring the contrast of the classifications.

	Dynamic WCST			Standard WCST			Dynamic RULIT			Standard RULIT			Latent Implicit TOH			Standard TOH
Pre IQ	*									*						
	NL/GL	NL/SL *	GL/SL							NL/L *	NL/SL	L/SL				
Current IQ	*			*			*			*			*			
	NL/GL	NL/SL *	GL/SL	NL/L	NL/SL *	GL/SL	NL/GL *	NL/SL *	GL/SL	NL/L *	NL/SL *	L/SL	NL/L	NL/SL *	L/SL *	
GCS ANOVA	*						*									
	NL/GL	NL/SL *	GL/SL				NL/GL	NL/SL *	GL/SL							
GCS Chi Square	*			*			*									
Age at Onset				*												
				NL/L	NL/SL	GL/SL										
Age at Testing																
Time since injury																
Pre CIQ																
Current CIQ	*									*			*			
Home	NL/GL	NL/SL	GL//SL							NL/L	NL/SL	L/SL	NL/L	NL/SL	L/SL	
Social	NL/GL *	NL/SL *	GL/SL							NL/L	NL/SL *	L/SL	NL/L	NL/SL	L/SL	
Productive	NL/GL	NL/SL *	GL/SL							NL/L	NL/SL	L/SL	NL/L	NL/SL	L/SL *	
Total CIQ	NL/GL *	NL/SL *	GL/SL							NL/L	NL/SL *	L/SL	NL/L	NL/SL	L/SL	
CIQ diff	*															
Home	NL/GL	NL/SL	GL/SL													
Social	NL/GL *	NL/SL *	GL/SL													
Productive	NL/GL	NL/SL *	GL/SL													
Total	NL/GL	NL/SL *	GL/SL													

Table 21: A Summary of Significant Findings for the Three Studies

Key ▨ = significant
NL/L = Non Learner vs Learners
NL/SL = Non Learner vs Spontaneous Learners
L/SP =Learner vs Spontaneous Learners
GL/NL = Guided Learner vs Non Learner
GL/SP = Guided Learner vs Spontaneous Learner

8.2 Investigation of the Hierarchy, Fit and Construct of the Collective Learner Status Classifications

The second part of this data analysis sees the learner status categories entered into a Rasch model (for both the Static and the Dynamic tests). This allows for an exploration of the hierarchy of test difficulty, as well as an investigation into the fit properties of the test. The item map is shown in Figure 35.

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                              80          T+
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    70       Standard ToH Learner Status   +
                                           |T X
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                                           |  XXXXX
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                              60           +S
                                           |  XXXXXX
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                                           |  X
                                           |  XXXXXX
                                           |
                                           |  X
 50   Latent Implicit ToH Learner Status  M+M XXXXXXXXXX
            Standard WCST Learner Status
             Static RULIT Learner Status   |
                                           |  XXX
                                           |  XXX
             Dynamic WCST Learner Status   |
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                              40           +S X
            Dynamic RULIT Learner Status   |  X
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                                          S|  XXXXX
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Figure 35: Item Map Representing the Hierarchy of Difficulty for Each of the Tests Administered (Both Standard and Dynamic)

The first observation, unsurprisingly, is that the two easiest items are the dynamic tests (the Dynamic WCST and Dynamic RULIT). They are followed by the two standard versions of these tests and the Latent Implicit ToH; these three items are plotted as being equally difficult. The most difficult test is the Standard ToH test. It is logical to assume that the Latent Implicit ToH (which measures the improvement over test occasion) would be a harder test to improve upon when compared to the other dynamic assessments, primarily as there is no instruction sandwiching the trials. It was perhaps less expected that it would be predicted by the Rasch model as being equally as difficult as the other standard tests. A possible explanation of this is that this Latent Implicit ToH version of the test is measuring learning over trials, as are the standard versions of the RULIT and the WCST. This perhaps explains why the Standard ToH, which only has one attempt in which to pass each trial, is the hardest test to pass.

It was noted that the easiest item fell quite high up along the hierarchical map (just under 40 logit points). Below this item were 23 participants. These people have a 75% chance of not passing any of the items. It should be noted that this Rasch analysis contains three levels of performance, as people within the model have been coded as 'Non Learners', 'Guided Learners' and 'Spontaneous Learners'. This means that those at the bottom would have a high probability of being Non Learners on every test, and those at the top of the item would have a high probability of being classified as Spontaneous Learners on every test. The placement of those individuals in the middle will characterise whether they are Learners, Spontaneous Learners or Non Learners depending upon whether they are above, below or next to an item. Having data that is not dichotomous makes it harder to interpret these classifications. To aid in the interpretation of this item map, a table summarising the distribution of learner status classifications of each of the versions of the tests is outlined in Table 22.

	Count	Percentage
WCST Dynamic Non learner	22	29
WCST Dynamic Guided Learner	25	32
WCST Dynamic Spontaneous Learner	30	39
WCST Standard Non learner	29	34
WCST Standard Learner	18	29
WCST Standard Spontaneous Learner	28	37
RULIT Dynamic Non learner	13	19
RULIT Dynamic Guided Learner	24	36
RULIT Dynamic Spontaneous Learner	30	45
RULIT Standard Non learner	21	31
RULIT Standard Learner	25	38
RULIT Standard Spontaneous Learner	21	31
Implicit ToH Non learner	16	27
Implicit ToH Guided Learner	26	44
Implicit ToH Spontaneous Learner	17	29
Standard ToH Non learner	21	35
Standard ToH Learner	29	48
Standard ToH Spontaneous Learner	10	17

Table 22: A Comparison of the Distribution of the Participants for Each Test Conducted

A comparison of the 23 Non Learners identified on the item map in Figure 35 to the distribution of Non Learners for each of the tests shown on Table 22 suggests that the classification of a Non Learner is not dependent upon the system of learning being utilised. This implies that those who are Non Learners for one system are likely to be Non Learners for all three, supporting Feurestein's (1979) view that learning potential is global.

As previously mentioned, the item map placed 13 individuals above all of the items, suggesting that they would be likely to reach Spontaneous Learner status for each of the tests. When compared to the number of Spontaneous Learners created by the battery of tests included this is quite a low number. Closer inspection of the distribution suggests that this number is influenced by the hardest test (the Standard Tower of Hanoi), which in itself only categorised ten people as Spontaneous Learners. This test has already been discussed as being not as valuable as the other tests, and could be influencing this reduction in the number of Spontaneous Learners. Between this item and the next most difficult item (Latent Implicit Tower of Hanoi) are 19 participants who would have been expected to be Spontaneous Learners on all of the other tests. This implies that the Tower of Hanoi first trial is considerably more difficult than the other tests. The remaining participants spread between the easiest and hardest items suggests that being a Non Learner is not modality specific but that individuals may have different strengths in terms of what they can achieve independently. Only two participants fell in the range between the two dynamic tests, suggesting that the remaining majority could be taught on both verbal and visuospatial domains.

This item map, interpreted in conjunction with Table 22, suggests that Non Learners have trouble learning across learning systems. Spontaneous Learners do well on all tasks, although may have relative strengths according to the processing system being employed. It is likely that Learners can be taught to adapt, or learn to improve across different systems of learning, with relative individual strengths affecting performance.

To further investigate whether learning is a dissociable construct a bubble chart was produced outlining the fit of the items (Figure 37).

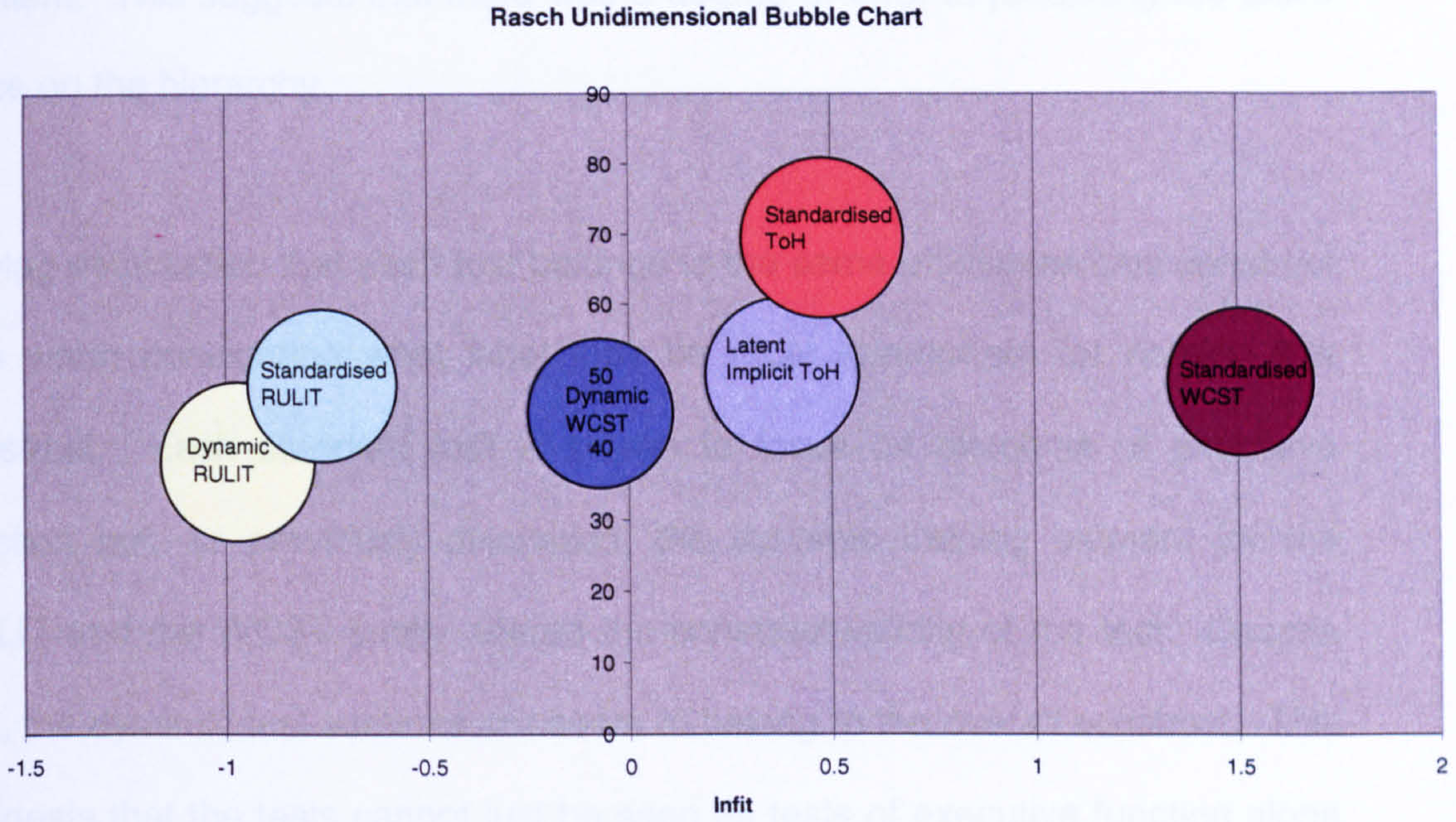

Figure 37: A Bubble Chart Representing the Rasch Model for Each of the Tests (Both Static and Dynamic)

Figure 37 confirms that all of the tests belong to the same unidimensional construct. This could be interpreted as corroborating the choices made regarding the tests included in this research. It was hoped that these tests each measured similar dimensions of executive functioning, but with learning occurring across different processing systems. The above chart confirms that these tests have enough in common for them to belong to the same underlying construct. It is, however, interesting that the dynamic and standard tests all belong to the same construct and seem to be measuring learning across a broad continuum. This implies that the process of teaching someone how to pass a test does not significantly interfere with the essential nature of the test or the interpretation of performance on that test.

The Dynamic WCST sits most closely to the centre of the bubble chart, and therefore best represents the construct. The size of the bubbles suggests that there was some imprecision in the model's ability to predict the exact location of the item. This suggests that there was a degree of error in predicting the test's place on the hierarchy.

Having established that each test belongs to the same unidimensional construct it is worth considering what label may be most appropriate for naming this construct. Each standard test is known to focus on elements of executive function but, as previously discussed, the dynamic training element for the RULIT and the WCST subtly altered the construct validity of the test. Despite this, the dynamic test versions still seem to belong to the overall construct. This suggests that the tests cannot just be seen as tests of executive function alone (as the errorless training interventions are thought to have removed this). Instead, the learner classifications are tapping into levels of understanding of what is required of the task and the necessary adjustments required to complete it. Each test has classified a learning ability (either spontaneous or with guidance) so it is possible that the construct could be labelled 'learning'. However, it is felt that a better term would be 'cognitive adaptability'. Each of the tests in this construct measures not only performance on a test of executive function (which requires flexibility in thought and adaptation to any difficulties encountered), but also whether the participant can adapt their performance in order to improve following a training intervention or following previous experience of the test.

On the basis that these tests may be measuring a construct related to cognitive adaptability it would be useful to know which of the above are the most clinically meaningful. This will be assessed by choosing the best test from each of the three studies (i.e. whichever test version yielded the most significant results in the studies) and comparing them. Once the test which has the most meaning clinically has been identified, it will then be compared to other factors known to predict outcome following ABI to establish whether it adds anything to our current understanding of outcome prediction.

8.3 Comparison of the Utility of the Learner Status Classifications

This third part of the study conducts a multiple regression using the Total Community Integration Score (CIS) as the dependent variable and the best learner classification for each of the three studies as the independent variables. Before a multiple regression was conducted, the dependent variable (CIS) was checked to establish that it fitted the assumptions of normality. The Histograms (see Appendices section 26) showed that the only measure found not to fit a normal distribution was the 'Home Integration' score. This finding may help to explain why Home Integration created no significant results with the ANOVAs completed in the earlier studies, as shown in Table 21.

8.3.1 Multiple Regression with Learner Status Groups

The Multiple Regression was conducted using 'Total CIQ' as the dependent variable; the three chosen learner classifications from each of the three studies (e.g. Dynamic WCST, Standard RULIT and Latent Implicit ToH) were the independent variables. This analysis was used to help confirm which classification is the best at predicting overall levels of recovery. The overall regression was highly significant ($F(3,49)=6.30$ $p<0.001$) suggesting that these three learner status categories allow a better prediction of community integration than chance alone. An analysis of the regression coefficients found that the Dynamic WCST learner status group made a significant contribution to the results ($\beta=0.37$, $p=0.01$), with a significant intercept ($p=0.001$). The remaining items were not significant (Standard RULIT $\beta=0.18$, $p=0.21$; Implicit ToH $\beta=0.08$, $p=0.57$).

A comparison of partial and semi-partial correlations showed no real difference, indicating that none of the independent variables could account for a proportion of variance of the dependent variable exclusively. The squared semi-partial correlation revealed that the Dynamic WCST learner status accounted for 10% of the variance of the independent variable. A case-wise plot of residuals revealed one outlier which was removed, but did not affect the overall result. The normal probability plot of residuals indicated that the assumption of linearity had not been broken. Table 23 summarises the information collected regarding the betas, partial and semi-partial correlations for each of the independent variables.

F(6,32)=3.9021 p<.00490 Std. Error of estimate: 5

Independent Variables	*Beta*	*Partial Correlation*	*Semi-Partial Correlation*	*P-level*
Intercept				<0.001
Dynamic WCST	0.37	0.35	0.32	0.01
Standard RULIT	0.18	0.18	0.15	0.21
Implicit ToH	0.08	0.08	0.07	0.57

Table 23: A Summary of the Multiple Regression with Total Community Integration Scale Score as the Dependent Variable.

8.3.2 Predictive Utility of Learner Status

In order to see whether the information gained from the previous studies, blended together with variables of known prognostic utility, adds to our understanding of outcome prediction, a further multiple regression was conducted, again using CIQ as the dependent variable. The information gained from the previous regression indicated that the Dynamic WCST learner status was the best classification at predicting levels of community integration and, therefore, this was included as the first independent variable. Other factors included were those known to be related to outcome, i.e. pre-injury and current IQ, socio-economic status, severity of injury and years of education. The results of this regression showed that overall these variables could predict outcome better than chance (F(6,33)=3.17 p<0.01). A case-wise plot of residuals using Mahalanobis distances revealed one outlier. Removing this outlier did have an affect on the overall results of the regression, increasing the sensitivity of the test and creating another significant item in the prediction of the dependent variable (F(6,32)=3.90 p<0.001).

With the outlier removed an analysis of the regression coefficients found that two items made a significant contribution to predicting outcome, these were the Dynamic WCST Learner status, (β=0.38, p=0.03) and Socio-Economic Status (β=-0.43, p=0.04). The intercept was also significant (p= 0.04). Table 24 summarises the information related to the multiple regression conducted using Total CIQ as the dependent variable, with the betas, partial and semi-partial correlations for each of the independent variables once the outlier had been removed.

F(6,32)=3.9021 p<.00490 Std. Error of estimate: 5				
Independent Variables	*Beta*	*Partial Correlation*	*Semi-Partial Correlation*	*P-level*
Intercept				0.04
WCST Learner Status	0.38	0.38	0.31	0.03
SES	-0.43	-0.35	-0.28	0.04
GCS	0.28	0.30	0.24	0.08
Pre-Injury IQ	-0.25	-0.20	-0.15	0.26
Education	-0.25	-0.23	-0.18	0.20
FSIQ	0.21	0.17	0.13	0.32

Table 24: A Summary of the Multiple Regression with Total Community Integration Levels as the Dependent Variables.

An investigation of the significant independent variables' partial and semi-partial correlations found a small difference between them (WCST partial = 0.38, semi-partial= 0.31, SES partial = -0.35, semi-partial =-0.28), which indicates that the significant independent variables were able to account for the variance of the dependent variable only when adjusted by the other independent variables. Therefore, the two significant items in relation to the other items were significant but could not account for a proportion of the overall significance independently. The WCST could account for 9% of the variance of the dependent variable and the SES variable could account for 7%. It is interesting to note that the relationship between the SES and the dependent variable is negative. This does not reflect a negative correlation between community integration and levels of socioeconomic status as the scoring system that was used scores higher levels of SES with lower numbers. The means for each category of SES have been plotted in Figure 37.

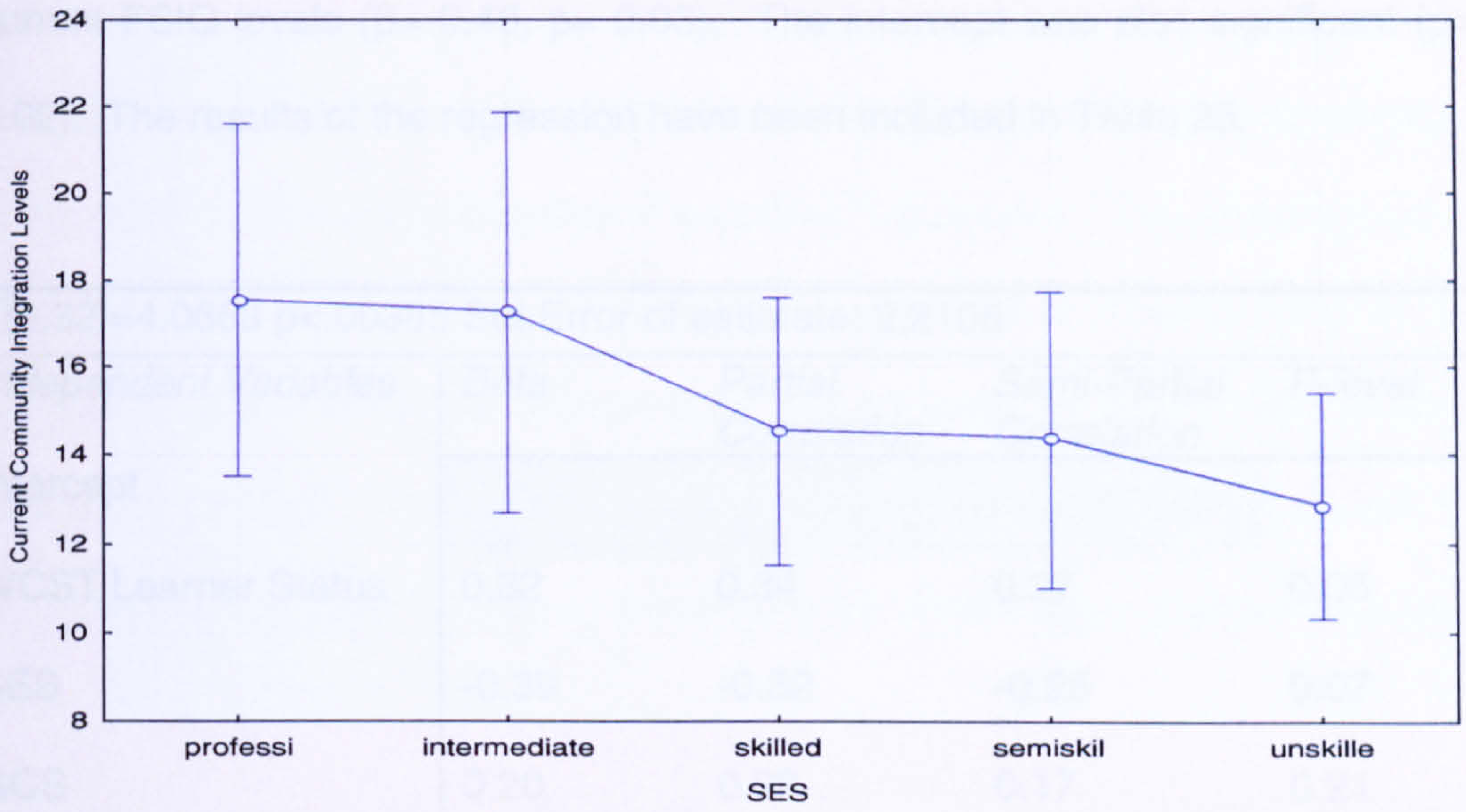

Figure 37: Graph Illustrating the Mean Community Integration Score For Each of the Socioeconomic Status Categories

It was felt that a more thorough investigation into the different levels of integration should be conducted, and therefore the same independent variables were applied to the remaining measures of the Community Integration scale (Productive Activity, Social, and Home integration).

The Multiple Regression using current Productive Activity levels as the dependent variable was not significant (F(6,33)=1.44 $p<0.23$). This suggests that the independent variables in this regression cannot predict Productive Activity.

The regression measuring current levels of Social Integration was significant (F(6,33)=3.23 $p<0.01$), and a case-wise plot of residuals using Mahalanobis distances revealed one outlier; removing this outlier increased the sensitivity of the test and created another significant item in the prediction of the dependent variable (F(6,32)=4.07 $p<0.001$). With the outlier removed an analysis of the regression coefficients found that two items made a significant contribution to predicting outcome. These were the pre-injury IQ (β= -0.56, p= 0.02) and current FSIQ levels (β= 0.48, p= 0.03). The intercept was also significant (p= 0.02). The results of the regression have been included in Table 25.

F(6,32)=4.0668 p<.00385 Std.Error of estimate: 2.2105

Independent Variables	*Beta*	*Partial Correlation*	*Semi-Partial Correlation*	*P-level*
Intercept				0.02
WCST Learner Status	0.32	0.34	0.27	0.05
SES	-0.39	-0.32	-0.25	0.07
GCS	0.20	0.22	0.17	0.21
Pre-Injury IQ	-0.56	-0.41	-0.34	0.02
Education	-0.12	-0.12	-0.09	0.51
FSIQ	0.48	0.37	0.30	0.03

Table 25: A Summary of the Multiple Regression with Total Social Integration Levels as the Dependent Variables.

Of the significant items the pre-injury IQ was able to independently account for 11% of the dependent variable and the FSIQ measure accounted for 9%. It was interesting to note that the relationship between pre-injury IQ and social integration levels was negative. This suggests that people with lower pre-injury cognitive ability had a greater level of social integration post-injury. There are several explanations that could account for this finding, e.g. it is possible that these individuals may have had less of a decline in function and found it easier to adapt. On the other hand, the participation that they enjoyed prior to injury may have been less taxing, making reintegration easier. These issues will be considered in the discussion section of this chapter (section 8.4). The regression using Home Integration as the dependent variable was not significant (F(6,33)=1.40 p=0.25).

During the literature review (section 1.9.4), mention was made of the concerns outlined by Griogorenko et al (1998) about using a dynamic assessment style with people with varying degrees of cognitive impairment. The potential risk is that the change in scores (or lack thereof) would be a consequence of the degree of that individual's impairments, as opposed to their ability to think flexibly or adapt. The authors proposed that learning potential should be compared to cognitive function to investigate the relationships between the two.

In an attempt to consider this further, profiles for each of the learner status groups were created and have been represented in the tables below (Table 26-28). Table 26 includes the mean percentiles, scaled scores, ranges and standard deviations for each of the main cognitive functions measured by the cognitive battery for the Non Learner group.

Variable	*Mean*	*Minimum*	*Maximum*	*Std. Deviation*
Visual Immediate Percentile	*10.97*	*1*	*76*	*21.00*
Visual Delayed Percentile	11.24	1	79	20.55
Colour Trails Attention Percentile	10.29	1	54	18.30
Colour Trails Working Memory Percentile	16.57	1	66	23.66
WAIS Digit Span Scaled Score	7.19	2	12	2.64
Verbal IQ	80.74	55	136	20.21
Performance IQ	81.63	55	109	14.33
Verbal Immediate Scaled Score	5.11	1	18	4.53
Verbal Delayed Scaled Score	6.37	1	11	2.03
Education in Years	12.40	10	27	3.97

Table 26: A Summary of the Cognitive Profile for the Non Learner Classification Group

The cognitive profile which can be surmised from Table 26 for the Non Learner group indicates that someone in this group could be expected to have a lower than expected cognitive function in every domain. 'Average' is considered to be in the percentile range of 25-75, with a WAIS/WASI Age Scaled score between 8 and 12 and an IQ between 85 and 115. The memory abilities for both the verbal and visual modalities are in the impaired range. Verbal and Performance IQ are in the borderline classification of function as are the measures of attention/concentration and working memory.

Variable	*Mean*	*Minimum*	*Maximum*	*Std. Deviation*
Visual Immediate Percentile	*24.63*	*1*	*99*	*33.58*
Visual Delayed Percentile	19.70	1	99	28.69
Colour Trails Attention Percentile	28.75	1	84	35.15
Colour Trails Working Memory Percentile	27.17	1	84	31.37
WAIS Digit Span Scaled Score	9.07	3	14	3.27
Verbal IQ	89.89	63	123	15.69
Performance IQ	92.95	57	123	19.83
Verbal Immediate Scaled Score	8.33	1	14	3.26
Verbal Delayed Scaled Score	7.76	5	16	2.96
Education in Years	12.83	11	23	3.49

Table 27: A Summary of the Cognitive Profile for the Guided Learner Classification Group

Table 27 demonstrates that the mean scores illustrating the cognitive profile for the Guided Learner group are generally higher than that of the Non Learners, but the standard deviations are larger, suggesting that there is more of a spread of abilities. Investigation into the minimum and maximum scores highlights that the range of abilities is larger than that of the Non Learners group.

Variable	*Mean*	*Minimum*	*Maximum*	*Std. Deviation*
Visual Immediate Percentile	*33*	*1*	*96*	*34.12*
Visual Delayed Percentile	27.8636	1	84	31.00
Colour Trails Attention Percentile	51.4211	5	95	28.96
Colour Trails Working Memory Percentile	55	5	96	28.42
WAIS Digit Span Scaled Score	9.3333	5	17	3.11
Verbal IQ	94.68	62	130	15.60
Performance IQ	104.72	78	131	13.93
Verbal Immediate Scaled Score	8.7407	2	14	3.01
Verbal Delayed Scaled Score	7.963	4	18	3.66
Education in Years	13.5714	11	20	2.99

Table 28: A Summary of the Cognitive Profile for the Spontaneous Classification Group

The cognitive profile for the Spontaneous Learner group as shown in Table 28 has a higher mean than for each of the measures in the Guided Learner group, but the range of abilities is smaller (the maximum scores for each of the variables in the Guided Learner group is higher). This would indicate that the Guided Learner group had a larger range of abilities, suggesting that cognitive function is not solely responsible for determining learner status ability.

Analyses of Variances were conducted to investigate whether there was a significant main effect of these learner status classifications on the variables included in the tables above. A summary for each of these ANOVAs is found in Table 28 and is described in detail below.

i) Visual Memory Immediate Recall Measure: This Analysis was non-significant, (F(2,56)= 2.47 =, p 0.09) indicating that visual memory is not significantly different across learner status groups. It is important to note here, however, that the test of homogeneity of variance was significant (p= 0.04) indicating that variance between variables was uneven; this may influence the non significant finding.

ii) Visual Memory Delayed: This ANOVA was also not significant (F (2,56) =1.75, p 0.18).

iii) Colour Trails One - Attention: The ANOVAs investigating attention using the colour trails yielded a significant F ratio for the main effect of Learner Groups, (F(2,44) = 8.82, p=0.001). Post hoc analysis using the Scheffe test revealed highly significant differences between the Non Learners and the Spontaneous Learners (p<0.001), but the Brown-Forsyth test was significant, (p= 0.05) indicating that the hypotheses for the homogeneity of variance should be rejected. This result will therefore be interpreted with caution.

iv) Colour Trails Two – (involving aspects of Working Memory): The ANOVA for the Colour Trails working memory was significant, (F(2,42)= 8.41, p=0.001) indicating that there was a main effect of Learner Status on working memory. Post Hoc Scheffe test revealed significant differences between the Non Learners and the Guided Learners (p= 0.03), and the Non Learners and the Spontaneous Learners (p= 0.001).

v) WAIS Digit Span Attention: The ANOVA for digit span was not significant, (F(2, 45)=2.46, p=0.09) indicating that there was no difference between the learner status groups on this test of attention. It is possible that sample size contributed to this finding.

vi) WAIS Verbal IQ: Learner Status yielded a significant F ratio for Verbal IQ, (F(2,60)=3.61, p= 0.03), and post hoc Sheffe analysis identified that the significant differences were between Non Learners and Spontaneous Learners (p= 0.03).

vii) WAIS Performance IQ: As with Verbal IQ, a highly significant F ratio was found for the main effect of learner status (F(2,60)=11.27, p=0.001). Post hoc analysis, however, only found significant differences between the Non Learners and Spontaneous Learners (p=0.001).

viii) Verbal Memory Immediate Recall: This ANOVA was found to be significantly related to Learner status (F(2,64)=6.44, p=0.001). Post hoc Scheffe analysis found a significant difference between Guided Learners and Spontaneous

Learners (p< 0.001) and Non Learners and Spontaneous Learners (p= 0.02). This suggests that the errorless learning technique was unable to compensate for the difficulties experienced by the most severe group.

ix) Verbal Memory Delayed Recall: Delayed Verbal Memory was not found to yield a significant F Ratio in its relationship with Learner status (F(2,64)= 1.68, p=0.195). This suggests that learner status is not related to delayed memory. As immediate memory has been found to have a significant effect on learner status this is surprising. It is possible that, had participants been required to recall their errorless learning training over a longer period, the delayed memory functioning may have been a more important discriminator. As it currently stands, the measure of learning potential using the verbal processing system might be more related to immediate verbal memory. This measure of learning potential might be a reflection of immediate learning potential.

x) Education: The investigation into the main effect of Learner status on education was not significant (F=(2,74) 1.6, p=0.20), which suggests that learning potential is not a reflection of education. This is important as it supports the belief that Vygotsky (1978) had, which was that guided learning circumvents an individual's performance determined by their education, heredity and the environment. A summary of the findings outlined above is summarised in Table 29 below. Please see Appendices 26 for summary statistics of key ANOVAs.

Variable	*Significance*	*NL vs SP*	*NL vs GL*	*GL vs SL*
Visual Immediate Percentile	0.09			
Visual Delayed Percentile	0.18			
Colour Trails Attention Percentile	<0.001	<0.0001	*0.26*	0.10
Colour Trails Working Memory Percentile	<0.001	<0.001	0.63	0.03
WAIS Digit Span Scaled Score	0.10			
Verbal IQ	0.03	0.03	0.27	0.66
Performance IQ	<0.0001	<0.0001	0.10	0.06
Verbal memory Immediate Scaled Score	<0.01	<0.01	0.02	0.93
Verbal Delayed Scale Score	0.20			
Education in Years	0.20			

Table 29: Summary of the Significant Differences for the Cognitive Profiles for Each of the Learner Status Groups

The cognitive profile for each of the learner status classifications illustrates which principal functions might be influencing learning ability; these are attention, working memory, intellectual function and immediate verbal memory. The profile suggests that the Colour Trails is one of the most sensitive tests for discriminating learner classifications. An important consideration with this finding, however, is that while the Colour Trails Two measure met the assumptions of parametric methods, the measure of attention from the Colour Trails One trial did not have a satisfactory homogeneity of variance. It is possible that this could be compromising the parametric testing, which perhaps is why the Colour Trails Two measure, which taps into many of the functions included in the measure of working memory, found more significant post hoc relationships. In it Non Learners and Guided Learners were both found to have a significantly lower percentile score than the Spontaneous Learners. Unfortunately, despite following the trend of the scores, the difference between the Non Learners and the Guided Learners was not significant. Whilst it is possible that findings may have been compromised due to sample size, and therefore insufficient power, this data cannot be used to differentiate these two groups. A variable that was able to differentiate the Non Learners and the Guided Learners was the measure of verbal immediate memory. This is an interesting finding for a few reasons. The first is that the Non Learner group was the only one with an immediate memory function that was in the impaired range (Guided Learners had a scaled score of eight, which is low average, Spontaneous Learners were closer to a scaled score of nine). This finding implies that memory is important in establishing learning ability. It suggests that the errorless learning intervention (included to avoid impaired individuals relying on memory ability) was not fully effective. It also raises the question of whether memory is important for all learning, or is important only on performance of this test (which requires a person to remember information and use it). If delayed memory had also been significant then it might have been easier to conclude that all learning relies on memory ability. However, as only immediate memory was involved, this suggests that the ability to hold onto verbal information immediately after it has been presented plays a role in learning.

8.4 Discussion

This final chapter has drawn together all of the information from each of the previous studies. It identified that, in terms of fit and construct, each of the learner status classifications (identified by both the standard and the dynamic versions of the test) all belong to the same unidimensional construct. This is an interesting finding; it suggests that the performances on each of these tests taps into the same construct. It could perhaps be thought of as an unexpected finding because two of the tests are measuring performance following instruction; a third taps into a latent ability to improve. These tests are measuring potential to learn, whereas the standard static tests are measuring independent actualised ability. The previous chapters (outlining the studies) have shown that there is a substantial amount of divergence between learner status classifications on the basis of test version (i.e. standard versus dynamic). However, the Rasch model shows that these classifications are close enough in terms of their statistical properties to be reflecting the same ability.

Not unexpectedly, the dynamic versions of the tests (Figure 35) were shown to be the easiest to pass, followed by the two standard versions of the same tests. These were plotted as equally difficult as the Latent Implicit Tower of Hanoi. The Standard ToH was shown to be the hardest test to pass.

Table 21 confirms that the Dynamic WCST has the most number of significant analyses of variance in the investigation of the relationship with outcome. This clarifies that it is the most sensitive task, and can discriminate learning ability and its effects on recovery better than the other tests. Confirmation of the role of dynamic assessment, as opposed to standard performance of the WCST, came from the fact that the analysis of variance investigating the main effect of the Standard WCST learner status classifications on recovery found no significant differences. This means that the classification of learning potential is related to outcome, whereas the classification solely from learning ability is not.

The Dynamic WCST could separate out the Guided Learner Group from the Non Learners in terms of recovery (this was the only learner classification that was able to do this). Table 21 highlights how the other dynamic test (the dynamic RULIT) was unable to find any significant main effect of learner status in relation to outcome. Despite this, the RULIT was able to find significant main effects of learner status in the investigations into variance with the factors known to predict outcome. In the ANOVA looking at current IQ, both the Standard and the Dynamic RULIT showed an ability to discriminate Non Learners from the

Learners (Standard RULIT) and Guided Learners (Dynamic RULIT). This suggests that there is something about the Visuospatial Learning that means that Learners tend to have a significantly higher intellectual ability than Non Learners, but that there is no significant difference between those who passed the test independent of guidance and those who passed only some items, or improved following training. This could be interpreted as indicating that the visuospatial test is the easier of the two, because the difference between those who cannot do it and those who can partially or with guidance is large enough to be significant, but the difference between those who can do it independently and those who can do it partially or with guidance is not significant. Despite this being an interesting finding, the RULIT did not show itself to have as much discriminative ability when compared to the Dynamic WCST.

A Multiple Regression investigating which test had the strongest predictive ability of outcome confirmed what Table 21 already indicated. This was that the Dynamic WCST has the most significant predictive ability. The other two (the Standard RULIT and the Latent Implicit ToH) had no significant predictive ability. This confirms that those learner status classifications were not as accurate at predicting recovery, suggesting that they were weaker tools in the field of neuropsychological rehabilitation.

As the Dynamic WCST has been found to be the best measure of learning potential a closer investigation has been paid to the significant relationships found in the other analyses conducted.

An observation of the relationships between the Dynamic WCST Learner Status and the factors that are known to influence outcome (i.e. pre-injury IQ, current IQ, severity of injury, stage in recovery, and age) found significant main effects, suggesting that learning ability is influenced by these variables. What is particularly interesting is that the post hoc analyses for each of these significant ANOVAs found no significant differences between the Guided Learner Group and the other two groups. It is recognised that the learner status classifications made throughout this research are artificial splits of a continuous data set. Attempts were made to ensure that these splits were as useful as could be, clinically, however it should be remembered that they were created to allow a comparison between levels of ability and that they are not discrete groups. During the investigation between factors known to influence outcome and the learner status classifications, when significant differences were found between the two extreme groups, it was considered that this could be down to the arbitrary splitting of the data. However, as hypothesised earlier (refer to Chapter Five, Study One, section 5.3.3), if this were the case then the Guided Learner Group would be statistically weak across all investigations and would not differentiate itself from both the other groups when measuring outcome. Instead the findings suggest that other factors that contribute to the non-significant findings involving the Guided Learner Group. A second hypothesis was that the differences do exist but that the effect size may be smaller than predicted, and as such the lack of effect may be the function of statistical error. Future studies would need to examine this further. A third hypothesis suggests that the factors known to influence outcome could significantly discriminate those who cannot learn and those who can learn independently (i.e. actualised learning ability), but was unable to discriminate those who had potential to learn. The findings that support this are important; had there been significant differences involving the group with potential to learn then it would be unnecessary to conduct dynamic assessment to identify who these individuals are, since instead a measure of their IQ or severity of injury could be used as a guide.

In summary, the relationships found in these analyses suggest that the ability to learn independently is affected by current and pre-injury cognitive ability as well as the severity of the brain injury. However, the potential to learn (from guidance) cannot be determined by these factors. The mean scores of the Guided Learner group follow the trend of the other groups, but the variance is such that a specific score within these variables cannot be pinpointed to predict who has potential to learn from the Non Learner and the Spontaneous Learner groups. This suggests that there are other factors that influence the potential to learn.

A further observation of these post hoc analyses for the Dynamic WCST was that there were no significant differences in relation to recovery between the Guided Learner and the Spontaneous Learner group. This is an important finding and should not be underestimated. The Guided Learner group are those who did badly in the standard administration of the test. Thus, if classifying performance as is currently done in clinical settings these 'Guided Learners', whose outcome is not significantly worse than Spontaneous Learners, would appear so impaired that they are failing either every item of the WCST or only passing the easiest items. These individuals are able to benefit from instruction and have probably been doing so in their everyday lives. Perhaps, therefore, individuals like these are the ones who have been confounding the data in previous research, where people who do badly on tests live well and have good outcomes.

Having established that the Guided Learning profile is not a weak classification when considering outcome, it was felt important to explore what other factors might be contributing to the ability to learn, and whether it was related to the consequences of the brain injury (i.e. those who had minimal consequences or had made significant natural recovery did better than those who had longstanding impairments).

The investigation into the cognitive profile suggests that the cognitive consequence of the injury might have an impact on learning ability, with performance on cognitive assessments indicating that the Spontaneous Learners are typically performing within usual limits, and Non Learners typically showing impaired function across the board. The variables shown to influence learning ability suggest that having an ability to attend to task, as well as intact features of working memory, were important. These all seem to be reflecting an ability to hold information online and manipulate it. If you cannot concentrate on a task you would not be able to perform the mental manipulation of information. If you are unable to hold the information in your mind before it degrades you will be unable to apply it.

In this final study the most significant finding was that the measure best representing learning potential was also found to predict outcome better than any of the variables that are currently known to do so. This is an exceptionally potent finding; it suggests that it might be possible to predict the overall level of community integration for an individual on the basis of their ability to learn both independently and following guidance.

This finding has face validity; following an injury, individuals will need to understand and adapt to any potential difficulties they experience. What is required to do this is an ability to have a good working relationship with professionals involved in their care, and to attend to, remember and benefit from instruction and rehabilitation. In addition, the ability to take guidance and learn from everyday experiences might also be reflected by performance on dynamic assessment tasks.

Another interesting finding from this multiple regression was that the only other variable that was found to predict overall outcome was the person's socioeconomic status (SES) (section 8.3.2). People with higher pre-injury SES had better post-injury integration scores. This suggests that the resources that individuals had available to them, as well as their levels of pre-injury socio-economic function, had an effect on their integration levels post-injury. A possible explanation for this is that pre-injury SES is reflective of a level of cognitive reserve (Scarmeas et al., 2003) which had a buffering effect on the impact of the brain injury. This finding supports previous research that identified pre-injury occupational status as one of the factors that predicts outcome (Ownsworth et al., 2004).

In the investigation of the subscales of the Community Integration Scale it was interesting that the WCST and SES did not predict any of the individual scales. In fact the only significant subscale was that of Social Integration. The possible reasons why the Home Integration scale was not significant could be because the variable was not found to be normally distributed, or possibly, as previously discussed because as a test, it has failings in the scoring system (refer to Chapter 1, section 1.3.1). For example, if you share household responsibilities with someone else, there is no way of identifying the proportion of shared responsibility. If, for instance, an individual had a 50% share in each of the household tasks pre-injury, and post-injury only completed 20% of them, as they still shared responsibility their score could be the same. An unexpected finding was that current and pre-injury IQ significantly predicted Social Integration; these were the only significant variables for this measure. The correlation between levels of Social Integration and pre-injury intellectual ability was negative, suggesting that people with lower pre-injury IQs tended to have better social integration. It is possible that their social networks were less able to discriminate changes in intellectual ability and this had less impact on their ability to engage in social and leisure activities generally. On investigation of what is involved in this variable, e.g. shopping, leisure activities, visiting friends, it is understandable why pre-injury intellectual ability might not be relevant, but a significant negative correlation is an unexpected finding. It is also interesting that a positive significant predictive relationship was found with current intellectual ability, suggesting that there is a role of intellectual functioning within these tasks.

In conclusion, this chapter has suggested that, whilst all of the tests when modelled through Rasch can produce a classification of learning ability with all belonging to the same construct, tests that are able to separate out the Guided Learners have more value clinically. Of the tests the measure that learnt using the verbal processing system was found to be more useful clinically. The Dynamic test of Visuospatial Learning was not found to relate to recovery (possibly because of problems with the cut-off or because it appeared easier and, therefore, not as complex).

The Dynamic WCST has shown itself to be a useful test in terms of relating to overall outcome and promises better predictive ability than the other variables that are currently used today. The only other factor that contributed was socioeconomic status. It is thought that this is a reflection of pre-injury cognitive reserve.

Whilst these findings are significant and meaningful, perhaps a further contribution would be in a prospective investigation, as well as considering whether learning potential is a static and fixed ability, or whether it can change over time.

Chapter 9 : Conclusions and Implications

This chapter will begin with a summary of the four studies conducted for this research, and a critical overview of the measures and techniques applied to this research will then be provided with the limitations of the study explored. The most significant clinically relevant findings will then be outlined and discussed, and suggestions for future research will be outlined.

9.1 Summary of Findings

The overall aim of this research was to explore whether a measure of learning potential, gained from a dynamic assessment, had greater clinical utility in predicting recovery when compared to static measures of cognitive ability. This research has found that measures of learning potential will vary in their utility and that this is dependent upon both the test used and how change is measured; more specifically it is a combination of both.

The three independent studies investigated static and dynamic styles of learning across different processing systems (Verbal, Non-Verbal and Implicit). These studies have found that when predicting levels of community integration, adding a training intervention to a test of executive function capitalising on a verbal processing system resulted in a more meaningful classification of learning. Adding an errorless learning training intervention to a visuospatial test of learning did not create a more meaningful measure of learning ability, whereas adding a further trial to a test of implicit learning created a more clinically meaningful measure of latent implicit ability, which tends to predict everyday ability better than the single trial alone.

When understanding why the dynamic test of Visuospatial Learning potential did not create better classifications of learning ability it was concluded that the training element of this assessment fundamentally altered the psychometric properties of the assessment. This meant that it was no longer a test of visuospatial learning and memory but simply one of visual memory. Therefore the training element of the Non-Verbal learning study made it a much easier test to pass than the more complex Verbal Learning test using the WCST. It is recognised that including a second trial on the ToH does not make it a true measure of learning potential according to Vygotsky's definition. However, it does reflect potential to improve and this appears to also be clinically meaningful.

Despite the Latent Implicit ToH showing potential as a clinically meaningful tool, the Explicit Verbal measure of learning potential showed itself to have the most significant predictive ability of recovery from the three chosen tests (Dynamic WCST, Latent Implicit ToH and the Standard RULIT).

With regard to the initial exploratory questions that were outlined in section 3.5, this research has found that people with brain injuries clearly have difficulty learning. According to the best identified classification of learning potential (Dynamic Verbal Learning Potential using the WCST), 29% of the population were unable to learn independently or with guidance, 39% were able to learn independently and 32% were unable to learn independently but could with guidance.

This research found that certain factors had an influential effect on actualised learning ability. These were intellectual ability (pre-injury and current) and severity of injury. The ability to learn with guidance, however, was not significantly discriminated by any of these factors. In actual fact more Guided Learners had suffered a severe injury than a mild/moderate one, suggesting that potential to learn was not determined by severity of injury. Age at time of injury or at onset of injury did not have a significant impact on ability to learn with or without guidance. This finding is important as it suggests that age should not be a barrier to accessing rehabilitation. Time since injury was also found to not have an impact on learning ability, suggesting that the stage you are at in your recovery is not what influences ability to learn and engage in a process of change. This could be interpreted to suggest that there are not particular times when an individual might best benefit from a rehabilitation programme. Before this conclusion should be made, however, it would be important to establish if learner status classification is static or whether it changes over time. If the latter is true then it would have the potential to establish when a person is most ready for rehabilitation. If the former is true it would be easy to establish very early on who would benefit from intensive rehabilitation and who would need slow stream, compensatory environments or a package of social care. However, any interpretation of this should be tentative as the current data cannot be generalised to groups outside this sample.

If further research found evidence to support these findings the implications would mean that these types of classifications could be used as more explicable predictors of prognosis than variables currently in use. Moreover, families, carers and Service Users may more readily accept and engage with rehabilitation programmes designed around these categories instead of having unrealistic positive or negative expectations of rehabilitation and recovery.

As outlined in Chapter 8, section 8.1, the analyses investigating the impact of learning potential ability on community integration levels found that there were significant differences in integration between the ability groups. Each of the learner classifications was found to have significantly different levels of overall outcome to at least one other group. This is incredibly significant and indicates that learning potential may have the power to be used as a tool to estimate recovery. These measures of learning potential have been shown to delineate ecologically meaningful levels of ability which may be clinically meaningful in that they predict outcome in terms of everyday behaviours. The Rasch models in Chapter 5, section 5.3.1 (figures 15-18) show that a measure of learning potential measured through the Verbal Learning system using the Dynamic WCST created a considerably better spread than the measure of actualised learning ability measured using the Standard version. This could be aided by the fact that there are twice as many items for it as there were for the Standard WCST. However, increasing the number of items did increase the risk of clustering. There was little evidence of clustering for the dynamic item map, which suggests that including both the pre and post items of the WCST add something unique to the model.

In the investigation into the cognitive profiles for each of the Verbal Learning Dynamic classifications the concerns outlined by Grigorenko et al (1998), i.e. that learning potential might be reflecting variance among the cognitive profile, was partially confirmed. The ANOVAs investigating the main effect of learner status on cognitive ability followed a similar trend to the previous findings, suggesting that significant differences were principally between Non Learners and Spontaneous Learners. The cognitive functions that relate to learning ability were attention, working memory, intellectual function (both verbal and performance measure) and immediate verbal memory. No one cognitive ability was able to significantly distinguish between all three of the learning abilities, but the Colour Trails task (Colour Trails Two), which taps into some of the abilities outlined in the working memory model, could distinguish Non Learners from Spontaneous Learners and Guided Learners from Spontaneous learners. In addition, the measure of immediate verbal memory (WMS Logical memory) was able to distinguish Non Learners from both Spontaneous and Guided Learners. The profile suggests that the Colour Trails task is one of the most sensitive tests for discriminating learner classifications. This profile is interesting, particularly as it is almost the opposite of the findings by Farmer & Eakman (1995), who concluded that attention and immediate verbal memory were not related to instrumental activities of daily living (IADL) and concluded that this might be because they were easier to compensate for. However, closer examination of this work indicates that the IADLs used to reflect functional ability were meal preparation, cooking safety, balancing a cheque book, using the phone book, getting information from a travel agent and map reading. Individuals were scored on the basis of their planning, time awareness, cognitive flexibility, attention to detail, time to task completion, attention span, frustration, tolerance and self-confidence. It is possible that these specific tasks did not require the same cognitive abilities as reflected in the more extensive measure of recovery used in this research.

The overall conclusion to be drawn from this research it that obtaining a measure of a person's potential to learn using dynamic assessment can significantly aid the prediction of levels of recovery following brain injury.

9.2 Appraisal of the Dynamic Assessment Technique, Learning Potential and Methodology for Reflecting Change

Before the implications of this research are explored it is first necessary to review the techniques applied to it with regard to gaining a measure of learning potential. As discussed in the Literature Review (section 1.9.1), Learning Potential was originally defined by Vygotsky as an individual's performance on a test that has been freed from the restrictions of previous experience, heredity and the environment (in this case their brain injury and the testing situation). The individual's Zone of Potential Development (ZPD) was reflected in the improvement they made following guidance from a more capable peer. This ZPD is therefore their latent potential. Using this definition it is possible to conclude that two of the studies include the bi-directional interaction outlined in Vygotsky's proposals for a dynamic style of assessment. This suggests that richer neuropsychological information is collected which would otherwise be missed; the studies are the Dynamic WCST and the Dynamic RULIT.

This research recognises that there are valid criticisms regarding the methodological approaches chosen for this research i.e. test – train – test approach. As outlined in section 1.11.5 of Chapter 1, Minick (1987) described how using a quantitative approach such as the dynamic sandwich technique focused on the product of learning potential rather than the process of it. Despite these criticisms around the purity of the approach it was felt that of the two available, the more quantitative method was necessary to ensure robust standardisation and comparison between individual participants in the research.

The dynamic assessment procedure did meet three of the five recommendations made by Cicerone et al (1986) for developing dynamic assessment (see section 1.10). Firstly it was able to measure each individual's potential improvement with training (rule 1), and could therefore generate a classification of their levels of modifiability (i.e. independently modifiable, modifiable with guidance and not modifiable) (rule 2). However, instead of providing a measure of the level of intervention that was required to bring about a set level of change, this research standardised the intervention so everyone received the same, and therefore measured the change (rule 3). This research did not measure how well the change could be generalised, but hopes that future research will be able to (rule 4), it was, however, able to identify individuals' strengths that could be exploited for change (i.e. some would require guidance whereas others could learn spontaneously) (rule 5). It is recognised that the Non Learner group here has limited applications with regard to predicting strengths to be exploited and that this label is the most unforgiving because it suggests that there is no potential to learn and no positive outcome. However, the reality is that for a proportion of the population this might be the truth. Identifying this group is useful in that it establishes who is going to require ongoing care and adaptive environments that will compensate as best they can for deficits.

In terms of establishing whether there are any better techniques that might be useful in measuring learning potential, this research would like to have adapted a graduated prompts approach (Campione et al., 1987). The design of this technique is quite complex and involves developing a score based on the ratio of the extent of help provided and the transferability of this information (see Chapter 1, section 1.9.4 for a more detailed description). The errorless learning training method that was used for this research may seem crude in comparison to the graduated prompts approach in that it does not consider that each individual will require different levels of intervention and simply provides everyone with the same amount. This goes against the ethos that the WHO guidelines (World Health Organisation, 2001) are promoting, seeing each individual as unique and tailoring assessment and rehabilitation packages to individual needs. Providing hierarchical hints could also be more ecologically meaningful because the answers to problems are not simply provided (as with errorless learning). Instead individuals are still encouraged to be actively involved in working out solutions with the information they have available to them, and the measure created is a ratio of how much intervention is required to reach a certain goal. This technique has the potential for obtaining a quantifiable measure of how much intervention an individual might require for a rehabilitation programme. An argument in favour of the test – train – test approach over the hierarchical hints approach, however, is that in brain injury the errorless learning approaches are encouraged in rehabilitation settings (Evans et al., 2004; Hunkin et al., 1998; Kalla et al., 2001; Kessels et al., 2003), particularly if people experience memory impairments. People are not encouraged to guess and make mistakes, so perhaps the test – train – test approach is more pragmatic and, therefore, easily transferable to other areas of a person's rehabilitation. The test – train – test (Budoff 1987) approach using the errorless learning technique has the additional benefit in that it creates a standardised administration which, whilst so little is known about dynamic assessment in this field, aids understanding and limits confounding variables that could influence type one or two errors.

Chapter 2, section 2.1 outlined some considerations to explore when measuring change following dynamic assessment. The first consideration focused on whether dynamic assessment alters the validity of the assessment. This research has used Rasch models to establish that dynamic training alters the validity of each assessment. Although the overall fit for each of the learner status classifications belonged to the same construct (as shown in Chapter 8, section 8.2 Figure 37), the individual items of each test changed their position of fit, error and hierarchical placement following training. This suggests that the intervention had affected what the items were originally measuring as well as influencing relative difficulty compared to the other items.

The second consideration focussed on the difficulty of quantifying change following dynamic assessment. For the WCST, one standard deviation above the mean of the dysfunctional population created an equal spread of ability without ceiling or basement effects. For the RULIT, one standard deviation created too much of a ceiling effect. The Reliable Change Index for the ToH was adequate, although having more items to measure change with would have been better. This suggests that the cut-off for change is variable and should be dependent upon the test being used.

The third consideration was with regard to how reliable the dynamic assessment procedure is in ensuring that the change score is clinically and statistically meaningful, but this remains unclear. Change was clearly observed almost across the board, but for the Non Learners this change was minimal and failed to reach the specified cut-off. The classification of learning potential created by the Verbal Dynamic learning system using the WCST appears to be both statistically and clinically meaningful as this classification was shown, in Study Four (Chapter 8, section 8.3.2), to have more predictive power then any other variable included in the regression. The change score created using the Non-Verbal Learning system with the RULIT was not valid statistically or clinically, but this may not be an indication that the test is weak – it may be related to the cut-off for change being inappropriate.

The final consideration outlined in section 2.1 of Chapter 2 was with regard to the effect size that was expected to be observed following dynamic learning. This research estimated a large effect size and, as there were many significant relationships found using the sample size required to meet the power criterion for a large effect size, there is evidence to support this choice. As outlined in Chapter 3 section 3.4.2, a large effect size is usually applied when there is little overlap expected within the groups. However, the Guided Learner group was found to have a large spread of variance, which suggests that a medium effect size may have been preferable. Despite this there were many significant relationships found throughout the analyses (refer to Table 21 for a summary). It is recognised that there is evidence that a large effect size was created by the dynamic assessment and that perhaps the non significant findings are correct, as opposed to being Type II errors. Until further research is conducted all non-significant findings need to be interpreted cautiously.

In conclusion, this research was able to create valid classifications of learning potential using the test – train – test approach. The cut-off applied to reflect clinically meaningful change has highlighted that information gained from dynamic assessment will vary according to the test being used. It appears that tests which tap into an Explicit Verbal Learning ability might lend themselves best to the dynamic assessment approach.

The following part of this chapter will evaluate the measures included and created by this research and will outlined some of its limitations. Following this the clinically significant findings will be outlined and attention paid to their implications.

9.3 Evaluation of this research

Before considering the clinically significant findings, it is first important to consider the measures (for both the independent and dependent variables) that have been included and subsequently created (i.e. cognitive adaptability). Particular attention will be paid to evaluating the CIQ as it is this scale which is being used to reflect recovery levels. Other variables that have been found to be problematic will be outlined and the limitations of the research will then be summarised.

Whilst the conclusions to be drawn from this research are promising, there were findings in the research that were unexpected. These were mainly in relation to the non-significant findings in the Home subscale of the Community Integration Questionnaire. It is important to establish if these were Type II errors, due to a weak assessment or if they were non significant because there was no significant relationship to find. As Altman and Bland (1995) emphasise, it is necessary to try and establish whether the study has strongly shown that specific findings were not significant, or whether the data simply points to lack of evidence due to the statistical quandaries suggested above.

The CIQ appears to be sensitive enough to discriminate between different levels of ability. However, over the three studies the differences found were mainly reflected in the Total Integration and Social Integration scores (with the exception of the dynamic WCST which found a significant difference for the Productive Activity scores in addition to these). The sub groups that tended not to find significant differences between learner classifications were the Home and Productive Activity integration scores. This suggests that typically these areas of functioning (i.e. activities that centre around running the home and purposeful activities outside of the home) do not differ across different learning ability groups. If this finding is accurate, then these dimensions of the CIQ may not be clinically useful for monitoring recovery. Alternative explanations for their lack of sensitivity in discriminating could be related to the two assumptions of parametric research which were broken by this item (i.e. non normal distribution and heterogeneity of variance). However, as previously mentioned, there is evidence that parametric assessment is robust against skewed data (Glass et al., 1972) and that in cases where data is skewed it is still preferable to use parametric research as opposed to non parametric analysis (Gangestad & Thornhill, 1998). A further explanation might be that the lack of variance across learning classifications might be a reflection of the demographics of the population. It was perceived that a significant proportion of this population were men in their twenties, many of whom lived at home with their parents. A significant amount of the Home Integration score reflected the fact that parents retained responsibility for the household chores. It is also interesting that, in this section, doing all these roles independently represented a more integrated function than if you were doing it with someone. This incongruence in the scoring was previously mentioned by Dijkers (1997) and discussed in the Literature review (Chapter 1 section 1.3.1).

The CIQ could be better interpreted if there was normative data available. This would allow an indication of what levels of functioning on the CIQ are likely to be related to clear functional impairment or likely to be a barrier to productive community participation. Normative data from the CIQ that would allow us to distinguish levels of functioning would be of value, and would allow a distinction between scores that predict a challenge to everyday functioning where participation might be affected. The current interpretation applied to this research establishes that Spontaneous Learners have significantly better integrated functioning compared to Non Learners, but it is unclear if these two discrete groups are functioning within a range expected of the general population. It is quite possible that even though some of the ANOVAs investigating CIQ subscales found no significant differences between learner groups, individuals within a group could be functioning above or below a threshold that could cause significant difficulty with everyday tasks. Having this normative information would mean that it is not relevant whether the difference between two of the groups is significant or not, rather the focus should be on whether the scores are within usual limits or not.

An ideal alternative would be for a measure to be developed from the vast International Classification of Functioning (World Health Organisation, 2001). This would provide a more comprehensive consideration of the individual as a whole. The WHO's ICF focuses on what an individual's impairments are and how these impact upon their function, with consideration paid to the environment in which they are functioning. This would take into account the buffering effect that an individual's environment and personal situation can have on the functional score. This is unlike the CIQ, which requires some interpretation when considering what might be influencing the integration levels. An example of this would be that the CIQ does not consider the individual, simply what their role is in the community. The ICF would be able to establish what might be limiting the individual from carrying out some of their pre-injury roles, for example physical impairment, as well as impaired learning ability.

Weaknesses in the other variables included throughout the studies could have an impact on why they were not found as useful. For example, as previously discussed in Chapter 1 section 1.4, there are weaknesses in using the amalgamated total score of the Glasgow Coma Scale, which can affect the rating of severity of injury; however, as it was common that the total score alone was provided in the medical records this was often the only indication of severity that was available. There was also no way to investigate what factors might be contaminating these scores, e.g. alcohol, sedation, tracheostomy, etc. Despite these weaknesses, the GCS was found to have a significant main effect on learning ability, but in the multiple regressions in Study Four it was not a variable considered important in predicting outcome. Other measures such as computed tomographic severity calculations (Dunham, Ranson, Flowers, Siegal, & Kohli, 2004) would probably have created a more sensitive measure. It also would have been helpful to include a measure of Post Traumatic Amnesia as this has been found to be significantly related to outcome (Bishara et al., 1992), but, as this information is not routinely collected in the medical records and as the ABI team was not consistently involved in the acute stage, it was not possible to collect this information. Retrospective assessment was thought to be too inaccurate and so was not included.

With regard to factors that are known to influence recovery rates, such as alcohol abuse and substance misuse, the exclusion criteria made explicit that people could not be currently engaged in these activities but, it is possible that people could have experienced pre-existing difficulties that are known to have an impact on neuropsychological outcome (Corrigan, 1995; Kelly et al., 1997; Solomon et al., 1992).

9.3.1 Potential Applications of the Measure of Cognitive Adaptability

If a measure of cognitive impairment can be used to predict the degree of difficulty an individual could experience, a measure of cognitive adaptability could reflect the degree of compensatory ability a person has available to them to overcome these limitations. This viewpoint is supported by the findings of Ezrachi et al (1991), who concluded that cognitive function predicted outcome in a pre-treatment group, but that after rehabilitation it was unable to. This suggests that once strategies have been mastered the degree of the impairment is irrelevant as it has been compensated for. A measure of cognitive adaptability might be able to provide clinicians with information about who needs assistance in learning skills to compensate, who does not and who is not yet able to learn how. Future research needs to establish whether this measure of adaptability changes in its sensitivity to predict outcome both before and after a rehabilitation programme. Prior to rehabilitation it could predict the ability to engage in and benefit from a rehabilitation programme. Post rehabilitation it could predict ability to use and transfer these skills in the real world (which is ever-changing and requires a need for flexibility and fluidity in thought). It is recognised that using classifications which may contribute to decisions about access to rehabilitation needs to be considered very carefully as it raises ethical concerns.

It is not suggested that dynamic assessments replace all standard assessments, as Hellawell et al (1999) concluded cognitive impairments are indirect markers that reflect functional outcome and as such they guide clinicians towards goals to work towards in a rehabilitation programme. The addition of measures of learning potential simply provides information about who is ready and what degree of support they might require.

9.3.2 Limitations

Problems with Power

In estimating a large effect size, which is not typical for this type of research, there was a risk that the required size of effect was not always achieved. As a result, findings that failed to reach significance may have been Type II errors (false negatives). If a medium effect size was chosen instead, this could have reduced the risk of Type II errors but risked doubling the number required for the sample. This would have had huge implications in the timescale for the research. Furthermore, the difficulty in this type of research is that you cannot predict who will fall into specific classifications. This means that, even if a very much larger sample had been collected an uneven distribution for the specific categories would still be a risk. Interpretation of any of the non significant findings has been tentative, as it is difficult to establish if they were due to inadequate power required for what should have been a medium effect size or simply down to there being no relationship to find. The fact that the Dynamic Verbal Learning classifications yielded so many significant relationships suggests that the effect size created by these classifications was large and therefore powerful enough to be able to differentiate between groups.

Increased Risk of Type I Errors

As well as there being a risk of Type II errors occurring as a result of compromised power, the findings from this research also run a risk of being interpreted with Type I errors. In guided discovery research such as this, multiple concurrent analyses can be conducted as part of an exploratory design. It is possible however that this type of investigation could be interpreted as fishing for significance. Perhaps this research could have benefited from applying a Bonferroni correction to the alpha, however as this is known to weaken power and increase the risk of a Type II error being made, it felt unsuitable to apply this to an already small sample; particularly as there were no null hypotheses to accept or reject. As this research has now begun to build some evidence, future research may be able to apply multiple hypotheses to be tested, in this situation applying the Bonferroni correction, would be advisable.

Problems with the cut-offs applied

In terms of understanding the impact that dynamic training had on the validity of the tests it is felt that future consideration should be paid to developing normative information relating to the pre and post training performance of a dynamic test. This would allow for an understanding of functional and dysfunctional performance at both trials. For this research using one standard deviation above the mean of the dysfunctional population appeared to be appropriate for the WCST but was perhaps not for the RULIT, as this made it too easy and created a ceiling effect. A limitation in using a cut-off is that it moves away from looking at the individual and how much change they achieved.

Instead it only provides a crude measure of whether they reached a relatively arbitrary point or not. Having normative information would remove the need to use cut-offs and would be preferable. These norms would need to be specifically developed for dynamic assessment as the aim is not to support someone to function within normal limits of the standard test (a better than average performance as determined by the static norms would be expected if training involves teaching someone how to pass), rather it is to establish how a person can use and apply guidance (therefore information about how much change is typical in the general population would be a useful comparison).

The Sandwich Test – Train – Test Approach

The aim of dynamic assessment is to measure a latent ability; i.e. the ability to take on information, to learn to adapt and then to apply and transfer this information. Perhaps errorless training removes some of this as people can learn parrot fashion (i.e. remember as opposed to understand). It is possible that the test – train – test approach creates a shallow processing of understanding which is not able to be applied as easily as if the knowledge had been developed hierarchically.

Errorless learning for this research is seen as a useful tool to overcome memory problems often encountered following an ABI. It should not necessarily be seen as a method for all models of training. This research recognises that errorless learning has its limitations (i.e. it runs the risk of removing active participation of the individual). It should be remembered that this research was not focussing on the benefits of errorless learning for rehabilitation, it was focussing on showing that people can take on information and use it (errorless learning was simply used as a tool to enable information to be retained long enough to be applied).

Creating Classifications of Ability

An important consideration in the interpretation of this research is that the discrete classifications applied to the data (i.e. Non learners, Guided Learners and Spontaneous Learners), came from a hierarchical distribution of a single underlying scale (the Rasch model). Attempts were made to ensure that the data was split at the most meaningful points (i.e. those who were unable to improve enough following training to reach the cut-off of the easiest item; those who did well independently and those who improved), however any comparisons between classifications should be tentative, as they are still arbitrary splits in a continuous data set. Future research could investigate ability based on a continuum, to allow correlational analyses between variables.

Lack of Inclusion of a Standardised Test of Learning in the Analysis

A potential limitation in this research was that it failed to include a standardised test of learning in the cognitive profile created for each of the Learner Status Classifications. Including such a test (e.g.. the California Verbal Learning test, (Delis, Kramer, Kaplan, & Ober, 2000)) would have allowed for an interesting comparison between the reflections of ability created by the standardised measure to the levels of ability created by the dynamic tests. Whilst standardised assessments have been described throughout this research as static and unnatural in that they fail to allow an individual to compensate for their impairments, it is accepted that it is difficult to conclude that the dynamic tests of learning are more useful than the standardised tests as a comparison between them has not been made. Future research would benefit from including them in the analyses for comparison.

9.4 Clinically Significant Findings

9.4.1 Learning Potential is the Best Predictor of Recovery

The most compelling and influential finding of this research is that utilising a measure of learning potential (which capitalises on the verbal processing system) predicts recovery more significantly than any other factor. Using Rasch Analysis to delineate learning ability on the Dynamic WCST allowed three classifications of performance to be created, Spontaneous Learners, Guided Learners and Non Learners. The investigations into the research questions for Study One and the cognitive profiles created in Study Four allow for a description of a typical presentation found within these groups.

The Spontaneous Learners are likely to have experienced a mild or moderate brain injury, they are likely to therefore have more passive cognitive reserve (i.e. less damage to the brain, therefore more left undamaged). There is evidence that pre-injury they had more active reserve (reflected by their higher predicted pre-injury IQ and their higher levels of SES (Scarmeas et al., 2003)), which could have buffered against the effects of the injury. This group's current intellectual abilities are within usual limits, visual memory is within the average range, but is likely to have been blunted by the injury. Attention and working memory sit comfortably within the average range, as does verbal immediate memory (these three abilities along with IQ are significantly higher than the Non Learner Group). The average time spent in education for this group was twelve years. The Spontaneous Learners group has the highest levels of community integration and has experienced significantly less change in integration levels when compared to the Non Learner population.

The Non Learners are most likely to have experienced a severe brain injury. This suggests that they have less passive reserve available to them compared to the Spontaneous Learner group. There is also evidence that there was less pre-injury active reserve to moderate the effect of the injury (predicted pre-injury IQ is significantly lower than the Spontaneous Learners). Current cognitive abilities are generally in the impaired range, and intellectual function is low average. Non Learners have a significantly lower level of community integration than the Spontaneous Learners and Guided Learner group.

The Guided Learners experienced a range of injury severity levels (GCS mean was 9, but the range was spread from the most to the least severe classifications i.e. 3-15). More individuals in this learning classification experienced a significant injury than a mild/moderate one. It is assumed, therefore, that this group had less passive reserve available to them than the Spontaneous Learners. Current intellectual ability was found to be at a similar level to that of the Non Learners. Measures of attention and working memory place ability in the low average range. Visual memory is in the borderline range and immediate verbal memory is low average. Perhaps the most interesting finding for this group is that levels of recovery (community integration) are not significantly different to that of the Spontaneous Learners, but are significantly better than the Non Learner Group. This group of individuals did not reach the cut-off for the pre-WCST items and only performed above the cut-off following guidance. This suggests that if only the Static Standard version of the WCST was used the majority of these Guided Learners would have failed the test

(Figure 19 identified that according to the 16th percentile cut-off, 45% of those individuals who were identified as being Non Learners had potential to learn).

The findings from this research support the evidence provided in McColl et al's (2001) paper. Their brain injury population identified that two of the factors which are important for a good outcome are, firstly, knowing the rules and, secondly, knowing how to follow them. This research proposes that dynamic assessment can highlight who will be able to identify and follow the rules independently (Spontaneous Learners), who are unable to identify the rules independently but can follow them once they are highlighted (Guided Learners), and those who due to severity of injury, reduced passive and pre-injury active reserve, impaired cognitive function and possibly other factors are unable to identify or follow the rules, with or without support (Non Learner Group). As this research has shown that being able to identify, or at least follow the rules, is significantly related to outcome it provides further evidence for McColl et al's conclusions. It also, perhaps, indicates that this test therefore reflects an ecologically valid ability.

9.4.2 Latent Potential to Learn cannot be Predicted by Variables Known to Influence Recovery

The Analyses of Variance investigating factors that are known to affect outcome (such as current and pre-injury IQ and severity of injury) were able to discriminate between Non Learners and Spontaneous Learners, but were unable to separate the Guided Learner group. This means that these variables had a significant effect on the group that learned independently as well as the group who were unable to learn both independently and with guidance, but were unable to distinguish those who had a latent ability to learn with guidance. It was concluded that this signifies that potential to learn is influenced by factors beyond those currently measured.

No significant main effect was found across the studies for current age and learning ability. This means that different age groups do not learn in different ways, or respond to guidance differently. This finding is unlike that for Campione and Brown's (1987), research which found that the elderly population viewed the guidance negatively, which in turn affected their performance. Perhaps because this research utilised an errorless training approach, as opposed to hierarchical hints, this meant that people viewed the training as a natural part of the assessment process, as opposed to the need for help due to failure.

9.4.3 Pre-injury Cognitive Reserve Is the Only Other Factor That Predicts Overall Outcome

The only other factor that was found to predict total levels of community integration was socioeconomic status. This finding supports that of Ownsworth et al (2004), who also found that one of the best predictors of outcome is pre-injury occupational status. This finding supports the active model of cognitive reserve that was discussed in the literature review (section 1.11). As previous research suggested that active reserve (the brain's efficiency) can be indirectly indicated by SES (Scarmeas et al., 2003) and because a correlation was found between SES and outcome, there is evidence to suggest that having a better SES pre-injury will moderate the impact of the injury. The measure of pre-injury IQ could also be used as a reflection of pre-injury active cognitive reserve ability. In Study One an analysis of variance investigating the main effect of learner status on pre-injury IQ found a significant difference between Non Learners and

Spontaneous Learners indicating that, at either extreme, pre-injury cognitive reserve could have a role in determining learning ability, but not learning potential. For the Standard RULIT pre-Injury IQ distinguished Non Learners from Learners, which is an interesting finding and indicates that Learners and Spontaneous Learners have the relatively equal degree of reserve, but that the Learner group has a significantly higher predicted pre-injury IQ than Non Learners.

As there was a negative relationship found between the severity of injury and learning ability, there is some evidence to support the passive reserve theory (although an assumption has to be made that a more severe injury, as measured by GCS, will result in a larger degree of physical damage to the brain). Unfortunately, there is no information available to establish how much damage the brain received proportionally to its size, compared with how much remains undamaged (passive reserve), it would be interesting to know this to confirm whether passive reserve has a moderating effect.

Having established that pre-injury reserve is related to outcome, this research also considered if Learning Potential might be a reflection of an individual's current levels of cognitive reserve. As Baltes et al (1992) (section 1.11.4) concluded, performance on a test following training (Development Reserve Capacity) would be more effective at predicting outcome than the baseline performance and this Development Reserve Capacity is moderated by cognitive reserve. This research has supported their hypothesis.

As SES and Learning Potential were the only factors found to predict outcome it could be interpreted that these measures reflect pre-injury levels of cognitive reserve (SES) and post-injury levels (Learning Potential). It appears that cognitive reserve plays an important role in moderating recovery following brain injury.

9.4.4 Dynamic Assessment Adds to the Current Understanding of Ability Following Brain Injury

This research has shown that dynamic assessment has an important role within a brain injury population. Performance on a standard test utilising the verbal learning system was less effective at predicting recovery than that on the dynamic version of the test. This was not found to be the case for the Non-Verbal test of learning however, which suggests that the choice of the test is important. It appears that the test must be complex enough so that even after errorless training it is still taxing. This perhaps requires a verbal element which must be maintained and manipulated in the working memory system (which is perhaps why the cognitive profile identified a test which taps into the working memory skills as a variable that significantly influences learning ability). An interesting finding is illustrated in Figure 37. Here the Bubble chart indicates that each of the learner status classifications (for both dynamic and standard versions of the tests) belongs to the same unidimensional construct, but they appear to have different sensitivities in terms of how they relate to recovery. The Dynamic Verbal Learning system relates to levels of community integration very well, whereas Dynamic Non-Verbal learning does not. Whilst the reasons behind this have been put down to the errorless learning intervention making the test too easy it is interesting that the investigation into fit did not rule it as an outlier. Adding a second trial to the Tower of Hanoi creates a better spread and the classifications of learning ability relate better to outcome. However, this might be because it allowed more items to be included, or because for the

Standard ToH the cut-off was different to the other standard tests or because the classifying criteria had to be changed to compensate for the large basement effect. Possible further research could explore in more detail whether it is these tests that have created these classifications, or if it is a true reflection of the processing system that they tap into.

Working Memory and Learning Potential

In the investigation of why the Verbal and Implicit learning tests appear to gain a more meaningful measure of learning potential when compared to the Non-Verbal system the role of working memory appears to be important. Intuitively working memory and learning potential are related; the ability to hear instructions, keep them in mind, constantly update information with feedback etc. seems to require the ability to hold information online and manipulate it. These all appear to be skills that are required for either successful independent completion of a relatively complex test, or successful completion following instruction. The cognitive profile found that the most significant measure for distinguishing learning potential was one that involved aspects of working memory ability (i.e. Colour Trails Two).

It is possible that the reason why the Dynamic WCST had the best discriminating ability is because it was complex enough so that, post-training, the significant amount of information which had been provided during the training needed to be held online, manipulated and updated for a successful completion to be achieved. In contrast, on the post-training RULIT individuals were simply required to remember a 15 step route that they had been taught. For the standard administration, the RULIT is likely to have required all of the working memory skills outlined by Gilhooly et al (2002), i.e. a fractionised working memory that involves the role of focussing and switching attention, activating representations in long term memory and co-ordinating multiple task performance. This is perhaps why the Standard RULIT provided more meaningful classifications of learning than the Dynamic version. The investigation into the Latent Implicit ToH suggests that there was still a role for the working memory system in holding onto information from the first trial and then using this information and manipulating it to make a significant improvement on the second trial (even if this was less conscious than the verbal test).

Despite the evidence that working memory is important in influencing learning ability previous research has shown that it does not correlate with learning (Parente et al., 2001). However, as discussed in the literature review (section 1.7.2), it was found to predict learning, suggesting that it is a necessary requirement for learning to take place. When seen this way, working memory could be thought of as the cornerstone on which the other processes involved in learning can begin. From the discussion above, working memory is still necessary for the ability to learn dynamically, and a possible explanation for why some individuals were unable to learn following training is because they do not have a functional working memory system.

With regard to the role of attention, it was interesting to note that the evidence base appears incongruent. Wood (2005) described attention as a thread which runs through the fabric of human life, whereas other research has concluded that it was not related to outcome and was more easily compensated for (Farmer et al., 1995). As this study has emphasised the different types of attention (section 1.7.1), it is possible that whichever modality was measured by

Farmer and his colleagues, it was not related to IADLs. In this research the items of the WCST that are thought to reflect attention were found to not belong to the overall construct of cognitive adaptability (see Figure 18). However, as with the measure of working memory, that is not to say that attention did not have a fundamental role, but it is simply that this role was not what was being measured by the test. As the cognitive profiles indicated that attention was only in the impaired range for the Non Learner group this suggests that attention is important and that impaired attention impacts on the ability to learn. Referring back to the models in the literature review (section 1.7.1) attention can be thought of as a limited resource. In novel situations (for example a test setting or a guided learning experience) active controlled processing is necessary. In the dynamic learning situation an individual is required to select, divide and sustain their attention. For those participants, whose attention is in the impaired range (and therefore limited already), this degree of controlled processing is difficult, if not impossible.

Whilst learning potential is not a direct measure of attention, attention is still essential for successful completion on the dynamic test.

9.4.5 Learning Potential is a Global Construct

As described in section 8.2 and outlined in Table 22, each of the classifications of learning ability created similar distributions for the Non Learner classification, but there was discrepancy in who was identified as Spontaneous Learners and Guided Learners. This indicates that the ability to learn is influenced by the processing system being used (suggesting that some systems are more difficult than others), but that fundamentally it all belongs to the same global construct. Figure 37 provides further support for this hypothesis, showing that each classification of learning ability belongs to the same unidimensional construct. The discrepancy suggests that individuals might have relative strengths according to the processing system being used or perhaps that whilst learning potential is global, some learning systems are easier than others (e.g. Visuospatial Learning is easier than Verbal, and Implicit is harder than both Non-Verbal and Verbal).

The fact that all of the learning classifications were shown to belong to the same construct suggests that the label of Learning Potential is not quite appropriate for this ability, but is mainly because the Standard versions of the test are measuring actualised learning ability rather than potential. In the exploration of what alternative label for this range of abilities might be available attention was paid to some of the models discussed throughout the literature review. One possible label of this overall ability could be 'fluid intelligence' which was discussed in Duncan et al's (1986) paper. The authors concluded that fluid intelligence and measures of executive ability might be tapping into the same underlying ability. They described the most influential factor in shaping behaviour as goal neglect, and that this is affected by novelty, weak feedback and multiple concurrent concerns (please see section 1.7.3 for more detail). The studies in this research have tended to focus on goal neglect (knowing what to do, but not being able to follow this instruction). The results appear to suggest that those with the most fluid intelligence are Spontaneous Learners; they are not overwhelmed by novelty, use feedback well and can juggle multiple concurrent concerns. Guided Learners are overwhelmed by novelty, can use feedback when it is explicit and can juggle multiple concurrent concerns. With only the static assessment it is possible to identify those with high and low levels of fluid intelligence, without an ability to separate out those in the middle.

Another label that could be applied to the underlying construct of the measures of learning potential could be found in Anthony's (1993) model of recovery. As discussed in the literature review (Chapter 1, section 1.6) this model identifies that, where possible, it is the individual's responsibility to enable change. Perhaps Learning Potential could be seen as a tool to reflect the adequacy of an individual's cognitive profile in providing the conditions necessary to work on change. The measure of Learning Potential could provide an understanding as to whether the person can take an active part in rehabilitation. The Non Learners appear to be stuck in an organically determined 'sick role', whereby they are unable to actively engage in the process of rehabilitation and cannot take responsibility for their recovery. Anthony suggests that the recovery model does not apply to those in this situation, and that the individual must be cared for until they are ready to engage. This is further reinforced by the CIQ scores, which show that this Non Learner group are those who require the most support living in the community. The measure of Learning Potential could be seen as a gauge of the person's readiness and potential for development (Darton, 2002). Being able to be insightful to, and aware of, themselves and their injury suggests an aspect of their personality style, possibly moderated by their cognitive impairments. It would have been interesting to have included a measure of insight in this study to see if it is connected with learning potential somehow. It seems that those who are in the Guided Learner group might somehow be more insightful into their difficulty, which perhaps makes them more amenable to adaptation. Alternatively, perhaps it could be that those who improved or who did well independently were simply less impaired.

It is possible that an alternative label of the construct of learning potential could be found in the model of executive function (Supervisory Attention System, Norman et al. 1986) that was applied to this research (please refer to Chapter 1 section 1.7.3 for more detail). In this model the Contention Scheduling process consists of three stages. The first stage is strategy generation, the second consists of the development of the chosen process and the final stage monitors the process and makes adjustments if necessary. Spontaneous Learners were able to perform at each of these stages independently, Guided Learners were those who were unable to generate strategies to manage this novel task, and so were provided with the process required for successful completion. They were then able to monitor the process and stick to it. It is possible that if the novel task was similar to one previously encountered the Guided Learner might be able to access information from memory that could assist, and thus Guided Learners might be Spontaneous Learners on more familiar or easier tasks. This could be supported by the results, which indicate that some tests created more Spontaneous Learners than others.

Feuerstein's (1979) Learning Potential Assessment Device proposed that cognitive function was modifiable and that dynamic assessment created a mediated learning experience which would provide information about how much intervention a person required for this change to occur. Although Cognitive Modifiability was a term coined with regard to dynamic assessment techniques it is not felt that it applies as well to this research, modifiability suggesting that the focus is on how much intervention is required, whereas this research focuses on whether significant change occurs following the standardised training intervention. Instead it is proposed that the term 'Cognitive Adaptability' would be more appropriate as it refers to a person's ability to adapt to a situation and take on board new information, either independently or through interaction with another.

9.4.6 The Utility of Rasch Analysis in Conceptualising Learning Potential

A tool that has been pivotal to the conceptualisation and interpretation of this research has been the Rasch Analysis Model. Without it the interpretation of change, the hierarchy of performance and ability would have been very difficult to express. This tool has made it possible to see the impact that dynamic assessment has on standard assessments, what it changes and how. It has shown that although overall constructs may not change, some individual items within a test do, and this information is crucial in the interpretation of performance for people after training. Not only has Rasch been able to show individual potential within this population, but also its own potential in terms of understanding and interpreting any form of cognitive assessment.

9.4.7 Further Research

As discussed earlier on in this chapter, future research could explore using a different style of Dynamic Assessment, i.e. the Graduated Prompts approach, to gain a different perspective on the measure of learning potential. The risk of the test – train – test technique is that it might make a test one of memory rather than latent learning ability. It is possible that providing hierarchical hints could measure this fluid ability more effectively. It would be interesting to develop assessments that might be more relevant ecologically in order to establish whether guidance provided from one test can be transferred in another setting. This could see the integration of dynamic style interventions applied to the rehabilitation setting.

It would be interesting to see this research reproduced in order to identify whether the same relationships could be recreated within a different brain injury sample. Ideally a medium effect size could be predicted and the number of participants involved could be increased. An interesting alternative design that could be applied to this research would be to incorporate a control group. This would make it possible to compare the improvement possible without instruction (i.e. practice effect), to the improvement made with it. Having a control group would be beneficial for two reasons; firstly it would then be possible to establish the degree of change that is attributable to the instruction being given (after controlling for practice effect), which might provide some sort of gauge for 'rehabability'. Secondly it is possible that a measure of practice effect alone would have more clinical utility than a measure of improvement following guidance.

Perhaps different measures of recovery could also be applied. This research would like to see outcome measures that indicate more explicitly the functional limitations that people experience in order to establish what might be contributing to them. Ideally an assessment based on the ICF (please refer to Chapter One, Section 1.3 for more information) could be developed.

Having concluded that Dynamic Verbal Learning (using the WCST) creates the most meaningful measure of 'cognitive adaptability', it would be interesting to compare other tests that have an explicit verbal role to establish if the value is in utilising the verbal system, or simply the specific elements of the WCST itself.

The possibility of conducting dynamic assessments and using prospective predictions of outcome would provide a rich evidence base about the role of cognitive adaptability and recovery. To use these classifications to predict the success of engagement in a rehabilitation programme as well as predicting outcome following rehabilitation would help to establish how best to harness this measure and apply it in a meaningful way. It is possible that this could have significant implications for carers, service users and commissioners of services alike. Careful consideration would need to be paid to the ethical implications of applying this kind of label. An alternative and perhaps more preferable approach could be to follow in Budoff's (1987) footsteps, to remove the classifications and begin to investigate learning potential ability along a continuum. Alternatively, the development of Learning Potential norms could begin to identify whether people had an acceptable degree of learning capacity to enable them to benefit from a rehabilitation setting. A future, but related, aspect would be to ascertain whether cognitive adaptability is a fixed ability or one which can change over time.

9.5 Conclusion

This research set out to investigate whether a measure of learning potential, as created by a dynamic style of assessment, could add to our understanding of person ability and could aid outcome prediction following brain injury. To ensure a thorough examination of learning potential ability, different tests were included each one capitalising on a different processing system (i.e. Implicit, Explicit Verbal and Explicit Non-Verbal/Visuospatial). As this type of assessment is relatively unexamined and is not known to have been applied to a brain injury setting, exploratory questions were applied as opposed to hypotheses to be confirmed or disconfirmed.

The investigations have found that a measure of learning potential (later renamed cognitive adaptability) utilising the verbal processing system is a better predictor of recovery levels following brain injury than measures identified by the current evidence base. The dynamic assessment process was able to create a better spread of person ability, separating impaired individuals into two groups (i.e. those who could improve with guidance and those who could not). In an attempt to explain this significant finding, it has been posited that dynamic assessment allows those individuals who are cognitively impaired the opportunity to learn to adapt, or to compensate for their impairments in a testing situation and to, therefore, improve their performance on the test. It is proposed that in everyday function these individuals, who are cognitive impaired, have learnt to compensate for their difficulties, but, in a novel static testing situation they are limited by their impairments and are, therefore, not allowed the opportunity to show how they can learn to compensate for them. Therefore the static assessment is unlikely to predict abilities in an ecologically valid way.

In an investigation of the construct of the assessment it was identified that the hierarchy of item difficulty and fit changes following an errorless training intervention, this could also be contributing to the improved predictive ability of the assessment.

The only other variable found to predict overall levels of integration was SES. This finding added weight to the theory of cognitive reserve playing an important role in determining outcome following brain injury, with pre-injury active reserve being reflected by levels of SES and current active reserve being reflected by cognitive adaptability levels. A measure of passive reserve (severity of injury) was not found to significantly predict outcome. However, it was suggested that this measure was not a good reflection of the degree of injury due to administrative and methodological limitations.

It is recognised that this research is only a preliminary examination and that extensive further research is required before any firm conclusions and decisions can be made on the basis of these classifications of learning ability. Particular attention will need to be paid to the ethical implications of labelling participants as Non Learners and the potential restrictions to rehabilitation that this may create. A possible alternative would be to consider abandoning the classification system and focus on a linear continuum of ability, or even on developing norms to establish functional and dysfunctional degrees of cognitive adaptability. Future research could also explore alternative methods of dynamic assessment and involve other tests to establish how much value is placed on the processing system being used, or how much is down to the nature of the test itself.

It is felt important to stress the value in applying the Rasch Analysis model to each of the studies. Without it this research would not have been able conceptualise the implications of adapting a standard test. The use of the Rasch has allowed an in-depth understanding of the impact that dynamic testing has on the validity of an assessment on an overall and individual test item basis. It has also been incredibly helpful in evaluating person ability in the context of individual item difficulty. It is recommended that any future investigations into dynamic assessment apply this approach where possible.

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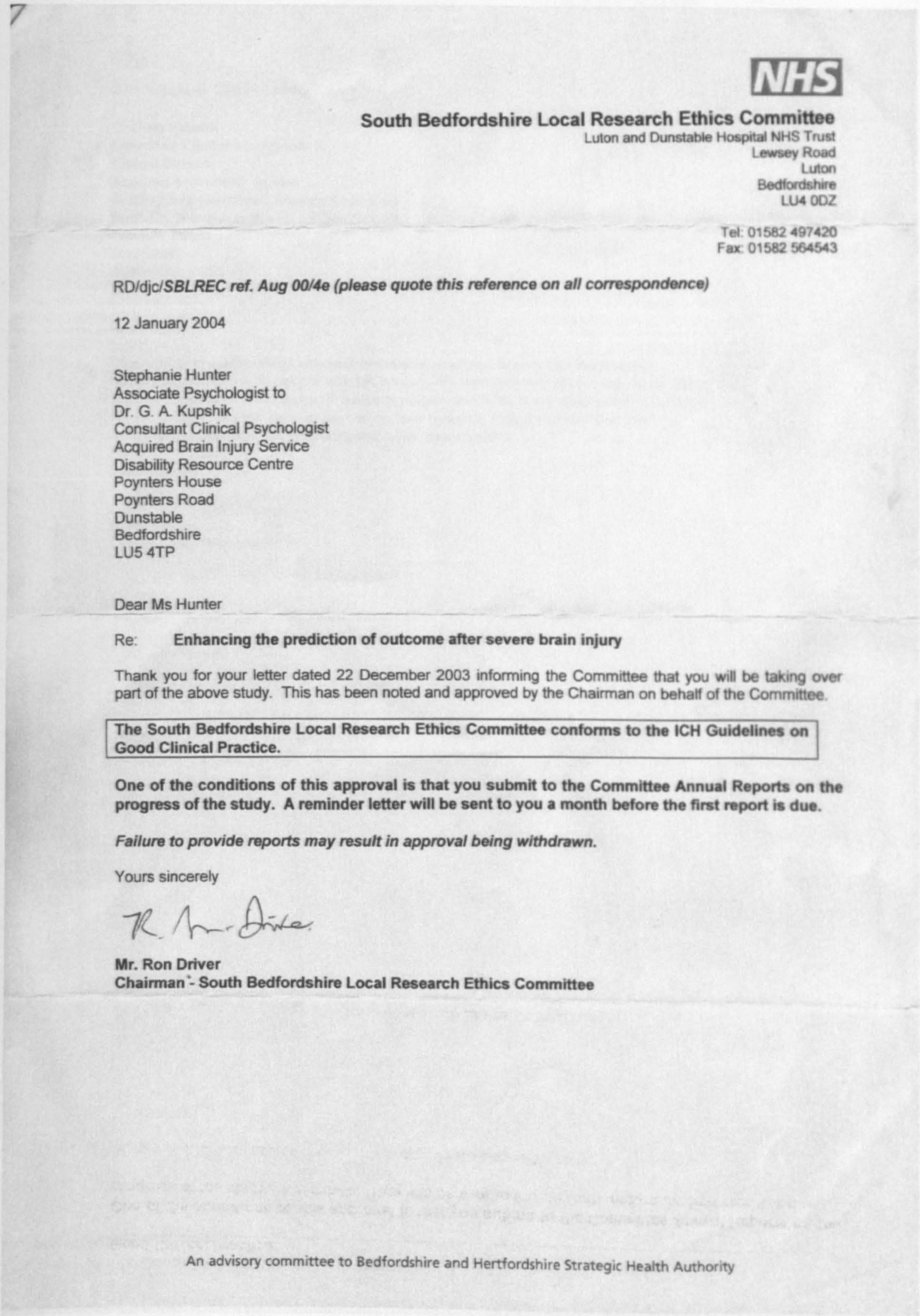
Chapter 10 Appendices

Appendices 1: Ethics Approval



7

NHS
South Bedfordshire Local Research Ethics Committee
Luton and Dunstable Hospital NHS Trust
Lewsey Road
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LU4 0DZ

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RD/djc/***SBLREC ref. Aug 00/4e (please quote this reference on all correspondence)***

12 January 2004

Stephanie Hunter
Associate Psychologist to
Dr. G. A. Kupshik
Consultant Clinical Psychologist
Acquired Brain Injury Service
Disability Resource Centre
Poynters House
Poynters Road
Dunstable
Bedfordshire
LU5 4TP

Dear Ms Hunter

Re: **Enhancing the prediction of outcome after severe brain injury**

Thank you for your letter dated 22 December 2003 informing the Committee that you will be taking over part of the above study. This has been noted and approved by the Chairman on behalf of the Committee.

The South Bedfordshire Local Research Ethics Committee conforms to the ICH Guidelines on Good Clinical Practice.

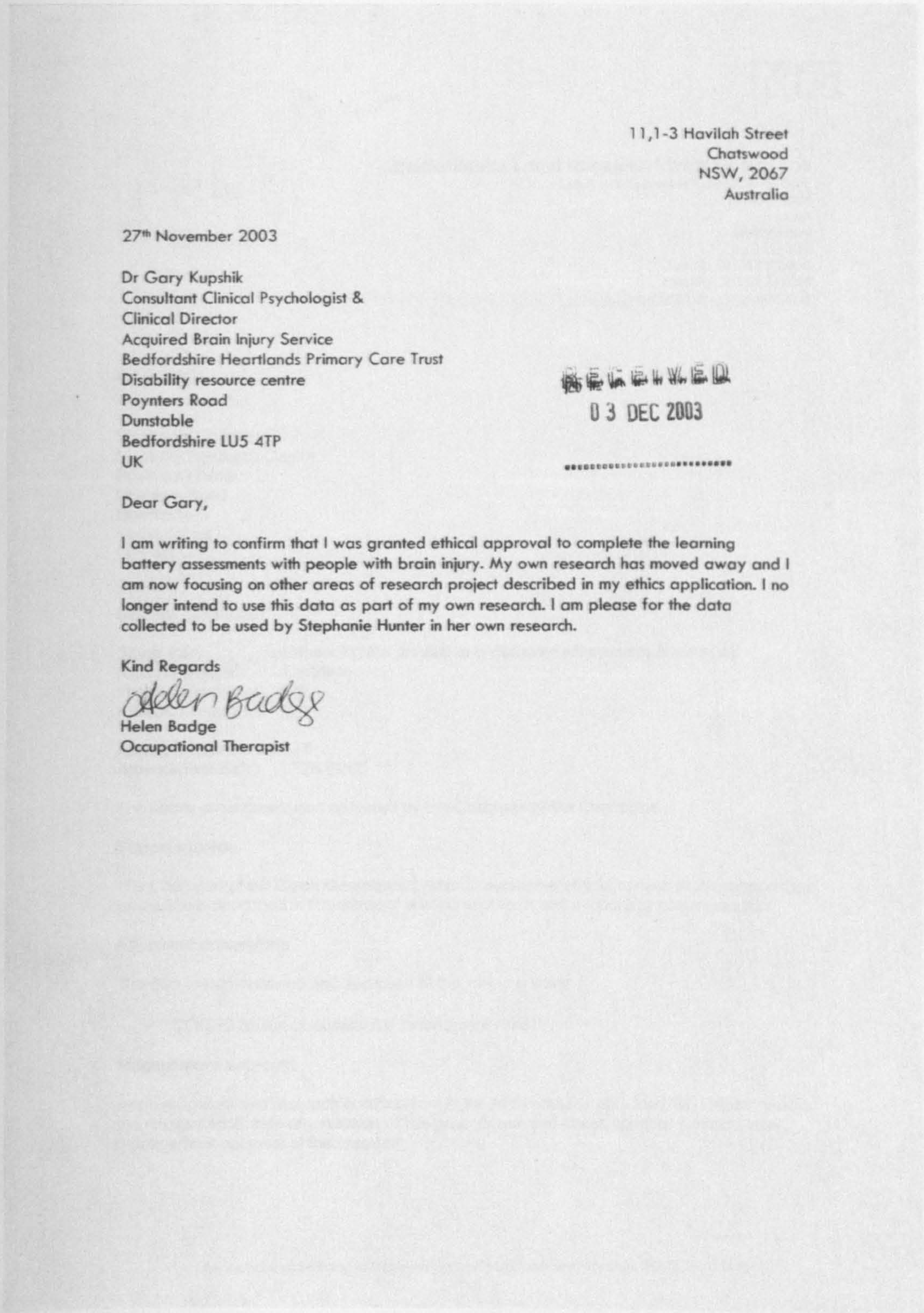
One of the conditions of this approval is that you submit to the Committee Annual Reports on the progress of the study. A reminder letter will be sent to you a month before the first report is due.

Failure to provide reports may result in approval being withdrawn.

Yours sincerely

Mr. Ron Driver
Chairman - South Bedfordshire Local Research Ethics Committee

An advisory committee to Bedfordshire and Hertfordshire Strategic Health Authority



11,1-3 Havilah Street
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27th November 2003

Dr Gary Kupshik
Consultant Clinical Psychologist &
Clinical Director
Acquired Brain Injury Service
Bedfordshire Heartlands Primary Care Trust
Disability resource centre
Poynters Road
Dunstable
Bedfordshire LU5 4TP
UK

RECEIVED
03 DEC 2003

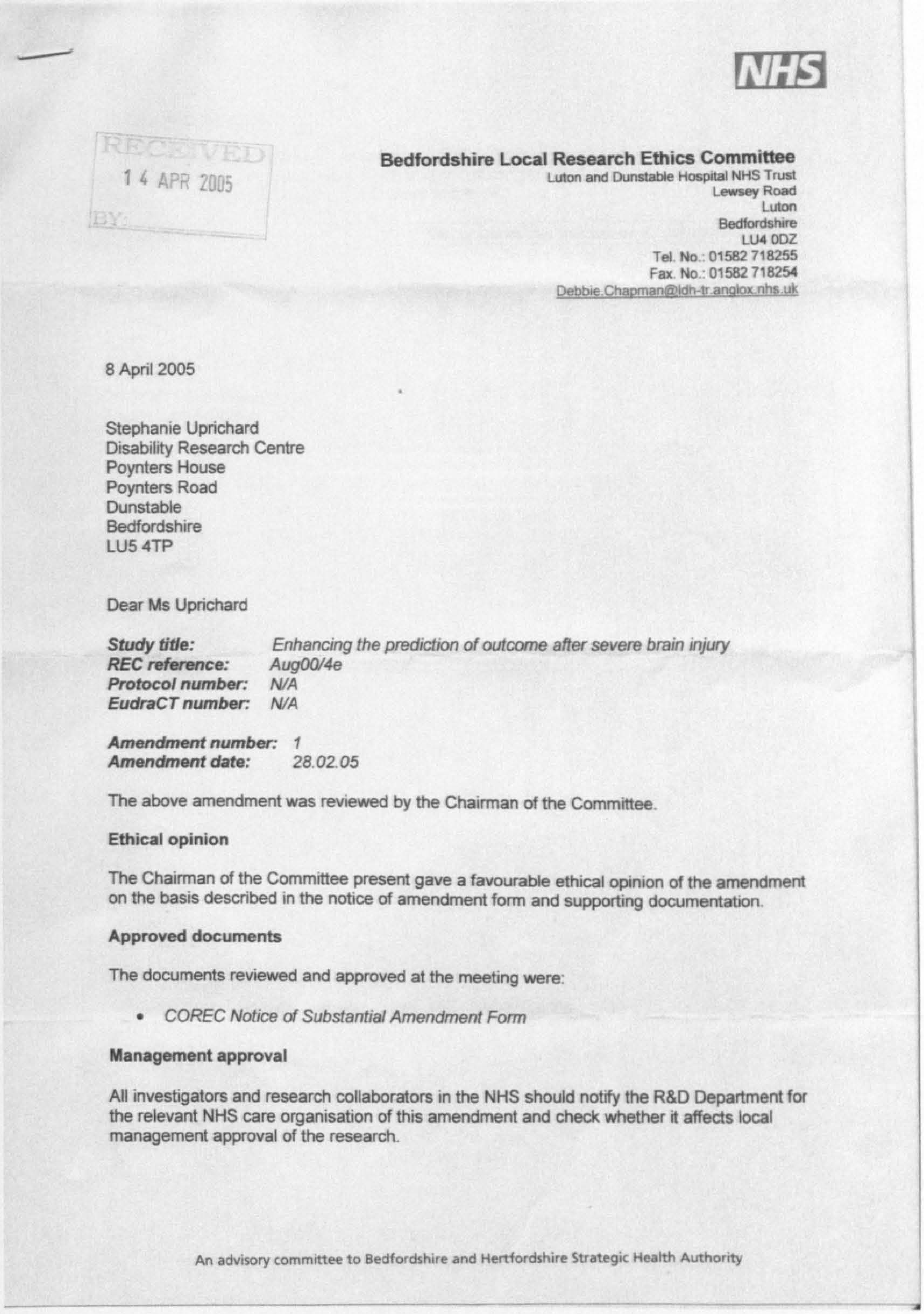
Dear Gary,

I am writing to confirm that I was granted ethical approval to complete the learning battery assessments with people with brain injury. My own research has moved away and I am now focusing on other areas of research project described in my ethics application. I no longer intend to use this data as part of my own research. I am please for the data collected to be used by Stephanie Hunter in her own research.

Kind Regards

Helen Badge

Helen Badge
Occupational Therapist



NHS

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RECEIVED
14 APR 2005
BY:

8 April 2005

Stephanie Uprichard
Disability Research Centre
Poynters House
Poynters Road
Dunstable
Bedfordshire
LU5 4TP

Dear Ms Uprichard

Study title: *Enhancing the prediction of outcome after severe brain injury*
REC reference: *Aug00/4e*
Protocol number: *N/A*
EudraCT number: *N/A*

Amendment number: *1*
Amendment date: *28.02.05*

The above amendment was reviewed by the Chairman of the Committee.

Ethical opinion

The Chairman of the Committee present gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

Approved documents

The documents reviewed and approved at the meeting were:

- *COREC Notice of Substantial Amendment Form*

Management approval

All investigators and research collaborators in the NHS should notify the R&D Department for the relevant NHS care organisation of this amendment and check whether it affects local management approval of the research.

Appendices 2: Research Leaflet

What will happen after the assessments have been completed?

Following assessment you and a relative/carer will be offered a feedback session to discuss the results of the assessments. If you are interested we can also send you a summary of the research once it has been completed. We will be able to offer support to the local services to use the test results in deciding how best to work with you to minimise problems and maximise your recovery.

You are under no obligation to take part in the study. Whether you do or not will not influence the service you receive from your local service or the Acquired Brain Injury Service. We are happy to discuss the study further if you have any questions. Please contact Helen Badge or Gary Kupshik on 01582 709037. If you would like to participate in the study please speak to Yvonne Clarke at Headway who will be able to arrange an appointment.

Enhancing the Prediction and Measurement of Outcome after Acquired Brain Injury

ABI Service

Research Patient Information Sheet

About the Study

The Acquired Brain Injury Service is currently undertaking a research study to evaluate what factors contribute to long term outcome after brain injury. We know that clinicians can be unnecessarily pessimistic in the early phase after injury based on their assessment of the severity of the initial injury. We are using several measures over time which we hope will improve our ability to assess the problems experienced after brain injury and improve the accuracy of early predictions. We know many of the factors that can contribute to recovery, but it remains unclear which set of factors assessed at certain points are the most important.

The Acquired Brain Injury Service is aware that uncertain outcomes can be the cause of additional stress to the patient and relatives at an already difficult time. We hope that better predictions will enable us to assist the local services to offer better support to you. Understanding the nature of the problems and likely recovery will also allow us to make more specific plans for appropriate rehabilitation and support. We also know that the tools with which we traditionally assess outcome after brain injury only measure a limited amount of change. On some tests a patient's scores will not change, despite family, friends and staff noticing significant improvement. We have designed as Outcome Assessment Scale based on the new International Classification of Impairment, Disability and Handicap, published by the World Health Organisation in 2001. We hope that this will be more sensitive to longer term change and more accurately measure the real life impact brain injury can have on an individual and their family.

What will participating in the study actually involve?

We will explain what participating in the study actually involves and will be happy to discuss this with you in further detail. We will interview you with a family member or other person to find out more about you and things you did prior to the brain injury and what has changed since. We will ask for information about your schooling, work history, interests and responsibilities. We will also ask your permission to write to your doctor to get information about the type and nature of your brain injury and any treatment you had.

There will be two parts of the formal assessment. The first part involves the assessments the ABI Service use with all patients after brain injury. For patients who are able to take part, this includes formal neuropsychological tests which look at the effect of the brain injury on thinking functions, behaviour and your ability to learn. These tests are done with pen and paper and on the computer with the Psychologist. We also like to complete formal assessment of your ability to complete practical daily tasks, like folding a basket of laundry, making a sandwich or vacuuming the floor. This allows us to gain a more detailed understanding of the needs of each patient and work with your local service to make further plans for the best type of rehabilitative care and support to meet your needs.

The final part to the assessment involves using a new assessment which measures the impact the brain injury has had on your ability to participate in important activities and social roles. Reintegrating back into the community after brain injury is very difficult and we hope this new tool helps us to understand how the brain injury has affected your everyday life.

Appendices 3: Research Consent Form

Enhancing the Prediction and Measurement of Outcome After Acquired Brain Injury

ABI Service Patient Consent Form

Patient Name .... D.O.B: ... ...

- I give my consent to participate in the study.
- I understand the information given in the handout explaining the purpose of the research.
- I understand that the results of the assessments will be kept in my file and as part of the study information.
- I understand that the results of the study may be shared with other clinical staff and may be published but that I will not be identifiable in any way.
- I understand that I can withdraw from the study at any time should I wish to, without giving an explanation.
- This form will not influence the service I receive from the Acquired Brain Injury Service

Signature.. Date
....

Witnessed by (signature)..
Date...

Appendices 4: Patient Consent Form

The Acquired Brain Injury Service would like consent to contact the following people for information to assist us. Please tick the appropriate boxes.

I ______________________________ give my permission for the Acquired Brain Injury Service, Bedfordshire Heartlands Primary Care Trust, to obtain information relating to my rehabilitation from:-

☐ **Acute Hospitals**
☐ **General Practitioner**
☐ **Other rehabilitation & care providers**
☐ **Other (please specify)**
____

☐ **Social Services**
☐ **Job Centre / Employer**
☐ **My family members**

The Acquired Brain Injury Service may wish to share information with others to assist with your rehabilitation. Please tick the appropriate boxes.

I also give my permission for the Acquired Brain Injury Services to release information relating to my rehabilitation to:-

☐ **Acute Hospitals**
☐ **General Practitioner**
☐ **Other rehabilitation & care providers**
☐ **Other (please specify)**
____

☐ **Social Services**
☐ **Job Centre / Employer**
☐ **My family members**

We may use this information anonymously for the purpose of improving the quality of our services and for research. If you are not happy with this please tick this box ☐

Client's signature____________________ Date____________

Witness signature____________________ Date____________

Witness Name______________________________________

Relationship to patient__________________________________

Appendices 5: Community Integration Questionnaire

COMMUNITY INTEGRATION QUESTIONNAIRE

HOME INTEGRATION SECTION

1. Who usually does the shopping for groceries or other necessities in your household?

Answer	Currently	Prior to Injury
yourself alone	2	2
yourself and someone else	1	1
someone else	0	0

2. Who usually prepares meals in your household?

Answer	Currently	Prior to Injury
yourself alone	2	2
yourself and someone else	1	1
someone else	0	0

3. In your home who usually does normal everyday housework?

Answer	Currently	Prior to Injury
yourself alone	2	2
yourself and someone else	1	1
someone else	0	0

4. Who usually cares for the children in your home?

Answer	Currently	Prior to Injury
yourself alone	2	2
yourself and someone else	1	1
someone else	0	0
not applicable/no children under 17 in the home	*	*

*score is average of items 1, 2, 3, and 5.

5. Who usually plans social arrangements such as get-togethers with family and friends?

Answer	Currently	Prior to Injury
yourself alone	2	2
yourself and someone else	1	1
someone else	0	0

HOME INTEGRATION SCORE =
(sum of items 1 through 5)

Currently	Prior to Injury

SOCIAL INTEGRATION SECTION

6. Who usually looks after your personal finances, such as banking or paying bills?

Answer	Currently	Prior to Injury
yourself alone	2	2
yourself and someone else	1	1
someone else	0	0

Questions 7-9: Can you tell me approximately how many times a month you now usually participate in the following activities outside your home?

7. Shopping

Answer	Currently	Prior to Injury
5 or more	2	2
1-4 times	1	1
Never	0	0

8. Leisure activities such as movies, sports, restaurants, etc.

Answer	Currently	Prior to Injury
5 or more	2	2
1-4 times	1	1
Never	0	0

9. Visiting friends or relatives

Answer	Currently	Prior to Injury
5 or more	2	2
1-4 times	1	1
Never	0	0

10. When you participate in leisure activities do you usually do this alone or with others?

Answer	Currently	Prior to Injury
mostly alone	0	0
mostly with friends who have brain injuries	1	1
mostly with family members	1	1
mostly with friends who do not have brain injuries	2	2
with a combination of family and friends	2	2

11. Do you have a best friend with whom you confide?

Answer	Currently	Prior to Injury
yes	2	2
no	0	0

SOCIAL INTEGRATION SCORE =
(sum of items 6 through 11)

Currently	Prior to Injury

PRODUCTIVITY SECTION

12. How often do you travel outside the home?

Answer	Currently	Prior to Injury
almost every day	2	2
almost every week	1	1
seldom/never (less than once per week)	0	0

JOBSCHOOL VARIABLE: (items 13 to 15)
The items, although collected individually, will be combined to form one variable, Jobschool

13. Please tick the answer below that best corresponds to your work situation:

Currently	Prior to Injury
full-time (more than 20 hrs per week)	full-time (more than 20 hrs per week)
part-time (less than or equal to 20 hrs per week)	part-time (less than or equal to 20 hrs per week)
not working, but actively looking for work	not working, but actively looking for work
not working, not looking for work	not working, not looking for work
not applicable, retired due to age	not applicable, retired due to age

14. Please tick the answer below that best corresponds to your school or training programme situation:

Currently	Prior to Injury
full-time	full-time
part-time	part-time
not attending school or training programme	not attending school or training programme
not applicable, retired due to age	not applicable, retired due to age

15. How often do/did you engage in volunteer activities?

Currently	Prior to Injury
5 or more	5 or more
1-4 times	1-4 times
never	never

JOBSCHOOL VARIABLE SCORING (items 13 to 15)
These items, although collected individually, will be combined to form one variable, Jobschool.
For the Jobschool variable, the following scoring system will apply:

JOBSCHOOL	Currently	Prior to Injury
Not working, not looking for work, not going to school, no volunteer activities	0	0
Volunteers 1 to 4 times a month AND not working, not looking for work, not in school	1	1
Actively looking for work AND/OR volunteers 5 or more times per month	2	2
Attends school part-time OR working part-time (less than 20 hours per work)	3	3
Attends school full-time OR works full-time	4	4
Works full-time AND attends school part-time OR Attends school full-time AND works part-time (less than 20 hours per week)	5	5

If Retired due to Age, the JOBSCHOOL variable is based on item 15 (Volunteer Activities) only

IF RETIRED, SCORE AS:
In the past month, how often did you engage in volunteer activities?

Answer	Currently	Prior to Injury
5 or more	4	4
1-4 times	2	2
Never	0	0

PRODUCTIVITY SCORE =
(sum of item 12 and the jobschool variable)

Currently	Prior to Injury

	Currently	Prior to Injury
HOME INTEGRATION SCORE +		
SOCIAL INTEGRATION SCORE +		
PRODUCTIVITY SCORE +		

TOTAL CIQ SCORE =

Appendices 6: WCST administration script.

Standard Assessment

"I can't tell you very much about how to complete this assessment. The aim of the assessment is to match each card shown to you here (indicate the cards at the bottom of the screen) to one of the four key cards shown at the top of the screen. Now, I can't tell you how to match the cards but the computer will tell you if your match was correct of not. Either way, you are to leave that card and try to get the next card correct. The computer will let you know when the assessment is over, you can use these keys to match the cards" *(indicate the keys shown on the keyboard).*

10.1.1.1.1.1 Dynamic Errorless Learning Training

"Now that you have completed the assessment I would like to show you exactly how to complete it without making any mistakes, then I'm going to ask you to have another go. As you may or may not have worked out the computer uses three rules when matching the cards, it uses the colour, shape or number of the cards to match to the key card. The computer also changes the rules at different times, but I'm going to tell you so you will know.

The first rule that the computer matches is the colour, this means that you will match the card shown at the bottom to the key card that matches in colour, the computer will stick to this rule until you have ten corrects in a row (ten consistent corrects), after this the rule will change, lets go until then and when you have had ten corrects in a row tell me and I'll tell you the next rule."

Use errorless learning technique to prompt if you think the individual is not sure of the correct answer of if you don't think they are counting.

"Good, so now you have had ten corrects in a row the computer has changed the rule, the computer is now matching by shape, that means that you will match the card shown at the bottom of the screen to the key card that has the same shape. The computer will stick to this rule until you have ten corrects in a row (ten consistent corrects), after this the rule will change, lets go until then and when you have had ten corrects in a row tell me and I'll tell you the next rule."

Use errorless learning technique to prompt in you think the individual is not sure of the correct answer of if you don't think they are counting.

"Good, now that you have had ten corrects in a row the computer has changed the rule again, the computer is now matching by number, that means that you will match the card shown at the bottom of the screen to the key card that has the same number of items on it. The computer will stick to this rule until you have ten corrects in a row (ten consistent corrects), after this the rule will change, lets go until then and when you have had ten corrects in a row tell me."

Use the errorless learning technique to prompt if you think the individual is not sure of the correct answer of if you don't think they are counting. At the end of *the trial explain that the process repeats again, sorting by colour shape and number again.*

Post Training Trial

Now that you have had a try with me I would like you to have one more try by yourself. I am not going to be able to help you with this trial. The assessment is exactly the same as the trial we have just done together.

Appendices 7: Summary Statistics 16th Percentile WCST Rasch

```
     SUMMARY OF 56 MEASURED (NON-EXTREME) persons
+-----------------------------------------------------------------------------+
|           RAW                          MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       4.5       9.0       49.86    9.23        .97     .1   1.05     .2 |
| S.D.       2.8        .0       17.21    1.63        .25     .7    .65     .9 |
| MAX.       8.0       9.0       72.97   11.11       1.57    2.0   3.18    2.6 |
| MIN.       1.0       9.0       27.63    7.02        .57   -1.5    .27   -1.4 |
|-----------------------------------------------------------------------------|
| REAL RMSE    9.77  ADJ.SD   14.17  SEPARATION  1.45  person RELIABILITY  .68 |
|MODEL RMSE    9.37  ADJ.SD   14.44  SEPARATION  1.54  person RELIABILITY  .70 |
| S.E. OF person MEAN = 2.32                                                  |
+-----------------------------------------------------------------------------+
   MAXIMUM EXTREME SCORE:      15 persons
   MINIMUM EXTREME SCORE:       2 persons

     SUMMARY OF 73 MEASURED (EXTREME AND NON-EXTREME) persons
+-----------------------------------------------------------------------------+
|           RAW                          MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       5.3       9.0       56.46   11.47                                 |
| S.D.       3.2        .0       22.28    4.30                                 |
| MAX.       9.0       9.0       86.67   18.86                                 |
| MIN.        .0       9.0       14.59    7.02                                 |
|-----------------------------------------------------------------------------|
| REAL RMSE   12.48  ADJ.SD   18.45  SEPARATION  1.48  person RELIABILITY  .69 |
|MODEL RMSE   12.24  ADJ.SD   18.61  SEPARATION  1.52  person RELIABILITY  .70 |
| S.E. OF person MEAN = 2.63                                                  |
+-----------------------------------------------------------------------------+
person RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) person RAW SCORE RELIABILITY = .89

     SUMMARY OF 9 MEASURED (NON-EXTREME) items
+-----------------------------------------------------------------------------+
|           RAW                          MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      27.8      56.0       50.00    3.53        .99    -.7   1.05    -.6 |
| S.D.       5.7        .0        7.20     .07        .70    3.1    .98    2.6 |
| MAX.      33.0      56.0       67.48    3.73       2.72    6.2   3.26    5.3 |
| MIN.      14.0      56.0       43.54    3.49        .43   -3.7    .32   -3.2 |
|-----------------------------------------------------------------------------|
| REAL RMSE    3.97  ADJ.SD    6.01  SEPARATION  1.51  item   RELIABILITY  .70 |
|MODEL RMSE    3.53  ADJ.SD    6.28  SEPARATION  1.78  item   RELIABILITY  .76 |
| S.E. OF item MEAN = 2.55                                                    |
+-----------------------------------------------------------------------------+
UMEAN=50.000 USCALE=10.000
item RAW SCORE-TO-MEASURE CORRELATION = -1.00
504 DATA POINTS. APPROXIMATE LOG-LIKELIHOOD CHI-SQUARE: 450.84
```

```
        item STATISTICS:  MISFIT ORDER

+-----------------------------------------------------------------------------------
----+
|ENTRY    RAW                          MODEL|   INFIT  |  OUTFIT  |PTMEA|EXACT MATCH|
|NUMBER  SCORE   COUNT   MEASURE   S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.| OBS%   EXP%|
item                                       |
|------------------------------------+----------+----------+-----+-----------+---
-----------------------------------|
|      8      29      56    48.41     3.50|2.72    6.2|3.26    5.3|A .27| 39.3   79.8|
Pre Failure to Maintain Set                 |
|      7      14      56    67.48     3.73|1.62    3.1|2.32    2.0|B .57| 73.2   81.1|
Pre Trials to Complete First Category|
|      9      26      56    52.09     3.52| .84    -.8|1.02     .2|C .76| 87.5   80.1|
Pre Learning to Learn                      |
|      4      32      56    44.76     3.49| .86    -.7| .76    -.8|D .73| 83.9   79.5|
Pre Non Perseverative Errors               |
|      2      33      56    43.54     3.50| .78   -1.2| .59   -1.4|E .75| 82.1   79.3|
Pre Perseverative Responses                |
|      3      31      56    45.97     3.50| .67   -1.9| .49   -2.1|d .80| 85.7   79.5|
Pre Perseverative Errors                   |
|      6      23      56    55.80     3.54| .51   -3.0| .38   -2.6|c .86| 91.1   80.3|
Pre Categories Complete                    |
|      5      32      56    44.76     3.49| .45   -3.7| .33   -3.0|b .84| 94.6   79.5|
Pre Conceptual Level Response              |
|      1      30      56    47.19     3.50| .43   -3.7| .32   -3.2|a .86| 94.6   79.5|
Pre Total Errors                           |
|------------------------------------+----------+----------+-----+-----------+---
-----| MEAN     27.8    56.0    50.00      3.53| .99    -.7|1.05    -.6|       | 81.3
79.8|                                            |
| S.D.      5.7      .0     7.20      .07| .70    3.1| .98    2.6|       | 16.2    .5|
|
+-----------------------------------------------------------------------------------
-----
```

Appendices 8: Summary Statistics Dynamic WCST Rasch

```
TABLE 3.1 1 sd above mean pre and post
INPUT: 75 persons, 22 items  MEASURED: 75 persons, 22 items, 2 CATS
3.59.1
--------------------------------------------------------------------------------

     SUMMARY OF 69 MEASURED (NON-EXTREME) persons
+-------------------------------------------------------------------------------+
|           RAW                            MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT      MEASURE    ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-------------------------------------------------------------------------------|
| MEAN      10.0       20.7        46.60     7.24        .97    -.2   1.36     .4 |
| S.D.       5.7        1.6        23.54     1.77        .56    1.3   1.69    1.2 |
| MAX.      20.0       21.0        98.29    11.39       3.91    4.2   9.90    2.9 |
| MIN.       1.0       11.0         8.55     5.53        .34   -1.9    .11   -1.3 |
|-------------------------------------------------------------------------------|
| REAL RMSE   8.09  ADJ.SD   22.10  SEPARATION  2.73  person RELIABILITY  .88 |
|MODEL RMSE   7.45  ADJ.SD   22.33  SEPARATION  3.00  person RELIABILITY  .90 |
| S.E. OF person MEAN = 2.85                                                    |
+-------------------------------------------------------------------------------+
  MINIMUM EXTREME SCORE:      6 persons
        BEYOND CAPACITY:      2 persons
        VALID RESPONSES:  98.5%

     SUMMARY OF 75 MEASURED (EXTREME AND NON-EXTREME) persons
+-------------------------------------------------------------------------------+
|           RAW                            MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT      MEASURE    ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-------------------------------------------------------------------------------|
| MEAN       9.2       20.7        42.52     8.15                               |
| S.D.       6.1        1.5        26.47     3.52                               |
| MAX.      20.0       21.0        98.29    18.60                               |
| MIN.        .0       11.0        -4.35     5.53                               |
|-------------------------------------------------------------------------------|
| REAL RMSE   9.37  ADJ.SD   24.76  SEPARATION  2.64  person RELIABILITY  .87 |
|MODEL RMSE   8.87  ADJ.SD   24.94  SEPARATION  2.81  person RELIABILITY  .89 |
| S.E. OF person MEAN = 3.08                                                    |
+-------------------------------------------------------------------------------+
person RAW SCORE-TO-MEASURE CORRELATION = .99 (approximate due to missing data)
CRONBACH ALPHA (KR-20) person RAW SCORE RELIABILITY = .93 (approximate due to
missing data)

     SUMMARY OF 21 MEASURED (NON-EXTREME) items
+-------------------------------------------------------------------------------+
|           RAW                            MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT      MEASURE    ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-------------------------------------------------------------------------------|
| MEAN      32.7       68.0        50.00     3.88        .92    -.4   1.43     .6 |
| S.D.      16.1        1.2        20.46      .76        .44    2.2   1.70    1.5 |
| MAX.      55.0       69.0        93.63     6.32       1.92    5.0   7.63    5.4 |
| MIN.       4.0       65.0        20.76     3.18        .43   -2.9    .20   -1.0 |
|-------------------------------------------------------------------------------|
| REAL RMSE   4.31  ADJ.SD   20.00  SEPARATION  4.64  item   RELIABILITY  .96 |
|MODEL RMSE   3.95  ADJ.SD   20.08  SEPARATION  5.08  item   RELIABILITY  .96 |
| S.E. OF item MEAN = 4.58                                                      |
+-------------------------------------------------------------------------------+
  MAXIMUM EXTREME SCORE:      1 items
UMEAN=50.000 USCALE=10.000
      SUMMARY OF 22 MEASURED (EXTREME AND NON-EXTREME) items
+-------------------------------------------------------------------------------+
|           RAW                            MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT      MEASURE    ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-------------------------------------------------------------------------------|
| MEAN      31.2       67.9        53.42     4.55                               |
| S.D.      17.1        1.2        25.41     3.14                               |
| MAX.      55.0       69.0       125.29    18.55                               |
| MIN.        .0       65.0        20.76     3.18                               |
|-------------------------------------------------------------------------------|
| REAL RMSE   5.78  ADJ.SD   24.74  SEPARATION  4.28  item   RELIABILITY  .95 |
|MODEL RMSE   5.53  ADJ.SD   24.80  SEPARATION  4.49  item   RELIABILITY  .95 |
| S.E. OF item MEAN = 5.54                                                      |
+-------------------------------------------------------------------------------+
item RAW SCORE-TO-MEASURE CORRELATION = -.96 (approximate due to missing data)
```

```
1427 DATA POINTS. APPROXIMATE LOG-LIKELIHOOD CHI-SQUARE: 966.13
       item STATISTICS:  MISFIT ORDER

+------------------------------------------------------------------------------
----+
|ENTRY    RAW                           MODEL|   INFIT  |  OUTFIT  |PTMEA|EXACT MATCH|
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.| OBS%  EXP%|
item                                        |
|------------------------------------+----------+----------+-----+-----------+---
-----
|    10     28     67    53.52     3.22|1.80    5.0|7.63    5.4|A .30| 68.7  77.8|
Pre Failure to Maintain Set                  |
|     6     10     67    77.05     4.45| .96     .0|4.23    1.7|B .47| 91.0  90.4|
Pre Non Perseverative Errors                |
|    21     33     69    48.98     3.18|1.40    2.8|2.46    2.2|C .52| 72.5  76.8|
Post Failure to Maintain Set                |
|    20     43     69    38.14     3.48|1.51    2.3|2.34    1.7|D .57| 76.8  84.1|
Post Trials to Complete First Category|
|    11     32     66    49.37     3.23|1.21    1.5|2.18    1.9|E .58| 74.2  76.7|
Pre Learning to Learn                       |
|     9      4     67    93.63     6.32|1.92    1.9|1.67    1.4|F .21| 89.6  95.0|
Pre Trials to Complete First Category |
|     2     31     67    50.42     3.22|1.11     .8|1.45     .9|G .62| 76.1  77.2|
Pre Total Correct                           |
|    22     50     69    28.70     3.86|1.20     .8|1.44     .7|H .67| 87.0  87.7|
Post Learning to Learn                      |
|     8     35     65    45.68     3.34|1.09     .6| .90     .0|I .67| 70.8  78.9|
Pre Categories Complete                     |
|    17     47     69    32.99     3.69| .50   -2.5| .80     .0|J .80| 95.7  86.7|
Post Non Perseverative Errors               |
|    15     39     69    42.73     3.31| .80   -1.2| .68    -.5|K .74| 87.0  80.8|
Post Perseverative Responses                |
|     7     11     67    75.15     4.28| .74   -1.0| .79     .3|j .56| 92.5  89.4|
Pre Conceptual Level Response               |
|    16     46     69    34.34     3.64| .60   -1.9| .79     .0|i .79| 91.3  86.2|
Post Perseverative Errors                   |
|     3     11     68    75.29     4.27| .72   -1.1| .60     .2|h .56| 92.6  89.5|
Pre Totoal Errors                           |
|     5      6     67    86.73     5.47| .68    -.9| .21     .4|g .51| 95.5  93.6|
Pre Perseverative Errors                    |
|    13     46     69    34.34     3.64| .65   -1.6| .41    -.7|f .79| 91.3  86.2|
Post Total Correct                          |
|     1     17     67    65.97     3.62| .61   -2.2| .40    -.5|e .66| 92.5  84.1|
Pre Trials Administered                     |
|    19     55     69    20.76     4.09| .46   -2.9| .20    -.3|d .80| 97.1  87.8|
Post Categories Complete                    |
|    12     47     69    32.99     3.69| .45   -2.8| .28   -1.0|c .83| 95.7  86.7|
Post Trials Administered                    |
|    14     48     69    31.60     3.75| .43   -2.9| .26    -.9|b .83| 94.2  87.1|
Post Total Errors                           |
|    18     48     69    31.60     3.75| .43   -2.9| .26    -.9|a .83| 94.2  87.1|
Post Conceptual Level Response              |
|------------------------------------+----------+----------+-----+-----------+---
----|
| MEAN    31.2   67.9    53.42     4.55| .92    -.4|1.43     .6|     | 87.0  85.2|
|
| S.D.    17.1    1.2    25.41     3.14| .44    2.2|1.70    1.5|     |  9.2   5.2|
|
+------------------------------------------------------------------------------
----+
```

Appendices 9: Item map Representing the Hierarchy of Difficulty for the Standard WCST Administration Using 25th Percentile Cut-off

```
                        persons MAP OF items
               <more>|<rare>
 73        #######  +
 72        .######  +
 71                 +
 70                 +
 69                 +
 68                 +
 67                 +
 66                S+
 65                 +
 64                 +  Pre Trials to Complete First Category
 63            ###  +
 62                 +
 61                 +T
 60                 +
 59                 +
 58                 +
 57             .#  +
 56                 +S
 55                 +
 54                 +
 53                 +  Pre Total Errors
 52              .  +
 51                 +  Pre Categories Complete
                       Pre Non Perseverative Errors
 50                 +M
 49                M+  Pre Conceptual Level Response
 48                 +
 47             .#  +  Pre Learning to Learn
 46                 +  Pre Perseverative Errors
                       Pre Perseverative Responses
 45                 +
 44                 +S
 43                 +  Pre Failure to Maintain Set
 42             ##  +
 41                 +
 40                 +
 39                 +T
 38                 +
 37          .####  +
 36                 +
 35                 +
 34                 +
 33                 +
 32                 +
 31                S+
 30                 +
 29                 +
 28     ##########  +
               <less>|<frequ>
EACH '#' IS 2.
```

Appendices 10: Item map Representing the Hierarchy of Difficulty for the Dynamic WCST Administration Using Reliable Change

```
   persons MAP OF items
        <more>|<rare>
76         X  +
75            +
74           T+
73            +
72            +
71            +
70            +
69   XXXXXXX  +
68            +
67            +
66            +
65         X  +
64            +
63           S+T
62            +
61 XXXXXXXXX  +
60            +
59        XX  +
58            +  Trials Administered
                 Trials to Complete First Category
57            +
56    XXXXXX  +S
55            +
54         X  +  Conceptual Level Response
53            +  Failure to Maintain set
52   XXXXXXX M+
51            +  Total Errors
50    XXXXXX  +M
49            +
48     XXXXX  +  Perseverative Errors
47            +
46         X  +
45            +  Perseverative Response
44      XXXX  +S
43            +  Non Perseverative Errors
42           S+
41      XXXX  +
40            +
39      XXXX  +  Categories Complete
38            +
37            +T
36            +
35        XX  +
34            +
33            +
32            +
31       XXX T+
30        XX  +
        <less>|<frequ>
```

Appendices 11: Mean scores and significances for all ANOVAs etc for WCST chapter

Dynamic WCST Pre Injury IQ ANOVA means and significance

WCST dynamic Logit cat	*PreIQ Mean*	*PreIQ Std.Err.*	*PreIQ -95.00%*	*PreIQ +95.00%*	*N*
non learner	92.1195	3.142392	85.84900	98.3901	22
learner	95.0905	3.295768	88.51390	101.6671	20
High scorer	103.2607	2.736986	97.79912	108.7223	29

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	649338.1	1	649338.1	2989.012	0.000000
WCST dynamic logit	1715.4	2	857.7	3.948	0.023869
Error	14772.4	68	217.2		

Dynamic WCST Current IQ ANOVA means and significance

WCST dynamic Logit cat	*FSIQ Mean*	*FSIQ Std.Err.*	*FSIQ -95.00%*	*FSIQ +95.00%*	*N*
non learner	79.47368	3.242207	72.98604	85.9613	19
learner	90.22222	3.331051	83.55680	96.8876	18
High scorer	99.20000	2.826491	93.54421	104.8558	25

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	487930.4	1	487930.4	2442.996	0.000000
WCST dynamic logit	4203.5	2	2101.8	10.523	0.000123
Error	11783.8	59	199.7		

Dynamic WCST GCS ANOVA means and significance

WCST dynamic Logit cat	*GCSO_TOT Mean*	*GCSO_TOT Std.Err.*	*GCSO_TOT -95.00%*	*GCSO_TOT +95.00%*	*N*
Non learner	7.47059	1.043472	5.374714	9.56646	17
Learner	9.00000	1.149850	6.690459	11.30954	14
High scorer	11.18182	0.917263	9.339442	13.02419	22

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	4351.888	1	4351.888	235.1080	0.000000
WCST dynamic logit	135.360	2	67.680	3.6564	0.032959
Error	925.508	50	18.510		

Dynamic WCST age at onset ANOVA means and significance

WCST dynamic Logit cat	*AGE Mean*	*AGE Std.Err.*	*AGE -95.00%*	*AGE +95.00%*	*N*
non learner	35.45455	2.671620	30.12749	40.78160	22
learner	29.26087	2.612895	24.05090	34.47084	23
high scorer	28.96552	2.326949	24.32571	33.60532	29

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	71110.29	1	71110.29	452.8565	0.000000
WCST dynamic logit	626.13	2	313.07	1.9937	0.143741
Error	11148.85	71	157.03		

Dynamic WCST Age at testing ANOVA means and significance

WCST dynamic Logit cat	*Age at testing Mean*	*Age at testing Std.Err.*	*Age at testing -95.00%*	*Age at testing +95.00%*	*N*
non learner	33.50000	2.509800	28.47609	38.52391	16
learner	28.90000	2.244833	24.40648	33.39352	20
high scorer	31.36000	2.007840	27.34087	35.37913	25

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	57645.49	1	57645.49	571.9621	0.000000
WCST dynamic logit	190.64	2	95.32	0.9458	0.394293
Error	5845.56	58	100.79		

Dynamic WCST Time since injury excluding outlier ANOVA means and significance

WCST dynamic Logit cat	*Time Mean*	*Time Std.Err.*	*Time -95.00%*	*Time +95.00%*	*N*
non learner	34.60000	7.397426	18.73410	50.46590	15
learner	29.61111	9.443724	9.68660	49.53563	18
high scorer	16.88000	3.186074	10.30427	23.45573	25

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Wcst dynamic logit	3403.551	2	1701.776	2.085857	0.133917
Error	44872.52	55	815.8640		

Dynamic WCST Time since injury including outlier ANOVA means and significance

WCST dynamic Logit cat	*Time Mean*	*Time Std.Err.*	*Time -95.00%*	*Time +95.00%*	*N*

non learner	46.06250	13.38920	13.38920	74.600896	16
learner	60.04762	18.59858	18.59858	98.8435688	21
high scorer	16.88000	3.18607	3.18607	23.4557333	25

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Wcst dynamic logit	22333.41	2	11166.70	3.389132	0.040430
Error	194396.5	59	3294.856		

Dynamic WCST Pre Injury Home Integration CIQ scale ANOVA means and significance

WCST dynamic Logit cat	*HIS_PRE Mean*	*HIS_PRE Std.Err.*	*HIS_PRE -95.00%*	*HIS_PRE +95.00%*	*N*
non learner	4.636364	0.796877	3.047042	6.225685	22
learner	5.772727	0.796877	4.183406	7.362048	22
high scorer	6.034483	0.694071	4.650203	7.418763	29

Dynamic WCST Pre Injury Social Integration CIQ scale ANOVA means and significance

WCST dynamic Logit cat	*SIS_PRE Mean*	*SIS_PRE Std.Err.*	*SIS_PRE -95.00%*	*SIS_PRE +95.00%*	*N*
non learner	10.22727	0.392061	9.445332	11.00921	22
Learner	10.09091	0.392061	9.308968	10.87285	22
high scorer	10.58621	0.341481	9.905145	11.26727	29

Dynamic WCST Pre Injury Productive Activity Integration CIQ scale ANOVA means and significance

WCST dynamic Logit cat	*PS_PRE Mean*	*PS_PRE Std.Err.*	*PS_PRE -95.00%*	*PS_PRE +95.00%*	*N*
non learner	5.636364	0.240635	5.156432	6.116295	22
Learner	5.681818	0.240635	5.201887	6.161749	22
high scorer	5.758621	0.209590	5.340606	6.176635	29

Dynamic WCST Pre Injury Total Integration CIQ scale ANOVA means and significance

WCST dynamic Logit cat	*CIS_PRE Mean*	*CIS_PRE Std.Err.*	*CIS_PRE -95.00%*	*CIS_PRE +95.00%*	*N*
non learner	20.54545	1.020462	18.51021	22.58070	22
Learner	21.54545	1.020462	19.51021	23.58070	22
high scorer	22.20690	0.888810	20.43422	23.97957	29

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.022546	726.1707	4	67	0.000000
WCST dynamic logit	Wilks	0.902025	0.8862	8	134	0.529996

Dynamic WCST Current Home Integration Scale ANOVA means and significance

WCST dynamic Logit cat	*HIS_NOW Mean*	*HIS_NOW Std.Err*	*HIS_NOW -95.00%*	*HIS_NOW +95.00%*	*N*
non learner	2.454545	0.743412	0.971857	3.937234	22
Learner	4.045455	0.743412	2.562766	5.528143	22
high scorer	4.896552	0.647503	3.605147	6.187956	29

Dynamic WCST Current Social Integration Scale ANOVA means and significance

WCST dynamic Logit cat	*SIS_NOW Mean*	*SIS_NOW Std.Err.*	*SIS_NOW -95.00%*	*SIS_NOW +95.00%*	*N*
non learner	5.500000	0.478833	4.544998	6.455002	22
Learner	7.545455	0.478833	6.590453	8.500456	22
high scorer	7.827586	0.417058	6.995791	8.659382	29

Dynamic WCST Current Productive Activity Scale ANOVA means and significance

WCST dynamic Logit cat	*PS_NOW Mean*	*PS_NOW Std.Err.*	*PS_NOW -95.00%*	*PS_NOW +95.00%*	*N*
non learner	2.454545	0.417653	1.621563	3.287528	22
Learner	3.772727	0.417653	2.939744	4.605710	22
high scorer	4.241379	0.363771	3.515861	4.966898	29

Dynamic WCST Current Total Integration Scale ANOVA means and significance

WCST dynamic Logit cat	*CIS_NOW Mean*	*CIS_NOW Std.Err.*	*CIS_NOW -95.00%*	*CIS_NOW +95.00%*	*N*
non learner	10.40909	1.156398	8.10273	12.71545	22
Learner	15.36364	1.156398	13.05727	17.67000	22
high scorer	16.96552	1.007209	14.95670	18.97433	29

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.085872	178.3066	4	67	0.000000
WCST dynamic logit	Wilks	0.763863	2.4149	8	134	0.018129

Dynamic WCST Change in Home Integration Scale ANOVA means and significance

WCST dynamic Logit cat	*Home Difference Mean*	*Home Difference Std.Err.*	*Home Difference -95.00%*	*Home Difference +95.00%*	*N*
non learner	-2.18182	0.551906	3.28256	-1.08108	22
Learner	-1.72727	0.551906	2.82801	-0.62653	22
high scorer	-1.13793	0.480704	2.09666	-0.17920	29

Dynamic WCST Change in Social Integration Scale ANOVA means and significance

WCST dynamic Logit cat	*Social Difference Mean*	*Social Difference Std.Err.*	*Social Difference -95.00%*	*Social Difference +95.00%*	*N*
non learner	-4.72727	0.569306	-5.86272	-3.59183	22
Learner	-2.54545	0.569306	-3.68090	-1.41001	22
high scorer	-2.75862	0.495859	-3.74758	-1.76966	29

Dynamic WCST Change in Productive Activity Scale ANOVA means and significance

WCST dynamic Logit cat	*Productive difference Mean*	*Productive difference Std.Err.*	*Productive difference -95.00%*	*Productive difference +95.00%*	*N*
non learner	-3.18182	0.411153	-4.00184	-2.36180	22
Learner	-1.90909	0.411153	-2.72911	-1.08907	22
high scorer	-1.51724	0.358110	-2.23147	-0.80301	29

Dynamic WCST Change in Total Integration Scale ANOVA means and significance

WCST dynamic Logit cat	*CIQ difference Mean*	*CIQ difference Std.Err.*	*CIQ difference -95.00%*	*CIQ difference +95.00%*	*N*
non learner	-10.1364	1.181341	-12.4925	-7.78025	22
Learner	-6.1818	1.181341	-8.5379	-3.82571	22
high scorer	-5.2414	1.028935	-7.2935	-3.18923	29

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.340226	32.48203	4	67	0.000000
WCST dynamic logit	Wilks	0.773304	2.29758	8	134	0.024402

Standard WCST ANOVAs

Standard WCST Pre Injury IQ ANOVA means and significance

WCST Standard Logit cat	*PreIQ Mean*	*PreIQ Std.Err.*	*PreIQ -95.00%*	*PreIQ +95.00%*	*N*
non learner	93.0530	2.661989	87.58117	98.5248	27
Learner	96.2029	4.304659	87.07747	105.3284	17
High scorer	101.5227	2.494166	96.38586	106.6595	26

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	629473.4	1	629473.4	2999.998	0.000000
WCST alternative logit	963.2	2	481.6	2.295	0.108613
Error	14058.2	67	209.8		

Standard WCST Current IQ ANOVA means and significance

WCST Standard Logit cat	*FSIQ Mean*	*FSIQ Std.Err.*	*FSIQ -95.00%*	*FSIQ +95.00%*	*N*
non learner	82.2963	2.737700	76.81619	87.7764	27
Learner	90.2308	3.945446	82.33310	98.1284	13
high scorer	100.4762	3.104260	94.26234	106.6900	21

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	461264.8	1	461264.8	2279.369	0.000000
WCST Standard logit	3904.1	2	1952.1	9.646	0.000242
Error	11737.2	58	202.4		

Standard WCST GCS ANOVA means and significance

WCST Standard Logit cat	*GCSO_TOT Mean*	*GCSO_TOT Std.Err.*	*GCSO_TOT -95.00%*	*GCSO_TOT +95.00%*	*N*
non learner	8.95455	0.933254	7.079100	10.82999	22
Learner	7.50000	1.263632	4.960636	10.03936	12
high scorer	10.94444	1.031752	8.871062	13.01783	18

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	4072.316	1	4072.316	212.5292	0.000000
WCST Standard logit	90.178	2	45.089	2.3531	0.105728
Error	938.899	49	19.161		

Standard WCST age at onset ANOVA means and significance

WCST Standard Logit cat	*AGE Mean*	*AGE Std.Err.*	*AGE -95.00%*	*AGE +95.00%*	*N*
non learner	35.51724	2.291632	30.94673	40.08776	29
learner	26.77778	2.908758	20.97644	32.57911	18
high scorer	28.57692	2.420233	23.74992	33.40393	26

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	64262.41	1	64262.41	421.9581	0.000000
WCST Standard logit	1064.42	2	532.21	3.4946	0.035759
Error	10660.70	70	152.30		

Standard WCST Age at testing ANOVA means and significance

WCST Standard Logit cat	*Age at testing Mean*	*Age at testing Std.Err.*	*Age at testing -95.00%*	*Age at testing +95.00%*	*N*
non learner	32.77273	2.156863	28.45368	37.09177	22
Learner	29.28571	2.703770	23.87151	34.69992	14
high scorer	30.29167	2.065039	26.15650	34.42684	24

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	53790.94	1	53790.94	525.5832	0.000000
WCST Standard logit	122.25	2	61.13	0.5973	0.553723
Error	5833.68	57	102.35		

Standard WCST Time since injury ANOVA means and significance

WCST Standard Logit cat	*Time Mean*	*Time Std.Err.*	*Time -95.00%*	*Time +95.00%*	*N*
non learner	45.18182	10.64147	23.05167	67.31196	22
Learner	44.64286	21.46799	-1.73593	91.02164	14
high scorer	30.84000	11.36525	7.38327	54.29673	25

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
WCST Standard logit	2949.169	2	1474.585	0.400219	0.672010
Error	213697.8	58	3684.446		

Standard WCST Pre Injury Home Integration CIQ scale ANOVA means and significance

WCST Standard Logit cat	*HIS_PRE Mean*	*HIS_PRE Std.Err.*	*HIS_PRE -95.00%*	*HIS_PRE +95.00%*	*N*
non learner	4.592593	0.720700	3.154458	6.030727	27
Learner	5.666667	0.882674	3.905319	7.428014	18
high scorer	6.269231	0.734429	4.803701	7.734761	26

Standard WCST Pre Injury Social Integration CIQ scale ANOVA means and significance

WCST Standard Logit cat	*SIS_PRE Mean*	*SIS_PRE Std.Err.*	*SIS_PRE -95.00%*	*SIS_PRE +95.00%*	*N*
non learner	10.33333	0.357384	9.620185	11.04648	27
Learner	10.00000	0.437704	9.126575	10.87343	18
high scorer	10.50000	0.364192	9.773266	11.22673	26

Standard WCST Pre Injury Productive Activity Integration CIQ scale ANOVA means and significance

WCST Standard Logit cat	*PS_PRE Mean*	*PS_PRE Std.Err.*	*PS_PRE -95.00%*	*PS_PRE +95.00%*	*N*
non learner	5.814815	0.219070	5.377668	6.251962	27
Learner	5.500000	0.268305	4.964606	6.035394	18
high scorer	5.692308	0.223243	5.246833	6.137782	26

Standard WCST Pre Injury Total Integration CIQ scale ANOVA means and significance

WCST Standard Logit cat	*CIS_PRE Mean*	*CIS_PRE Std.Err.*	*CIS_PRE -95.00%*	*CIS_PRE +95.00%*	*N*
non learner	20.74074	0.929199	18.88655	22.59493	27
Learner	21.16667	1.138032	18.89576	23.43757	18
high scorer	22.30769	0.946900	20.41818	24.19720	26

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.023373	678.9972	4	65	0.000000
WCST Standard logit	Wilks	0.903773	0.8432	8	130	0.566387

Standard WCST Current Home Integration Scale ANOVA means and significance

WCST Standard Logit cat	*HIS_NOW Mean*	*HIS_NOW Std.Err*	*HIS_NOW -95.00%*	*HIS_NOW +95.00%*	*N*
non learner	2.962963	0.667248	1.631490	4.294436	27
Learner	3.000000	0.817209	1.369285	4.630715	18
high scorer	5.538462	0.679959	4.181625	6.895298	26

Standard WCST Current Social Integration Scale ANOVA means and significance

WCST Standard Logit cat	*SIS_NOW Mean*	*SIS_NOW Std.Err.*	*SIS_NOW -95.00%*	*SIS_NOW +95.00%*	*N*
non learner	6.222222	0.455115	5.314054	7.130391	27
Learner	6.888889	0.557400	5.776614	8.001164	18
high scorer	8.076923	0.463785	7.151455	9.002392	26

Standard WCST Current Productive Activity Scale ANOVA means and significance

WCST Standard Logit cat	*PS_NOW Mean*	*PS_NOW Std.Err.*	*PS_NOW -95.00%*	*PS_NOW +95.00%*	*N*
non learner	3.000000	0.399456	2.202898	3.797102	27
Learner	3.666667	0.489232	2.690420	4.642913	18
high scorer	4.038462	0.407065	3.226175	4.850748	26

Standard WCST Current Total Integration Scale ANOVA means and significance

WCST Standard Logit cat	*CIS_NOW Mean*	*CIS_NOW Std.Err.*	*CIS_NOW -95.00%*	*CIS_NOW +95.00%*	*N*
non learner	12.18519	1.094252	10.00164	14.36873	27
Learner	13.55556	1.340179	10.88127	16.22984	18
high scorer	17.65385	1.115097	15.42871	19.87899	26

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.093617	157.3298	4	65	0.000000
WCST Standard logit	Wilks	0.808134	1.8264	8	130	0.077653

Standard WCST Change in Home Integration Scale ANOVA means and significance

WCST Standard Logit cat	*Home Difference Mean*	*Home Difference Std.Err.*	*Home Difference -95.00%*	*Home Difference +95.00%*	*N*
non learner	-1.62963	0.480225	-2.58790	-0.67135	27
Learner	-2.66667	0.588154	-3.84031	-1.49302	18
high scorer	-0.73077	0.489373	-1.70730	0.24576	26

Standard WCST Change in Social Integration Scale ANOVA means and significance

WCST Standard Logit cat	*Social Difference Mean*	*Social Difference Std.Err.*	*Social Difference -95.00%*	*Social Difference +95.00%*	*N*
non learner	-4.11111	0.531569	-5.17184	-3.05038	27
Learner	-3.11111	0.651037	-4.41023	-1.81199	18
high scorer	-2.42308	0.541695	-3.50401	-1.34214	26

Standard WCST Change in Productive Activity Scale ANOVA means and significance

WCST Standard Logit cat	*Productive difference Mean*	*Productive difference Std.Err.*	*Productive difference -95.00%*	*Productive difference +95.00%*	*N*
non learner	-2.81481	0.386636	-3.58633	-2.04329	27
Learner	-1.83333	0.473530	-2.77825	-0.88842	18
high scorer	-1.65385	0.394001	-2.44006	-0.86763	26

Standard WCST Change in Total Integration Scale ANOVA means and significance

WCST Standard Logit cat	*CIQ difference Mean*	*CIQ difference Std.Err.*	*CIQ difference -95.00%*	*CIQ difference +95.00%*	*N*
non learner	-8.55556	1.100314	-10.7512	-6.35991	27
Learner	-7.61111	1.347604	-10.3002	-4.92201	18
high scorer	-4.65385	1.121274	-6.8913	-2.41638	26

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.383669	26.10424	4	65	0.000000
WCST Standard logit	Wilks	0.798537	1.93469	8	130	0.060016

Appendices 12: RULIT Administration Script

Administration of 15-Step Trail Learning Trial
Administrator presents the Stimulus Card 1 to the participant. **I would like you to learn a specific trail that starts here** (*administrator points to the circle with the word START)* **and ends here** *(administrator points to the circle with the word END).*

I have memorised a trail that I want you to learn. You can neither see the trail, nor will it be the shortest trail. Instead, I will teach you one specific trail. Start at the beginning and move your finger one step at a time. After each step, I will tell you whether you are on the correct trail, or whether you need to select an alternate trail. If you are right you will proceed to the next step.
If I say "go back", you should go back to your preceding position on the trail, and simply choose again. Obviously, on your first time through, your choices will be by chanced. When I ask you again, try to recall the correct trail. You will be given feedback on each choice. Finally you must repeat the trail correct two times in a row to master the test"

The Administrator provides feedback with the word "correct" for correct choices and "go back" or "go back please" for incorrect choices.

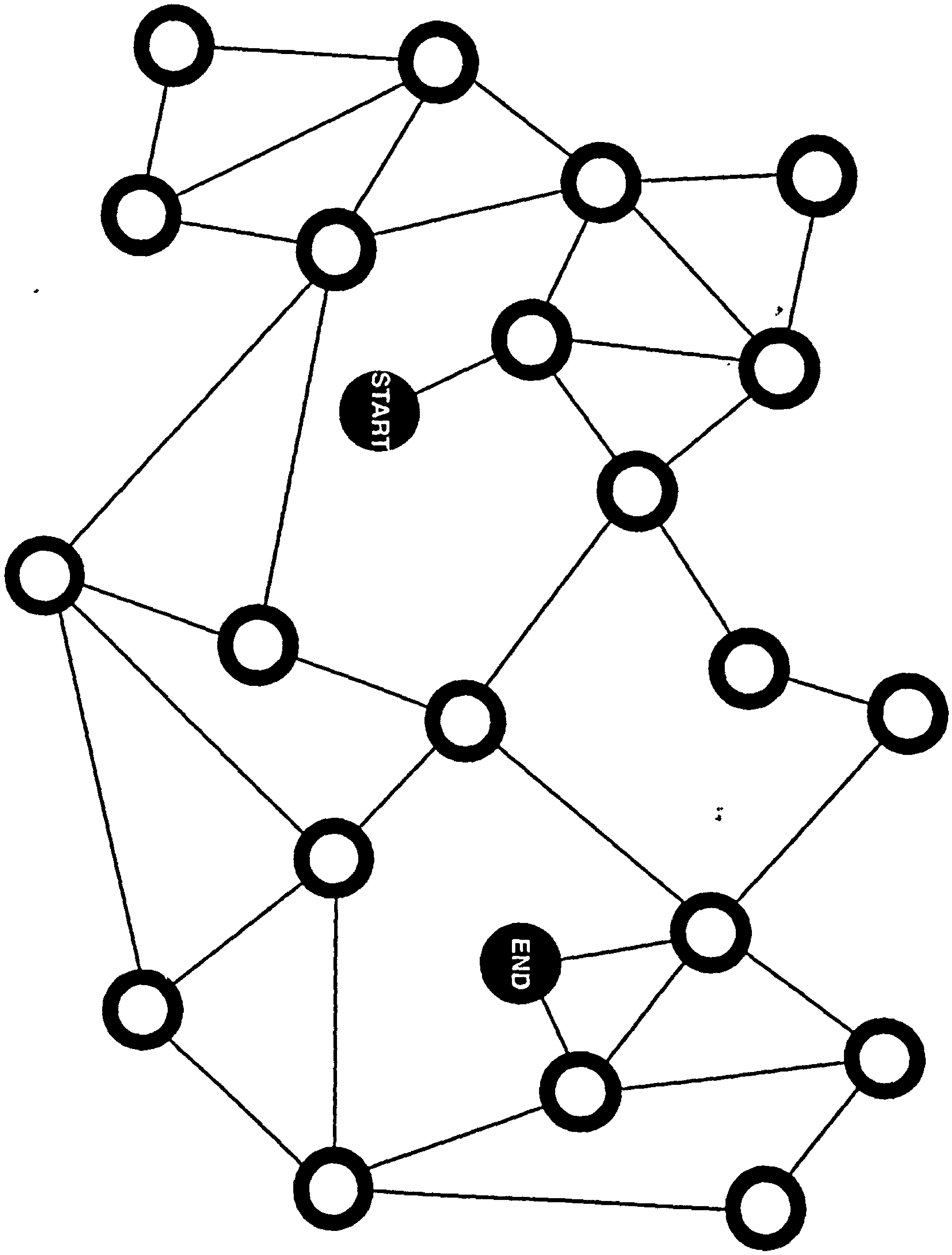
Administration of Delayed Recall Trial
After a 60 minute delay following the last trial competed, the administrator places the same stimulus Card in front of the respondent, with the following instructions. **"Some time ago I asked you to learn a trail. Now, I'd like you to run through that trail again. I will give you feedback after every choice, as before"**

Administration of the Dynamic Trail
Administrator presents Stimulus Card 2 to the participant.
Do you remember that I asked you to learn a specific trial using a card similar to this one? This time I am going to ask you to learn a different route in a different way. Instead of learning the route with trial-and-error, I am going to provide you with the route and ask you to learn it.
Administrator places overlay on top of the Stimulus card 2 so that route lines up with the steps. **As you can see, the route starts here** (*administrator points to start)* **and ends here** *administrator points to end).* **"Each step of the route has been numbered to show you the order, lets go through the route together"**
(Administrator assists the participants to go through the route, ensuring that they understand it and make no errors. Verbal explanation is kept as minimal as possible). **Ok I would like you to spend some time learning the route, after you have been round the route 10 times I will take away the overlay and see how much you have remembered.**
(Participant is encouraged to follow the route round and after ten attempts the overlay is removed)
Ok, lets see how much you can remember, if you place your finger on start and go through the route, as we have done on the previous trial. I will tell give you feedback after each step.

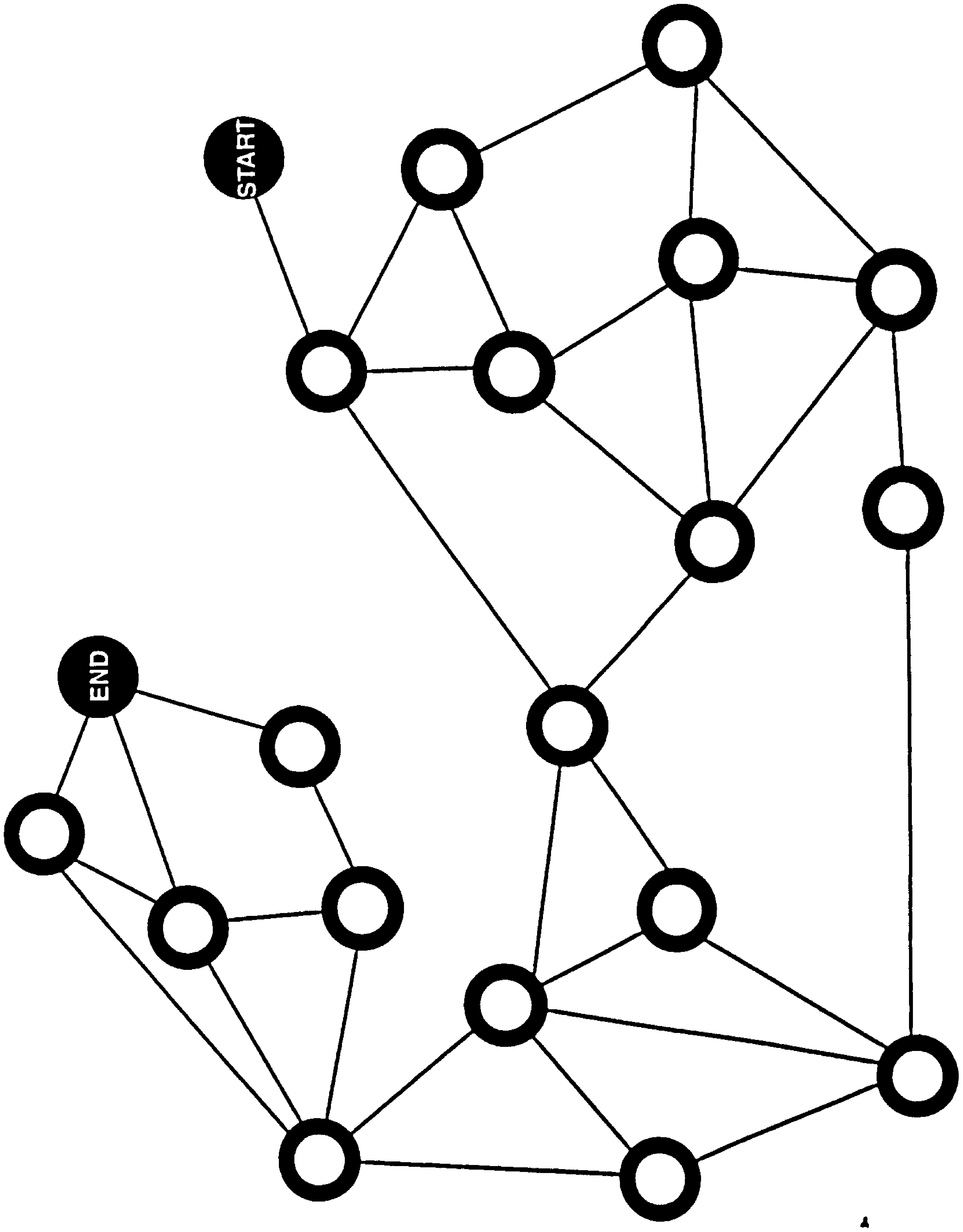
The Administrator provides feedback with the word "correct" for correct choices and "go back" or "go back please" for incorrect choices.

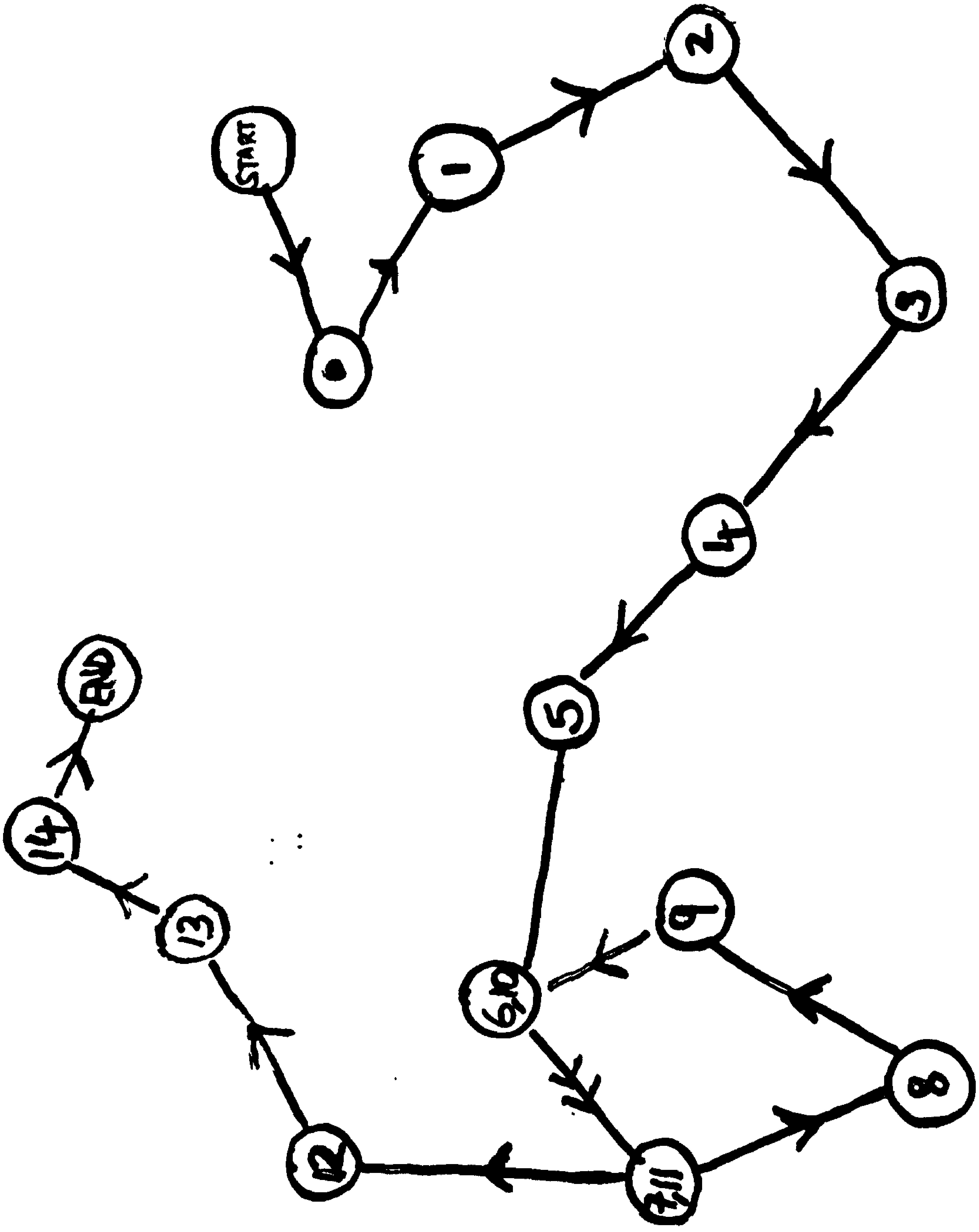
Administration of Delayed Recall Trial
After a 60 minute delay following the last trial competed, the administrator places the same stimulus Card in front of the respondent, with the following instructions. "**Some time ago I asked you to learn a trail. Now, I'd like you to run through that trail again. I will give you feedback after every choice, as before**"

Appendices 13: RULIT Stimulus Card 1



Appendices 14: RULIT Stimulus Card 2




START
0
1
2
3
4
5
6,10
7,11
8
9
12
13
14
END

Appendices 16: Alternative RULIT Chapter

Question 1: To what extent do people with brain injuries have difficulty learning?

The table below highlights the number of participants that fall into each category using the natural layout of the items to determine the number per category.

	Count	*Percentage*
Non learner	22	33
Learner	25	37
High Scorer	20	30

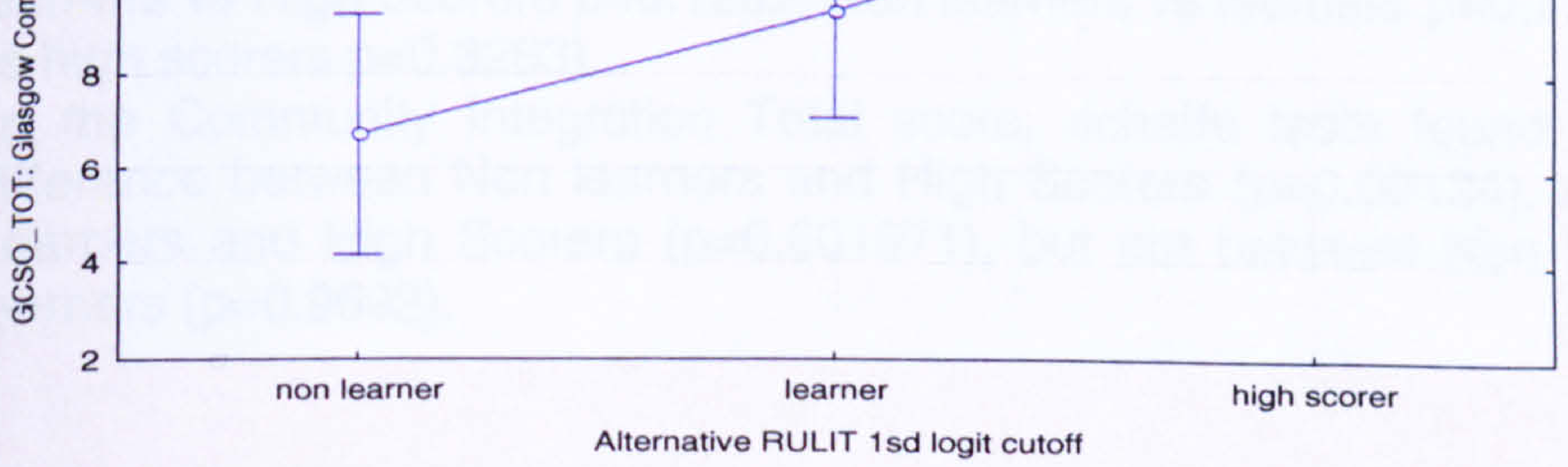
Number and percentage of participants in each learner status category, as identified by the Dynamic RULIT Rasch map.

Question 2: Does intellectual ability impact learning?

Premorbid IQ
ANOVA for premorbid IQ (calculated using Vanderploeg and Schinka's 1995 algorithms) was not significant (F(2,59)=.45495, p=.63669).

Current IQ.
ANOVA for current IQ (using WASI), was significant (F(2,54)=7.0256, p=0.00194). Post hoc Scheffe test found a significant difference between Non Learners and High Scorers (p=0.002050), but not between Non Learners and Learners (p=0.2156) or learners and High Scorers (p=0.091935).

Question 3: Does Severity of Injury impact learning?
ANOVA for Glasgow Coma Scale score at onset of injury found a significant difference between learning categories (F(2,41)=7.4687, p=.00171). Post hoc scheffe found significant differences between Non Learners and High Scorers (p=0.0018) but not between Non Learners and Learners (p=0.2228) or Learners and High Scorers (p=0.097).



It is important to note that despite N being low for GCS collected the ANOVA was still significant. Using description of injury made at referral, individual's were also categorised into severe, or mild/moderate injury, these categories were then compared using a Chi square with Yates correction. The results of which are shown below.

	Non Learner	Learner	High Scorer
Severe Brain Injury	15	13	6
Mild/Moderate Brain Injury	7	8	22

χ^2= 8.348474 (df=2) (p=.01539)

Question 4: Does age have an impact on learning ability?

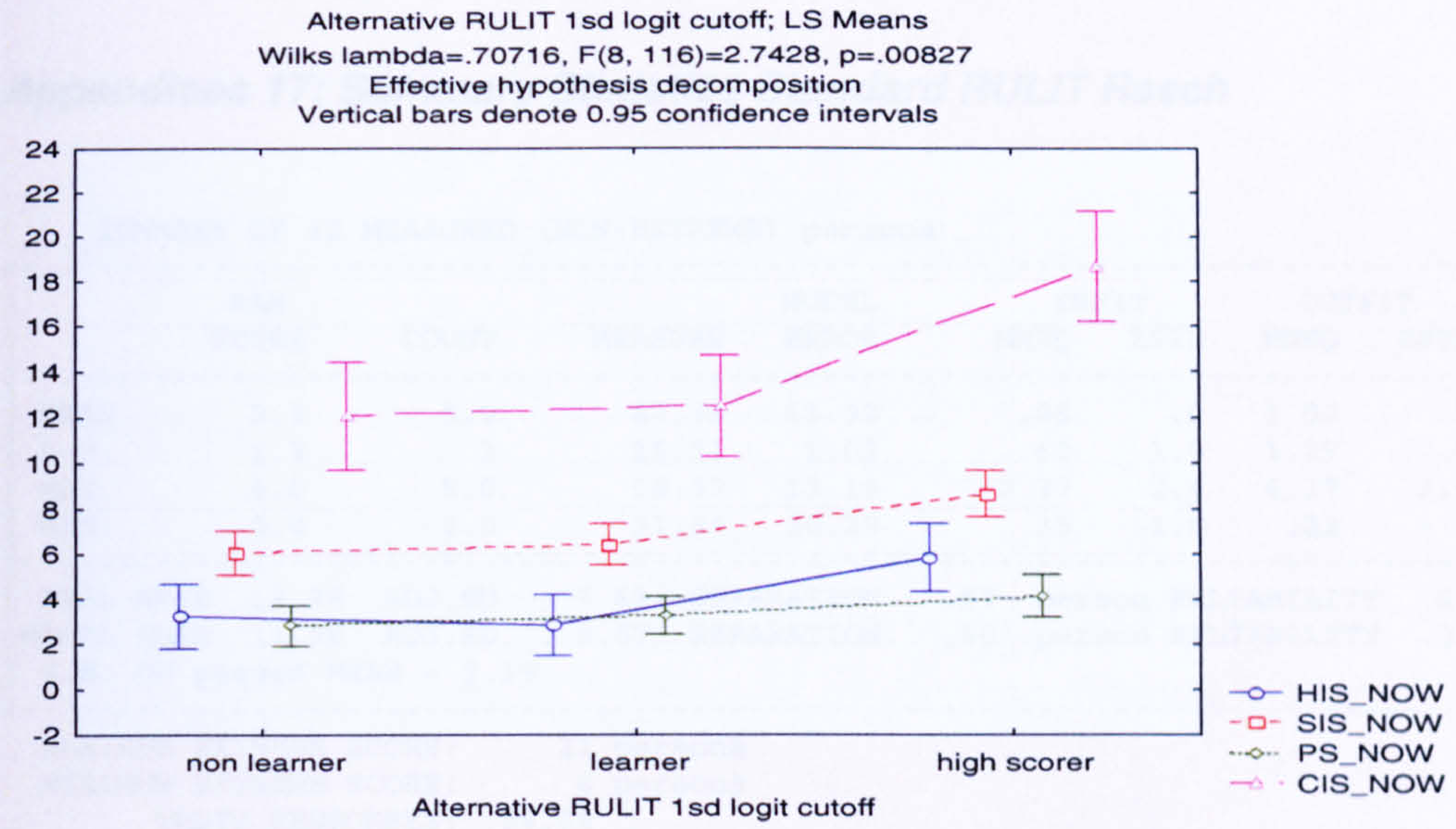
An analysis of variance showed that the effect of learner status on age at onset of injury was not significant, (F(2,62)= 1.9527, p=0.150515 but that and age at time of testing did yield a significant main effect F(2,52)= 4.886734 , p=0.011356.

Question 5: Does time since injury have an impact on learning?

The analysis of variance investigating the relationship of time since injury on learner status found a significant main effect, F (2,53)= 3.830669, p= 0.027935. The post hoc analysis of this AVNOA found significant differences between the mean of the Non Learner Group (mean= 68.06250, standard deviation = 74.68018, and the mean of the Spontaneous Learner Group (mean = 13.68421, sd = 15.58864). Indicating that the learner status (as determined by the alternative Dynamic RULIT was impacted upon by the time since injury.

Question 6 What impact does learning have on outcome?
Premorbid Community Integration
ANOVA for premorbid functioning showed no significant difference between groups (F(8,116)=1.8984; p=.0665).

Current Community Integration
ANOVA for current functioning was significant, (F(8,116)=2.7428, p=.0082). Scheffe test for Home Integration found a significant difference between Learners and High Scorers (p=0.0156) but not between non learners and learners (p=0.9185) or between non learners and high scorers (p=0.0504). Social integration found a significant difference between non learners and High Scorers (p=0.0020) and between learners and High Scorers (p=0.006819), but not between non learners and learners (p=0.8596). Scheffe tests for the Productive Activity found no significant differences between categories (non learners vs High Scorers p=0.1262; Non learners vs learners p=0.7744; learners vs high scorers p=0.3263).
In the Community Integration Total score, scheffe tests found a significant difference between Non learners and High Scorers (p=0.00134), and between Learners and High Scorers (p=0.001971), but not between Non learners and learners (p=0.9692).



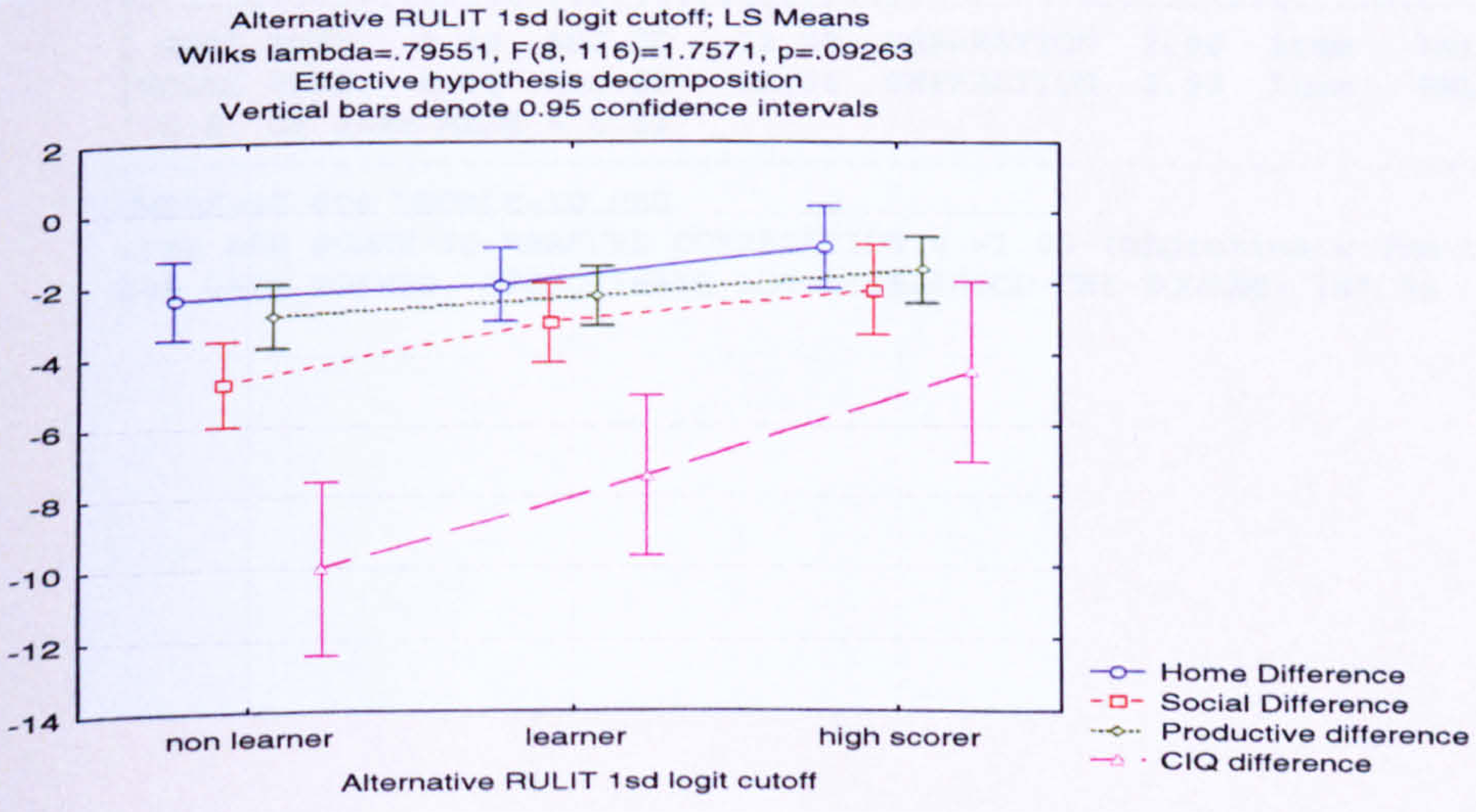
Difference between Current and Premorbid Community Integration

The Analysis of variance for the final outcome measure (current integration scores minus premorbid integration scores) was not significant. (F(8,116)=1.7572, p=.09263).

Post hoc Scheffe tests for 'Home Integration Difference' showed no significant differences between variables. For 'Social Integration Differences' scheffe test showed a significant difference between Non-Learners and High Scorers (p=0.05517) but not between Non-Learners and Learners (p=0.3338) or learners and High Scorers (p=0.5523).

Post hoc Scheffe tests for 'Productive Activity Differences' showed no significant differences between variables.

The Scheffe test for 'Community Integration Total Difference' showed a significant difference between Non-Learners and High Scorers (p=0.0102) but no other (Non-Learners vs Learners p=0.304, Learners vs High scorers P=0.2335).



Appendices 17: Summary Statistics Standard RULIT Rasch

```
     SUMMARY OF 42 MEASURED (NON-EXTREME) persons
+-----------------------------------------------------------------------------+
|           RAW                              MODEL         INFIT      OUTFIT  |
|          SCORE     COUNT      MEASURE     ERROR      MNSQ  ZSTD  MNSQ  ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       2.3       5.0        47.35     11.92        .95    .0  1.02    .3 |
| S.D.       1.3        .3        15.31      1.02        .62   1.0  1.25    .8 |
| MAX.       4.0       5.0        68.37     13.18       2.37   2.4  6.17   2.6 |
| MIN.       1.0       3.0        31.94     10.29        .35  -1.0   .22   -.9 |
|-----------------------------------------------------------------------------|
| REAL RMSE  13.28  ADJ.SD    7.63  SEPARATION   .57  person RELIABILITY  .25 |
|MODEL RMSE  11.96  ADJ.SD    9.57  SEPARATION   .80  person RELIABILITY  .39 |
| S.E. OF person MEAN = 2.39                                                  |
+-----------------------------------------------------------------------------+
  MAXIMUM EXTREME SCORE:     21 persons
  MINIMUM EXTREME SCORE:      4 persons
       VALID RESPONSES:  99.0%

     SUMMARY OF 67 MEASURED (EXTREME AND NON-EXTREME) persons
+-----------------------------------------------------------------------------+
|           RAW                              MODEL         INFIT      OUTFIT  |
|          SCORE     COUNT      MEASURE     ERROR      MNSQ  ZSTD  MNSQ  ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       3.0       5.0        57.49     14.87                             |
| S.D.       1.8        .2        23.53      3.92                             |
| MAX.       5.0       5.0        85.44     19.97                             |
| MIN.        .0       3.0        17.14     10.29                             |
|-----------------------------------------------------------------------------|
| REAL RMSE  16.05  ADJ.SD   17.21  SEPARATION  1.07  person RELIABILITY  .53 |
|MODEL RMSE  15.38  ADJ.SD   17.80  SEPARATION  1.16  person RELIABILITY  .57 |
| S.E. OF person MEAN = 2.90                                                  |
+-----------------------------------------------------------------------------+
person RAW SCORE-TO-MEASURE CORRELATION = 1.00 (approximate due to missing data)
CRONBACH ALPHA (KR-20) person RAW SCORE RELIABILITY = .80 (approximate due to
missing data)

     SUMMARY OF 5 MEASURED (NON-EXTREME) items
+-----------------------------------------------------------------------------+
|           RAW                              MODEL         INFIT      OUTFIT  |
|          SCORE     COUNT      MEASURE     ERROR      MNSQ  ZSTD  MNSQ  ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      19.2      41.6        50.00      4.12        .99    .0  1.03   -.1 |
| S.D.       7.8        .5        13.04       .41        .27   1.5   .41   1.2 |
| MAX.      29.0      42.0        72.96      4.93       1.36   2.2  1.72   1.5 |
| MIN.       6.0      41.0        34.74      3.84        .62  -1.8   .59  -1.5 |
|-----------------------------------------------------------------------------|
| REAL RMSE   4.39  ADJ.SD   12.28  SEPARATION  2.80  item   RELIABILITY  .89 |
|MODEL RMSE   4.14  ADJ.SD   12.36  SEPARATION  2.99  item   RELIABILITY  .90 |
| S.E. OF item MEAN = 6.52                                                    |
+-----------------------------------------------------------------------------+
UMEAN=50.000 USCALE=10.000
item RAW SCORE-TO-MEASURE CORRELATION = -1.00 (approximate due to missing data)
208 DATA POINTS. APPROXIMATE LOG-LIKELIHOOD CHI-SQUARE: 185.56
```

```
        item STATISTICS:  MISFIT ORDER

+------------------------------------------------------------------------------
----+
|ENTRY    RAW                              MODEL|   INFIT   |  OUTFIT   |PTMEA|EXACT MATCH|
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.| OBS%  EXP%|
item                 |
|------------------------------------+----------+----------+-----+-----------+---
----|
|     2     29     42    34.74    3.87|1.36    2.2|1.72    1.5|A .55| 61.9  74.6|
Pre Step Errors      |
|     4      6     41    72.96    4.93|1.21     .9|1.05     .3|B .77| 85.4  85.3|
Pre Delayed Correct |
|     5     22     41    44.54    3.91|1.02     .2|1.17     .6|C .72| 75.6  77.4|
Pre Delayed Errors   |
|     3     23     42    43.51    3.84| .75   -1.3| .62   -1.4|b .78| 83.3  76.7|
Pre Trials 2 Correct|
|     1     16     42    54.25    4.03| .62   -1.8| .59   -1.5|a .86| 85.7  79.4|
Pre Total Correct    |
|------------------------------------+----------+----------+-----+-----------+---
----|
| MEAN     19.2    41.6    50.00    4.12| .99     .0|1.03    -.1|     | 78.4  78.7|
| S.D.      7.8      .5    13.04     .41| .27    1.5| .41    1.2|     |  9.0   3.6|
+------------------------------------------------------------------------------
----+
```

Appendices 18: Summary Statistics Dynamic RULIT Rasch

```
     SUMMARY OF 54 MEASURED (NON-EXTREME) persons
+-----------------------------------------------------------------------------+
|          RAW                               MODEL         INFIT       OUTFIT  |
|         SCORE      COUNT      MEASURE    ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       6.4       13.0        48.40     8.83        .96    -.3   1.19     .7 |
| S.D.       3.4         .0        21.96     1.78        .76    1.3   2.07     .9 |
| MAX.      12.0       13.0        93.50    13.36       3.32    3.9   9.90    3.0 |
| MIN.       1.0       13.0         9.95     7.07        .31   -1.5    .08    -.3 |
|-----------------------------------------------------------------------------|
| REAL RMSE  10.33  ADJ.SD   19.38  SEPARATION  1.88  person RELIABILITY  .78 |
|MODEL RMSE   9.01  ADJ.SD   20.02  SEPARATION  2.22  person RELIABILITY  .83 |
| S.E. OF person MEAN = 3.02                                                  |
+-----------------------------------------------------------------------------+
  MINIMUM EXTREME SCORE:      13 persons

     SUMMARY OF 67 MEASURED (EXTREME AND NON-EXTREME) persons
+-----------------------------------------------------------------------------+
|          RAW                               MODEL         INFIT       OUTFIT  |
|         SCORE      COUNT      MEASURE    ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       5.1       13.0        37.86    10.92                              |
| S.D.       3.9         .0        29.16     4.54                              |
| MAX.      12.0       13.0        93.50    19.59                              |
| MIN.        .0       13.0        -5.93     7.07                              |
|-----------------------------------------------------------------------------|
| REAL RMSE  12.67  ADJ.SD   26.26  SEPARATION  2.07  person RELIABILITY  .81 |
|MODEL RMSE  11.83  ADJ.SD   26.65  SEPARATION  2.25  person RELIABILITY  .84 |
| S.E. OF person MEAN = 3.59                                                  |
+-----------------------------------------------------------------------------+
person RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) person RAW SCORE RELIABILITY = .90

     SUMMARY OF 13 MEASURED (NON-EXTREME) items
+-----------------------------------------------------------------------------+
|          RAW                               MODEL         INFIT       OUTFIT  |
|         SCORE      COUNT      MEASURE    ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      26.4       54.0        50.00     4.40        .95    -.2   1.26     .6 |
| S.D.      13.2         .0        22.69     1.17        .20    1.0   1.20    1.1 |
| MAX.      50.0       54.0        99.18     7.95       1.26    1.4   5.05    3.6 |
| MIN.       2.0       54.0         7.72     3.71        .70   -1.7    .20   -1.0 |
|-----------------------------------------------------------------------------|
| REAL RMSE    4.71  ADJ.SD   22.19  SEPARATION  4.71  item    RELIABILITY  .96 |
|MODEL RMSE    4.56  ADJ.SD   22.22  SEPARATION  4.87  item    RELIABILITY  .96 |
| S.E. OF item MEAN = 6.55                                                    |
+-----------------------------------------------------------------------------+
  MAXIMUM EXTREME SCORE:      1 items
UMEAN=50.000 USCALE=10.000

     SUMMARY OF 14 MEASURED (EXTREME AND NON-EXTREME) items
+-----------------------------------------------------------------------------+
|          RAW                               MODEL         INFIT       OUTFIT  |
|         SCORE      COUNT      MEASURE    ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      24.5       54.0        55.04     5.40                              |
| S.D.      14.4         .0        28.42     3.78                              |
| MAX.      50.0       54.0       120.54    18.40                              |
| MIN.        .0       54.0         7.72     3.71                              |
|-----------------------------------------------------------------------------|
| REAL RMSE    6.69  ADJ.SD   27.63  SEPARATION  4.13  item    RELIABILITY  .94 |
|MODEL RMSE    6.59  ADJ.SD   27.65  SEPARATION  4.19  item    RELIABILITY  .95 |
| S.E. OF item MEAN = 7.88                                                    |
+-----------------------------------------------------------------------------+
item RAW SCORE-TO-MEASURE CORRELATION = -.97
702 DATA POINTS. APPROXIMATE LOG-LIKELIHOOD CHI-SQUARE: 478.44
```

```
         item STATISTICS:  MISFIT ORDER

+--------------------------------------------------------------------------------
----+
|ENTRY    RAW                        MODEL|   INFIT   |  OUTFIT   |PTMEA|EXACT MATCH|
|NUMBER  SCORE  COUNT  MEASURE  S.E.  |MNSQ  ZSTD|MNSQ  ZSTD|CORR.| OBS%  EXP%|
item
|--------------------------------------+----------+----------+-----+-----------+---
----|
|     4     18     54    60.87    3.79|1.26   1.4|5.05   3.6|A .51| 74.1  80.7|
Pre Trials 2 Correct      |
|    12     31     54    42.87    3.78|1.12    .6|1.91   1.5|B .69| 81.5  82.2|
Post Trial 2 Errors       |
|     3      8     54    78.05    4.77|1.04    .2|1.67    .9|C .44| 88.9  89.1|
Pre Trials to Completion |
|    13     30     54    44.28    3.76|1.11    .6|1.35    .8|D .70| 79.6  82.0|
Post Delayed Correct      |
|    14     30     54    44.28    3.76|1.11    .6|1.35    .8|E .70| 79.6  82.0|
Post Delayed Errors       |
|    11     50     54     7.72    5.82|1.25    .8| .74    .9|F .72| 92.6  92.5|
Post Trials 2 Correct     |
|     1     11     54    71.97    4.28| .76  -1.1| .99    .4|G .56| 90.7  85.9|
Pre Total Correct         |
|     5      2     54    99.18    7.95| .94    .1| .20   1.2|f .29| 96.3  96.2|
Pre Trial 2 Errors        |
|     9     30     54    44.28    3.76| .83   -.8| .92    .0|e .75| 87.0  82.0|
Post Step Errors          |
|     8     42     54    25.93    4.18| .80  -1.0| .39   -.3|d .80| 83.3  84.6|
Post Total Correct        |
|     6     27     54    48.45    3.72| .75  -1.3| .57   -.9|c .76| 87.0  81.1|
Pre Delayed Correct       |
|    10     39     54     30.92    4.00| .70  -1.5| .74    .0|b .80| 88.9  83.0|
Post Trials to Completion|
|     7     25     54     51.19    3.71| .70  -1.7| .55  -1.0|a .75| 87.0  80.0|
Pre Delayed Errors        |
|--------------------------------------+----------+----------+-----+-----------+---
----|
| MEAN    24.5   54.0    55.04    5.40| .95   -.2|1.26    .6|     | 85.9  84.7|
| S.D.    14.4     .0    28.42    3.78| .20   1.0|1.20   1.1|     |  5.8   4.8|
+--------------------------------------------------------------------------------
----+
```

Appendices 19: Mean scores and significances for all ANOVAs etc for the RULIT chapter

Dynamic RULIT Pre Injury IQ ANOVA means and significance

RULIT Dynamic Logit cat	*PreIQ Mean*	*PreIQ Std.Err.*	*PreIQ -95.00%*	*PreIQ +95.00%*	*N*
non learner	94.03417	4.487558	85.05458	103.0138	12
Learner	97.75850	3.476048	90.80294	104.7141	20
High scorer	99.97167	2.838181	94.29248	105.6509	30

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	510758.6	1	510758.6	2113.558	0.000000
RULIT Dynamic logit	305.8	2	152.9	0.633	0.534721
Error	14257.8	59	241.7		

Dynamic RULIT Current IQ ANOVA means and significance

RULIT Dynamic Logit cat	*FSIQ Mean*	*FSIQ Std.Err.*	*FSIQ -95.00%*	*FSIQ +95.00%*	*N*
non learner	73.66667	4.934520	63.77355	83.5598	9
Learner	90.00000	3.230402	83.52343	96.4766	21
high scorer	97.07407	2.848947	91.36228	102.7859	27

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	347278.5	1	347278.5	1584.694	0.000000
RULIT Dynamic logit	3718.2	2	1859.1	8.483	0.000625
Error	11833.9	54	219.1		

Dynamic RULIT GCS ANOVA means and significance

RULIT Dynamic Logit cat	*GCSO_TOT Mean*	*GCSO_TOT Std.Err.*	*GCSO_TOT -95.00%*	*GCSO_TOT +95.00%*	*N*
non learner	5.62500	1.482463	2.631104	8.61890	8
Learner	8.53846	1.162940	6.189857	10.88707	13
high scorer	11.52174	0.874309	9.756036	13.28744	23

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	2688.370	1	2688.370	152.9083	0.000000
RULIT Dynamic logit	225.951	2	112.975	6.4258	0.003737
Error	720.845	41	17.582		

Dynamic RULIT age at onset ANOVA means and significance

RULIT Dynamic Logit cat	*AGE Mean*	*AGE Std.Err.*	*AGE -95.00%*	*AGE +95.00%*	*N*
non learner	38.58333	3.643255	31.30057	45.86610	12
Learner	34.04348	2.631578	28.78303	39.30393	23
high scorer	28.53333	2.304197	23.92731	33.13936	30

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	63900.71	1	63900.71	401.1856	0.000000
RULIT Dynamic logit	969.21	2	484.61	3.0425	0.054897
Error	9875.34	62	159.28		

Dynamic RULIT Age at testing ANOVA means and significance

RULIT Dynamic Logit cat	*Age at testing Mean*	*Age at testing Std.Err.*	*Age at testing -95.00%*	*Age at testing +95.00%*	*N*
non learner	38.00000	3.319160	31.33962	44.66038	9
Learner	32.44444	2.347000	27.73484	37.15405	18
high scorer	29.14286	1.881787	25.36678	32.91894	28

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	49004.76	1	49004.76	494.2417	0.000000
RULIT Dynamic logit	550.24	2	275.12	2.7747	0.071617
Error	5155.87	52	99.15		

Dynamic RULIT Time since injury ANOVA means and significance

RULIT Dynamic Logit cat	*Time Mean*	*Time Std.Err.*	*Time -95.00%*	*Time +95.00%*	*N*
non learner	72.00000	24.90203	14.57582	129.4242	9
Learner	45.05263	13.29566	17.11948	72.9858	19
high scorer	29.96429	11.14793	7.09062	52.8380	28

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
RULIT Dynamic logit	12331.64	2	6165.821	1.641676	0.203349
Error	199057.9	53	3755.810		

Dynamic RULIT Pre Injury Home Integration CIQ scale ANOVA means and significance

RULIT Dynamic Logit cat	*HIS_PRE Mean*	*HIS_PRE Std.Err.*	*HIS_PRE -95.00%*	*HIS_PRE +95.00%*	*N*

non learner	5.153846	1.008567	3.137092	7.170600	13
Learner	5.636364	0.775292	4.086072	7.186655	22
high scorer	5.931034	0.675270	4.580749	7.281320	29

Dynamic RULIT Pre Injury Social Integration CIQ scale ANOVA means and significance

RULIT Dynamic Logit cat	*SIS_PRE Mean*	*SIS_PRE Std.Err.*	*SIS_PRE -95.00%*	*SIS_PRE +95.00%*	*N*
non learner	10.69231	0.539884	9.612744	11.77187	13
Learner	10.09091	0.415012	9.261042	10.92078	22
high scorer	10.34483	0.361470	9.622023	11.06763	29

Dynamic RULIT Pre Injury Productive Activity Integration CIQ scale ANOVA means and significance

RULIT Dynamic Logit cat	*PS_PRE Mean*	*PS_PRE Std.Err.*	*PS_PRE -95.00%*	*PS_PRE +95.00%*	*N*
non learner	5.384615	0.319405	4.745926	6.023305	13
Learner	5.818182	0.245528	5.327217	6.309146	22
high scorer	5.655172	0.213852	5.227548	6.082797	29

Dynamic RULIT Pre Injury Total Integration CIQ scale ANOVA means and significance

RULIT Dynamic Logit cat	*CIS_PRE Mean*	*CIS_PRE Std.Err.*	*CIS_PRE -95.00%*	*CIS_PRE +95.00%*	*N*
non learner	21.23077	1.339346	18.55258	23.90896	13
Learner	21.54545	1.029563	19.48672	23.60419	22
high scorer	21.79310	0.896738	19.99997	23.58624	29

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.027146	519.6516	4	58	0.000000
RULIT Dynamic logit	Wilks	0.907886	0.7178	8	116	0.675402

Dynamic RULIT Current Home Integration Scale ANOVA means and significance

RULIT Dynamic Logit cat	*HIS_NOW Mean*	*HIS_NOW Std.Err*	*HIS_NOW -95.00%*	*HIS_NOW +95.00%*	*N*
non learner	2.461538	0.948910	0.564076	4.359001	13
Learner	3.500000	0.729433	2.041409	4.958591	22
high scorer	4.758621	0.635328	3.488205	6.029037	29

Dynamic RULIT Current Social Integration Scale ANOVA means and significance

RULIT Dynamic Logit cat	*SIS_NOW Mean*	*SIS_NOW Std.Err.*	*SIS_NOW -95.00%*	*SIS_NOW +95.00%*	*N*
non learner	5.538462	0.636742	4.265217	6.811706	13
Learner	6.409091	0.489468	5.430340	7.387842	22

high scorer	8.034483	0.426321	7.182002	8.886964	29

Dynamic RULIT Current Productive Activity Scale ANOVA means and significance

RULIT Dynamic Logit cat	*PS_NOW Mean*	*PS_NOW Std.Err.*	*PS_NOW -95.00%*	*PS_NOW +95.00%*	*N*
Non learner	2.076923	0.552710	0.971711	3.182135	13
Learner	3.272727	0.424872	2.423144	4.122310	22
High scorer	4.034483	0.370058	3.294506	4.774460	29

Dynamic RULIT Current Total Integration Scale ANOVA means and significance

RULIT Dynamic Logit cat	*CIS_NOW Mean*	*CIS_NOW Std.Err.*	*CIS_NOW -95.00%*	*CIS_NOW +95.00%*	*N*
Non learner	10.07692	1.543948	6.98961	13.16424	13
Learner	13.18182	1.186842	10.80858	15.55506	22
High scorer	16.82759	1.033726	14.76052	18.89465	29

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.105689	122.6944	4	58	0.000000
RULIT Dynamic logit	Wilks	0.776662	1.9533	8	116	0.058526

Dynamic RULIT Change in Home Integration Scale ANOVA means and significance

RULIT Dynamic Logit cat	*Home Difference Mean*	*Home Difference Std.Err.*	*Home Difference -95.00%*	*Home Difference +95.00%*	*N*
Non learner	-2.69231	0.700835	-4.09371	-1.29090	13
Learner	-2.13636	0.538736	-3.21363	-1.05909	22
High scorer	-1.17241	0.469233	-2.11070	-0.23412	29

Dynamic RULIT Change in Social Integration Scale ANOVA means and significance

RULIT Dynamic Logit cat	*Social Difference Mean*	*Social Difference Std.Err.*	*Social Difference -95.00%*	*Social Difference +95.00%*	*N*
Non learner	-5.15385	0.758867	-6.67129	-3.63640	13
Learner	-3.68182	0.583346	-4.84829	-2.51535	22
High scorer	-2.31034	0.508087	-3.32633	-1.29436	29

Dynamic RULIT Change in Productive Activity Scale ANOVA means and significance

RULIT Dynamic Logit cat	*Productive difference Mean*	*Productive difference Std.Err.*	*Productive difference -95.00%*	*Productive difference +95.00%*	*N*
non learner	-3.30769	0.555894	-4.41927	-2.19611	13
Learner	-2.54545	0.427319	-3.39993	-1.69098	22
High scorer	-1.62069	0.372190	-2.36493	-0.87645	29

Dynamic RULIT Change in Total Integration Scale ANOVA means and significance

RULIT Dynamic Logit cat	*CIQ difference Mean*	*CIQ difference Std.Err.*	*CIQ difference -95.00%*	*CIQ difference +95.00%*	*N*
non learner	-11.1538	1.510680	-14.1746	-8.13305	13
Learner	-8.3636	1.161269	-10.6857	-6.04154	22
High scorer	-4.9655	1.011452	-6.9880	-2.94299	29

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.310173	32.24812	4	58	0.000000
RULIT Dynamic logit	Wilks	0.801495	1.69637	8	116	0.106442

Standard RULIT ANOVAs

Standard RULIT Pre Injury IQ ANOVA means and significance

RULIT Standard Logit cat	*PreIQ Mean*	*PreIQ Std.Err.*	*PreIQ -95.00%*	*PreIQ +95.00%*	*N*
non learner	91.5806	3.510508	84.55605	98.6051	18
Learner	103.6422	3.105577	97.42793	109.8564	23
High scorer	97.6433	3.250099	91.13990	104.1468	21

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	584854.1	1	584854.1	2636.545	0.000000
RULIT Standard logit	1475.9	2	737.9	3.327	0.042761
Error	13087.7	59	221.8		

Standard RULIT Current IQ ANOVA means and significance

RULIT Standard Logit cat	*FSIQ Mean*	*FSIQ Std.Err.*	*FSIQ -95.00%*	*FSIQ +95.00%*	*N*
non learner	79.82353	3.670443	72.46473	87.1823	17
Learner	92.90476	3.302428	86.28379	99.5257	21
high scorer	98.21053	3.471892	91.24980	105.1713	19

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	461469.3	1	461469.3	2014.916	0.000000
RULIT Standard logit	3184.6	2	1592.3	6.952	0.002057
Error	12367.4	54	229.0		

Standard RULIT GCS ANOVA means and significance

RULIT Standard Logit cat	*GCSO_TOT Mean*	*GCSO_TOT Std.Err.*	*GCSO_TOT -95.00%*	*GCSO_TOT +95.00%*	*N*
non learner	8.23077	1.282733	5.640236	10.82130	13
Learner	8.92857	1.236073	6.432272	11.42487	14
high scorer	11.11765	1.121718	8.852292	13.38300	17

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	3859.478	1	3859.478	180.4315	0.000000

RULIT Standard logit	69.794	2	34.897	1.6315	0.208089
Error	877.001	41	21.390		

Standard RULIT age at onset ANOVA means and significance

RULIT Standard Logit cat	*AGE Mean*	*AGE Std.Err.*	*AGE -95.00%*	*AGE +95.00%*	*N*
non learner	36.76190	2.799210	31.16636	42.35745	21
Learner	31.08696	2.674738	25.74023	36.43368	23
high scorer	29.28571	2.799210	23.69017	34.88126	21

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	68017.40	1	68017.40	413.3612	0.000000
RULIT Standard logit	642.63	2	321.32	1.9527	0.150515
Error	10201.92	62	164.55		

Standard RULIT Age at testing ANOVA means and significance

RULIT Standard Logit cat	*Age at testing Mean*	*Age at testing Std.Err.*	*Age at testing -95.00%*	*Age at testing +95.00%*	*N*
non learner	34.57143	2.689836	29.17388	39.96898	14
Learner	33.23810	2.196242	28.83101	37.64518	21
high scorer	28.00000	2.250478	23.48409	32.51591	20

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	54301.06	1	54301.06	536.0789	0.000000
RULIT Standard logit	438.87	2	219.44	2.1663	0.124829
Error	5267.24	52	101.29		

Standard RULIT Time since injury ANOVA means and significance

RULIT Standard Logit cat	*Time Mean*	*Time Std.Err.*	*Time -95.00%*	*Time +95.00%*	*N*
non learner	54.92857	15.41459	21.62738	88.22976	14
Learner	35.40909	12.53543	9.34023	61.47795	22
high scorer	39.75000	15.57256	7.15626	72.34374	20

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
RULIT Standard logit	3395.557	2	1697.778	0.432619	0.651078
Error	207994.0	53	3924.415		

Standard RULIT Pre Injury Home Integration CIQ scale ANOVA means and significance

RULIT Standard Logit cat	*HIS_PRE Mean*	*HIS_PRE Std.Err.*	*HIS_PRE -95.00%*	*HIS_PRE +95.00%*	*N*
non learner	4.750000	0.802685	3.144932	6.355068	20
Learner	6.250000	0.732748	4.784780	7.715220	24
high scorer	5.900000	0.802685	4.294932	7.505068	20

Standard RULIT Pre Injury Social Integration CIQ scale ANOVA means and significance

RULIT Standard Logit cat	*SIS_PRE Mean*	*SIS_PRE Std.Err.*	*SIS_PRE -95.00%*	*SIS_PRE +95.00%*	*N*
non learner	10.30000	0.436532	9.427100	11.17290	20
Learner	10.16667	0.398497	9.369822	10.96351	24
high scorer	10.55000	0.436532	9.677100	11.42290	20

Standard RULIT Pre Injury Productive Activity Integration CIQ scale ANOVA means and significance

RULIT Standard Logit cat	*PS_PRE Mean*	*PS_PRE Std.Err.*	*PS_PRE -95.00%*	*PS_PRE +95.00%*	*N*
non learner	5.600000	0.255165	5.089766	6.110234	20
Learner	5.916667	0.232933	5.450889	6.382445	24
high scorer	5.400000	0.255165	4.889766	5.910234	20

Standard RULIT Pre Injury Total Integration CIQ scale *ANOVA means and* significance

RULIT Standard Logit cat	*CIS_PRE Mean*	*CIS_PRE Std.Err.*	*CIS_PRE -95.00%*	*CIS_PRE +95.00%*	*N*
non learner	20.65000	1.069102	18.51220	22.78780	20
Learner	22.33333	0.975952	20.38180	24.28487	24
high scorer	21.65000	1.069102	19.51220	23.78780	20

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.024498	577.3936	4	58	0.000000
RULIT Standard logit	Wilks	0.843087	1.2918	8	116	0.254510

Standard RULIT Current Home Integration Scale ANOVA means and significance

RULIT Standard Logit cat	*HIS_NOW Mean*	*HIS_NOW Std.Err*	*HIS_NOW -95.00%*	*HIS_NOW +95.00%*	*N*
non learner	2.550000	0.759021	1.032243	4.067757	20
Learner	3.958333	0.692889	2.572817	5.343850	24
high scorer	5.050000	0.759021	3.532243	6.567757	20

Standard RULIT Current Social Integration Scale ANOVA means and significance

RULIT Standard Logit cat	*SIS_NOW Mean*	*SIS_NOW Std.Err.*	*SIS_NOW -95.00%*	*SIS_NOW +95.00%*	*N*
non learner	5.600000	0.505955	4.588280	6.611720	20
Learner	6.958333	0.461872	6.034764	7.881903	24
high scorer	8.350000	0.505955	7.338280	9.361720	20

Standard RULIT Current Productive Activity Scale ANOVA means and significance

RULIT Standard Logit cat	*PS_NOW Mean*	*PS_NOW Std.Err.*	*PS_NOW -95.00%*	*PS_NOW +95.00%*	*N*
non learner	2.550000	0.458414	1.633344	3.466656	20
Learner	3.875000	0.418473	3.038212	4.711788	24
high scorer	3.600000	0.458414	2.683344	4.516656	20

Standard RULIT Current Total Integration Scale ANOVA means and significance

RULIT Standard Logit cat	*CIS_NOW Mean*	*CIS_NOW Std.Err.*	*CIS_NOW -95.00%*	*CIS_NOW +95.00%*	*N*
non learner	10.70000	1.255858	8.18876	13.21124	20
Learner	14.79167	1.146436	12.49923	17.08411	24
high scorer	17.00000	1.255858	14.48876	19.51124	20

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.085541	155.0086	4	58	0.000000
RULIT Standard logit	Wilks	0.721128	2.5750	8	116	0.012663

Standard RULIT Change in Home Integration Scale ANOVA means and significance

RULIT Standard Logit cat	*Home Difference Mean*	*Home Difference Std.Err.*	*Home Difference -95.00%*	*Home Difference +95.00%*	*N*
non learner	-2.20000	0.563004	-3.32580	-1.07420	20
Learner	-2.29167	0.513950	-3.31937	-1.26396	24
high scorer	-0.85000	0.563004	-1.97580	-0.27580	20

Standard RULIT Change in Social Integration Scale ANOVA means and significance

RULIT Standard Logit cat	*Social Difference Mean*	*Social Difference Std.Err.*	*Social Difference -95.00%*	*Social Difference +95.00%*	*N*
non learner	-4.70000	0.620258	-5.94028	-3.45972	20
Learner	-3.20833	0.566215	-4.34055	-2.07612	24
high scorer	-2.20000	0.620258	-3.44028	-0.95972	20

Standard RULIT Change in Productive Activity Scale ANOVA means and significance

RULIT Standard Logit cat	*Productive difference Mean*	*Productive difference Std.Err.*	*Productive difference -95.00%*	*Productive difference +95.00%*	*N*
non learner	-3.05000	0.457280	-3.96439	-2.13561	20
Learner	-2.04167	0.417438	-2.87639	-1.20695	24

high scorer	-1.80000	0.457280	-2.71439	-0.88561	20

Standard RULIT Change in Total Integration Scale ANOVA means and significance

RULIT Standard Logit cat	*CIQ difference Mean*	*CIQ difference Std.Err.*	*CIQ difference -95.00%*	*CIQ difference +95.00%*	*N*
non learner	-9.95000	1.249084	-12.4477	-7.45230	20
Learner	-7.54167	1.140253	-9.8217	-5.26159	24
high scorer	-4.65000	1.249084	-7.1477	-2.15230	20

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.342388	27.84964	4	58	0.000000
RULIT Standard logit	Wilks	0.798879	1.72286	8	116	0.100207

Alternative dynamic RULIT ANOVAs

Alternative dynamic RULIT Pre Injury IQ ANOVA means and significance

RULIT Alternative dynamic Logit cat	*PreIQ Mean*	*PreIQ Std.Err.*	*PreIQ -95.00%*	*PreIQ +95.00%*	*N*
non learner	95.4467	3.674931	88.09315	102.8002	18
Learner	98.3113	3.182584	91.94291	104.6796	24
High scorer	100.2610	3.486346	93.28484	107.2372	20

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	587188.0	1	587188.0	2415.495	0.000000
RULIT Alternative dynamic logit	221.2	2	110.6	0.455	0.636689
Error	14342.4	59	243.1		

Alternative dynamic RULIT Current IQ ANOVA means and significance

RULIT Alternative dynamic Logit cat	*FSIQ Mean*	*FSIQ Std.Err.*	*FSIQ -95.00%*	*FSIQ +95.00%*	*N*
non learner	81.1250	3.779339	73.54788	88.7021	16
Learner	89.8696	3.152186	83.54981	96.1893	23
High scorer	100.5000	3.563195	93.35622	107.6438	18

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	456308.8	1	456308.8	1996.674	0.000000
RULIT Alternative dynamic logit	3211.2	2	1605.6	7.026	0.001941
Error	12340.9	54	228.5		

Alternative dynamic RULIT GCS ANOVA means and significance

RULIT Alternative dynamic Logit cat	*GCSO_TOT Mean*	*GCSO_TOT Std.Err.*	*GCSO_TOT -95.00%*	*GCSO_TOT +95.00%*	*N*
non learner	6.53846	1.141051	4.23406	8.84286	13
Learner	9.25000	1.028529	7.17284	11.32716	16
high scorer	12.53333	1.062260	10.38806	14.67861	15

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	3892.111	1	3892.111	229.9493	0.000000
RULIT Alternative dynamic logit	252.831	2	126.416	7.4687	0.001715
Error	693.964	41	16.926		

Alternative dynamic RULIT age at onset ANOVA means and significance

RULIT Alternative dynamic Logit cat	*AGE Mean*	*AGE Std.Err.*	*AGE -95.00%*	*AGE +95.00%*	*N*
non learner	37.95238	2.751070	32.45307	43.45169	21
Learner	29.16667	2.573390	24.02253	34.31080	24
high scorer	30.25000	2.819007	24.61488	35.88512	20

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	68017.40	1	68017.40	413.3612	0.000000
RULIT Alternative dynamic logit	642.63	2	321.32	1.9527	0.150515
Error	10201.92	62	164.55		

Alternative dynamic RULIT Age at testing ANOVA means and significance

RULIT Alternative dynamic Logit cat	*Age at testing Mean*	*Age at testing Std.Err.*	*Age at testing -95.00%*	*Age at testing +95.00%*	*N*
non learner	37.93750	2.402753	33.11602	42.75898	16
Learner	29.75000	2.149087	25.43754	34.06246	20
high scorer	28.42105	2.204917	23.99656	32.84554	19

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	55936.33	1	55936.33	605.5581	0.000000
RULIT Alternative dynamic logit	902.79	2	451.40	4.8867	0.011356
Error	4803.32	52	92.37		

Alternative dynamic RULIT Time since injury ANOVA means and significance

RULIT Alternative dynamic Logit cat	*Time Mean*	*Time Std.Err.*	*Time -95.00%*	*Time +95.00%*	*N*
non learner	68.06250	18.67004	28.26824	107.8568	16
Learner	47.33333	15.17051	15.68820	78.9785	21
high scorer	13.68421	3.57628	6.17072	21.1977	19

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
RULIT Alternative dynamic logit	26697.84	2	13348.92	3.830669	0.027935
Error	184691.7	53	3484.749		

Alternative dynamic RULIT Pre Injury Home Integration CIQ scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*HIS_PRE Mean*	*HIS_PRE Std.Err.*	*HIS_PRE -95.00%*	*HIS_PRE +95.00%*	*N*
non learner	5.619048	0.776028	4.067283	7.170812	21
Learner	4.833333	0.725908	3.381791	6.284876	24
high scorer	6.789474	0.815850	5.158081	8.420867	19

Alternative dynamic RULIT Pre Injury Social Integration CIQ scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*SIS_PRE Mean*	*SIS_PRE Std.Err.*	*SIS_PRE -95.00%*	*SIS_PRE +95.00%*	*N*
non learner	10.80952	0.402727	10.00422	11.61483	21
Learner	9.50000	0.376717	8.74671	10.25329	24
high scorer	10.84211	0.423393	9.99548	11.68873	19

Alternative dynamic RULIT Pre Injury Productive Activity Integration CIQ scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*PS_PRE Mean*	*PS_PRE Std.Err.*	*PS_PRE -95.00%*	*PS_PRE +95.00%*	*N*
non learner	5.666667	0.253291	5.160180	6.173153	21
Learner	5.583333	0.236932	5.109559	6.057108	24
high scorer	5.736842	0.266289	5.204365	6.269319	19

Alternative dynamic RULIT Pre Injury Total Integration CIQ scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*CIS_PRE Mean*	*CIS_PRE Std.Err.*	*CIS_PRE -95.00%*	*CIS_PRE +95.00%*	*N*
non learner	22.09524	1.009776	20.07607	24.11441	21
Learner	19.91667	0.944559	18.02790	21.80543	24
high scorer	23.15789	1.061593	21.03511	25.28068	19

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.022792	621.6851	4	58	0.000000
RULIT Alternative dynamic logit	Wilks	0.781869	1.8984	8	116	0.066650

Alternative dynamic RULIT Current Home Integration Scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*HIS_NOW Mean*	*HIS_NOW Std.Err*	*HIS_NOW -95.00%*	*HIS_NOW +95.00%*	*N*
non learner	3.238095	0.716521	1.805322	4.670868	21
Learner	2.833333	0.670244	1.493097	4.173570	24
high scorer	5.842105	0.753290	4.335809	7.348401	19

Alternative dynamic RULIT Current Social Integration Scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*SIS_NOW Mean*	*SIS_NOW Std.Err.*	*SIS_NOW -95.00%*	*SIS_NOW +95.00%*	*N*
non learner	6.047619	0.489460	5.068883	7.026355	21
Learner	6.416667	0.457848	5.501143	7.332191	24
high scorer	8.684211	0.514577	7.655250	9.713171	19

Alternative dynamic RULIT Current Productive Activity Scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*PS_NOW Mean*	*PS_NOW Std.Err.*	*PS_NOW -95.00%*	*PS_NOW +95.00%*	*N*
non learner	2.809524	0.449012	1.911669	3.707378	21
Learner	3.250000	0.420012	2.410134	4.089866	24
high scorer	4.157895	0.472053	3.213967	5.101823	19

Alternative dynamic RULIT Current Total Integration Scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*CIS_NOW Mean*	*CIS_NOW Std.Err.*	*CIS_NOW -95.00%*	*CIS_NOW +95.00%*	*N*
non learner	12.09524	1.182066	9.73155	14.45892	21
Learner	12.50000	1.105721	10.28897	14.71103	24
high scorer	18.68421	1.242723	16.19923	21.16919	19

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.080889	164.7588	4	58	0.000000
RULIT Alternative dynamic logit	Wilks	0.707164	2.7428	8	116	0.008273

Alternative dynamic RULIT Change in Home Integration Scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*Home Difference Mean*	*Home Difference Std.Err.*	*Home Difference -95.00%*	*Home Difference +95.00%*	*N*
non learner	-2.38095	0.553112	-3.48697	-1.27494	21
Learner	-2.00000	0.517389	-3.03458	-0.96542	24
high scorer	-0.94737	0.581495	-2.11014	-0.21540	19

Alternative dynamic RULIT Change in Social Integration Scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*Social Difference Mean*	*Social Difference Std.Err.*	*Social Difference -95.00%*	*Social Difference +95.00%*	*N*
non learner	-4.76190	0.600656	-5.96299	-3.56082	21
Learner	-3.08333	0.561862	-4.20685	-1.95982	24
high scorer	-2.15789	0.631479	-3.42061	-0.89517	19

Alternative dynamic RULIT Change in Productive Activity Scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*Productive difference Mean*	*Productive difference Std.Err.*	*Productive difference -95.00%*	*Productive difference +95.00%*	*N*
non learner	-2.85714	0.447507	-3.75199	-1.96230	21
Learner	-2.33333	0.418605	-3.17038	-1.49628	24
high scorer	-1.57895	0.470471	-2.51971	-0.63818	19

Alternative dynamic RULIT Change in Total Integration Scale ANOVA means and significance

RULIT Alternative dynamic Logit cat	*CIQ difference Mean*	*CIQ difference Std.Err.*	*CIQ difference -95.00%*	*CIQ difference +95.00%*	*N*
non learner	-10.0000	1.211631	-12.4228	-7.57720	21
Learner	-7.4167	1.133377	-9.6830	-5.15034	24
high scorer	-4.4737	1.273805	-7.0208	-1.92655	19

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.346293	27.37210	4	58	0.000000
RULIT Alternative dynamic logit	Wilks	0.795514	1.75714	8	116	0.092632

Appendices 20: Tower of Hanoi Administration Scripts

Administrator presents the Tower of Hanoi to the participant
The goal of this assessment is to move all three discs from this left hand peg, to the right hand peg in the same order as they are now.
There are certain rules that you must follow, these are

1) **you cannot place a larger disc on top of a smaller one**
(Administrator illustrates what you cannot do)

2) **You cannot move more than one disc at a time**
(Administrator illustrates that you cannot move two discs at a time)

3) **You cannot put the discs anywhere else except on the pegs)**
(Administrator illustrates that where you can and cannot place the discs).

Ok, why don't you have a try? I will be timing you and recording how many moves you manage to complete the test in.

(Begin timing regardless of whether participant has begun to move a disc or not, record number of moves – a move is counted if the disc is lifted of a peg – regardless of whether it is placed back on the same peg).
If a rule is broke, inform the participant and ask them to correct the mistake and continue.

After the participant has completed the first trial replace the discs back to their original position.

Well done, now I would like you to have another try, again I will be timing you and recording how many moves you manage to complete the test in.

If participant has completed either trial in the minimum number of moves – administer the test with four discs.

If participant completes either of the four disc trials in the minimum number of moves – administer the test with five discs.

Appendices 21: RCI calculations for the Tower of Hanoi change Scores

3 discs
Moves SD = 3.9
Time SD= 42 (2 outliers removed (above 200 seconds) 69 was original sd

4 discs
Moves SD = 8.39 (1 outlier removed – above 100 moves) 15.2 was original sd
Time SD = 81.82 – there is a big range of times for this one but none were removed.

5 discs
Moves SD = 19.4 (1 outlier was removed – anything above 110) 30.01 was original sd
Time SD = 138.69

3discs
moves
3.9X.447 = 1.743
SEM = 1.743
SD= 1.743X1.4142= **2.465**

Time
42 X 0.447= 18.774
SEM = 18.774
SD = 18.774 X 1.4142 = **26.55**

4 Discs
Moves
8.39 X 0.447 = 3.75
SEM 3.75
SD = 3.75 X 1.4142 = **5.3037**

Times
81.82 X 0.447 = 36.5735
SEM = 36.5735
SD= 36.5735 X 1.4142 = **51.722**

5 Discs
Moves
19.4 X 0.447 = 8.6718
SEM = 8.6718
SD = 8.6718 X 1.4142 = **12.2636**

Time 138.69
138.69 X 0.447 = 61.99
SEM = 61.99
SD = 61.99 X 1.4142 = **87.66**

Accounting for High Scorers
3 disc moves: if sd is 2.46 and min moves is 7 then anything under 9.46 is a high scorer
3 disc time: if sd =26.55 then anything under 26.55 seconds is a high scorer

4 disc moves: if sd is 5.3037 and min moves is 15 then anything under 20.3037 is a high scorer
4 disc time: 51.722 then anything under 51.722 is a high scorer

5 discs: 12.2636 sd and min moves is 31 then 43.2636 is a high scorer
5 discs time: 87.66 then anything under 87.66 is a high scorer

Appendices 22: Summary Statistics Standard ToH Rasch

```
     SUMMARY OF 48 MEASURED (NON-EXTREME) persons
+-----------------------------------------------------------------------------+
|           RAW                            MODEL         INFIT        OUTFIT   |
|          SCORE      COUNT      MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       1.6        3.0        52.86   23.84        .72     .0     .63    1.4 |
| S.D.        .5         .1        17.80    6.02       2.00     .9    1.97    1.0 |
| MAX.       2.0        3.0        66.03   28.30       9.90    2.6    9.90    3.2 |
| MIN.       1.0        2.0        28.82   15.70        .06    -.9     .05    -.9 |
|-----------------------------------------------------------------------------|
| REAL RMSE  30.42  ADJ.SD     .00  SEPARATION   .00  person RELIABILITY  .00 |
|MODEL RMSE  24.59  ADJ.SD     .00  SEPARATION   .00  person RELIABILITY  .00 |
| S.E. OF person MEAN = 2.60                                                  |
+-----------------------------------------------------------------------------+
  MAXIMUM EXTREME SCORE:     10 persons
  MINIMUM EXTREME SCORE:      5 persons
        VALID RESPONSES:  99.3%

     SUMMARY OF 63 MEASURED (EXTREME AND NON-EXTREME) persons
+-----------------------------------------------------------------------------+
|           RAW                            MODEL         INFIT        OUTFIT   |
|          SCORE      COUNT      MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       1.7        3.0        57.00   23.24                                |
| S.D.        .8         .2        27.24    5.37                                |
| MAX.       3.0        3.0       100.85   28.30                                |
| MIN.        .0        2.0         8.58   15.70                                |
|-----------------------------------------------------------------------------|
| REAL RMSE  28.52  ADJ.SD     .00  SEPARATION   .00  person RELIABILITY  .00 |
|MODEL RMSE  23.86  ADJ.SD   13.15  SEPARATION   .55  person RELIABILITY  .23 |
| S.E. OF person MEAN = 3.46                                                  |
+-----------------------------------------------------------------------------+
person RAW SCORE-TO-MEASURE CORRELATION = .99 (approximate due to missing data)
CRONBACH ALPHA (KR-20) person RAW SCORE RELIABILITY = .40 (approximate due to
missing data)

     SUMMARY OF 3 MEASURED (NON-EXTREME) items
+-----------------------------------------------------------------------------+
|           RAW                            MODEL         INFIT        OUTFIT   |
|          SCORE      COUNT      MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      26.3       47.7        50.00    5.60        .92    -.3    1.90     .2 |
| S.D.      17.6         .5        31.08    1.17        .29    1.2    2.01    1.7 |
| MAX.      43.0       48.0        92.60    7.20       1.25    1.0    4.74    2.1 |
| MIN.       2.0       47.0        19.30    4.41        .54   -2.0     .31   -2.0 |
|-----------------------------------------------------------------------------|
| REAL RMSE   5.92  ADJ.SD   30.51  SEPARATION  5.16  item    RELIABILITY  .96 |
|MODEL RMSE   5.73  ADJ.SD   30.55  SEPARATION  5.34  item    RELIABILITY  .97 |
| S.E. OF item MEAN = 21.98                                                   |
+-----------------------------------------------------------------------------+
UMEAN=50.000 USCALE=10.000
item RAW SCORE-TO-MEASURE CORRELATION = -1.00 (approximate due to missing data)
143 DATA POINTS. APPROXIMATE LOG-LIKELIHOOD CHI-SQUARE: 71.54

          item STATISTICS:  MISFIT ORDER

+--------------------------------------------------------------------------------
----+
|ENTRY    RAW                    MODEL|   INFIT   |  OUTFIT   |PTMEA|EXACT MATCH|
|
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.| OBS%  EXP%|
item  |
|------------------------------------+----------+----------+-----+-----------+---
----|
|     1     43     48    19.30    5.20|1.25   1.0|4.74   2.1|A .49| 89.6  89.5| 3
disc|
|     3      2     47    92.60    7.20| .97    .2| .65    .5|B .68| 95.7  95.6| 5
disc|
|     2     34     48    38.11    4.41| .54  -2.0| .31  -2.0|a .80| 93.8  86.2| 4
disc|
|------------------------------------+----------+----------+-----+-----------+---
----|
```

```
| MEAN    26.3    47.7    50.00      5.60| .92    -.3|1.90     .2|      | 93.0  90.5|
|
| S.D.    17.6      .5    31.08      1.17| .29    1.2|2.01    1.7|      |  2.6   3.9|
|
+----------------------------------------------------------------------------------
----+
```

Appendices 23: Alternative Standard ToH Rasch map using min no. of moves as the cut-off

```
           persons MAP OF items
            <more>|<rare>
90            .#  +  5 disc
                  |
                  |
                  |
                  |
                  |
                  |
80                +S 4 disc
                  |
                  |
                  |
                  |
                  |
                  |
70                +
                  |
                  |
                  |
                  |
                  |
                  |
60                +
                  |
                  |
                  |
                  |
                  |
                  |
50      .####### M+M
                  |
                  |
                  |
                  |
                  |
                  |
40                +
                  |
                  |
                  |
                  |
                  |
                  |
30                +
                  |
                  |
                  |
                  |
                  |
                  |
20                +S 3 disc
                  |
                  |
                  |
                  |
                  |
                  |
10  ############  +
            <less>|<frequ>
            EACH '#' IS 3.
```

Appendices 24: Alternative Dynamic ToH Rasch map using 1 standard deviation above the mean of the dysfunctional population as the cut-off

```
                        persons MAP OF items
                                <more>|<rare>
                    73             .  +  4 1st  5 1st  5 2nd
                    72                +
                    71                +
                    70             #  +
                    69               T+S
                    68                +
                    67                +
                    66                +
                    65                +  4 2nd
                    64                +
                    63                +
                    62                +
                    61                +
                    60                +
                    59                +
                    58                +
                    57                +
                    56               S+
                    55                +
                    54                +
                    53                +
                    52                +
                    51                +
                    50           ###  +M
                    49                +
                    48                +
                    47                +
                    46                +
                    45                +
                    44                +
                    43                +
                    42               M+
                    41                +
                    40                +
                    39                +
                    38                +
                    37                +
                    36                +
                    35                +
                    34                +
                    33                +
                    32                +  3 2nd
                    31                +S
                    30   ###########  +  3 1st
                                <less>|<frequ>
EACH '#' IS 4.
```

Appendices 25: Mean scores and significances for all ANOVAs etc for the ToH chapter

Dynamic TOH Pre Injury IQ ANOVA means and significance

TOH Dynamic Logit cat	*PreIQ Mean*	*PreIQ Std.Err.*	*PreIQ -95.00%*	*PreIQ +95.00%*	*N*
non learner	97.1886	4.144797	88.87143	105.5057	14
Learner	96.8908	3.101682	90.66682	103.1148	25
High scorer	101.8194	3.877103	94.03940	109.5994	16

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	503402.4	1	503402.4	2093.055	0.000000
TOH Dynamic logit	264.6	2	132.3	0.550	0.580269
Error	12506.6	52	240.5		

Dynamic TOH Current IQ ANOVA means and significance

TOH Dynamic Logit cat	*FSIQ Mean*	*FSIQ Std.Err.*	*FSIQ -95.00%*	*FSIQ +95.00%*	*N*
non learner	85.6923	4.116564	77.41085	93.9738	13
Learner	89.2727	3.164428	82.90672	95.6387	22
high scorer	102.0667	3.832312	94.35705	109.7763	15

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	405971.3	1	405971.3	1842.817	0.000000
TOH Dynamic logit	2199.3	2	1099.7	4.992	0.010820
Error	10354.1	47	220.3		

Dynamic TOH GCS ANOVA means and significance

TOH Dynamic Logit cat	*GCSO_TOT Mean*	*GCSO_TOT Std.Err.*	*GCSO_TOT -95.00%*	*GCSO_TOT +95.00%*	*N*
non learner	9.58333	1.261444	7.029674	12.13699	12
Learner	8.10000	0.977110	6.121944	10.07806	20
high scorer	12.11111	1.456590	9.162399	15.05982	9

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	3631.536	1	3631.536	190.1838	0.000000
TOH Dynamic logit	100.346	2	50.173	2.6276	0.085345
Error	725.606	38	19.095		

Dynamic TOH age at onset ANOVA means and significance

TOH Dynamic Logit cat	*AGE Mean*	*AGE Std.Err.*	*AGE -95.00%*	*AGE +95.00%*	*N*
non learner	34.62500	3.202736	28.20657	41.04343	16
Learner	32.73077	2.512433	27.69574	37.76580	26
high scorer	30.62500	3.202736	24.20657	37.04343	16

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	58730.83	1	58730.83	357.8523	0.000000
TOH Dynamic logit	128.16	2	64.08	0.3904	0.678615
Error	9026.62	55	164.12		

Dynamic TOH Age at testing ANOVA means and significance

TOH Dynamic Logit cat	*Age at testing Mean*	*Age at testing Std.Err.*	*Age at testing -95.00%*	*Age at testing +95.00%*	*N*
non learner	31.08333	2.811212	25.41771	36.74896	12
Learner	32.86364	2.076218	28.67929	37.04798	22
high scorer	27.53846	2.700925	22.09510	32.98182	13

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	40686.14	1	40686.14	429.0204	0.000000
TOH Dynamic logit	232.07	2	116.04	1.2235	0.303998
Error	4172.74	44	94.83		

Dynamic TOH Time since injury ANOVA means and significance

TOH Dynamic Logit cat	*Time Mean*	*Time Std.Err.*	*Time -95.00%*	*Time +95.00%*	*N*
non learner	42.08333	19.13487	-0.03223	84.19890	12
Learner	54.63636	17.15659	18.95728	90.31545	22
high scorer	29.64286	9.50628	9.10579	50.17992	14

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
TOH Dynamic logit	5416.695	2	2708.347	0.607049	0.549358
Error	200767.2	45	4461.494		

Dynamic TOH Pre Injury Home Integration CIQ scale ANOVA means and significance

TOH Dynamic Logit cat	*HIS_PRE Mean*	*HIS_PRE Std.Err.*	*HIS_PRE -95.00%*	*HIS_PRE +95.00%*	*N*
non learner	4.562500	0.930864	2.694585	6.430415	16
Learner	6.120000	0.744691	4.625668	7.614332	25
high scorer	6.785714	0.995136	4.788829	8.782600	14

Dynamic TOH Pre Injury Social Integration CIQ scale ANOVA means and significance

TOH Dynamic Logit cat	*SIS_PRE Mean*	*SIS_PRE Std.Err.*	*SIS_PRE -95.00%*	*SIS_PRE +95.00%*	*N*
non learner	10.25000	0.482218	9.282358	11.21764	16
Learner	10.28000	0.385775	9.505887	11.05411	25
high scorer	10.42857	0.515513	9.394119	11.46302	14

Dynamic TOH Pre Injury Productive Activity Integration CIQ scale ANOVA means and significance

TOH Dynamic Logit cat	*PS_PRE Mean*	*PS_PRE Std.Err.*	*PS_PRE -95.00%*	*PS_PRE +95.00%*	*N*
non learner	5.812500	0.300624	5.209254	6.415746	16
Learner	5.280000	0.240499	4.797403	5.762597	25
high scorer	6.142857	0.321380	5.497960	6.787754	14

Dynamic TOH Pre Injury Total Integration CIQ scale ANOVA means and significance

TOH Dynamic Logit cat	*CIS_PRE Mean*	*CIS_PRE Std.Err.*	*CIS_PRE -95.00%*	*CIS_PRE +95.00%*	*N*
non learner	20.56250	1.247260	18.05969	23.06531	16
Learner	21.68000	0.997808	19.67775	23.68225	25
high scorer	23.07143	1.333377	20.39581	25.74704	14

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.027085	440.0243	4	49	0.000000
TOH Dynamic logit	Wilks	0.776652	1.6503	8	98	0.120473

Dynamic TOH Current Home Integration Scale ANOVA means and significance

TOH Dynamic Logit cat	*HIS_NOW Mean*	*HIS_NOW Std.Err*	*HIS_NOW -95.00%*	*HIS_NOW +95.00%*	*N*
non learner	3.187500	0.949338	1.282513	5.092487	16
Learner	4.720000	0.759471	3.196010	6.243990	25
high scorer	4.214286	1.014886	2.177769	6.250803	14

Dynamic TOH Current Social Integration Scale ANOVA means and significance

TOH Dynamic Logit cat	*SIS_NOW Mean*	*SIS_NOW Std.Err.*	*SIS_NOW -95.00%*	*SIS_NOW +95.00%*	*N*
non learner	6.375000	0.588723	5.193640	7.556360	16
Learner	7.360000	0.470979	6.414912	8.305088	25
high scorer	8.285714	0.629372	7.022788	9.548641	14

Dynamic TOH Current Productive Activity Scale ANOVA means and significance

TOH Dynamic Logit cat	*PS_NOW Mean*	*PS_NOW Std.Err.*	*PS_NOW -95.00%*	*PS_NOW +95.00%*	*N*
Non learner	3.500000	0.506649	2.483335	4.516665	16
Learner	2.880000	0.405319	2.066668	3.693332	25
High scorer	4.928571	0.541630	3.841711	6.015432	14

Dynamic TOH Current Total Integration Scale ANOVA means and significance

TOH Dynamic Logit cat	*CIS_NOW Mean*	*CIS_NOW Std.Err.*	*CIS_NOW -95.00%*	*CIS_NOW +95.00%*	*N*
Non learner	13.06250	1.567138	9.91781	16.20719	16
Learner	14.96000	1.253710	12.44425	17.47575	25
High scorer	17.42857	1.675341	14.06675	20.79039	14

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.089293	124.9383	4	49	0.000000
TOH Dynamic logit	Wilks	0.723266	2.1541	8	98	0.037631

Dynamic TOH Change in Home Integration Scale ANOVA means and significance

TOH Dynamic Logit cat	*Home Difference Mean*	*Home Difference Std.Err.*	*Home Difference -95.00%*	*Home Difference +95.00%*	*N*
Non learner	-1.37500	0.653374	-2.68609	-0.06391	16
Learner	-1.40000	0.522699	-2.44887	-0.35113	25
High scorer	-2.57143	0.698486	-3.97304	-1.16981	14

Dynamic TOH Change in Social Integration Scale ANOVA means and significance

TOH Dynamic Logit cat	*Social Difference Mean*	*Social Difference Std.Err.*	*Social Difference -95.00%*	*Social Difference +95.00%*	*N*
Non learner	-3.87500	0.687547	-5.25466	-2.49534	16
Learner	-2.92000	0.550038	-4.02373	-1.81627	25
High scorer	-2.14286	0.735019	-3.61778	-0.66793	14

Dynamic TOH Change in Productive Activity Scale ANOVA means and significance

TOH Dynamic Logit cat	*Productive difference Mean*	*Productive difference Std.Err.*	*Productive difference -95.00%*	*Productive difference +95.00%*	N
non learner	-2.31250	0.527825	-3.37166	-1.25334	16
Learner	-2.40000	0.422260	-3.24733	-1.55267	25
High scorer	-1.21429	0.564269	-2.34657	-0.08200	14

Dynamic TOH Change in Total Integration Scale ANOVA means and significance

TOH Dynamic Logit cat	*CIQ difference Mean*	*CIQ difference Std.Err.*	*CIQ difference -95.00%*	*CIQ difference +95.00%*	*N*

non learner	7.50000	1.482370	10.4746	4.52541	16
Learner	6.72000	1.185896	9.0997	4.34033	25
High scorer	5.64286	1.584720	8.8228	2.46288	14

	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.425441	16.54365	4	49	0.000000
TOH Dynamic logit	Wilks	0.766485	1.74214	8	98	0.098124

Means for Standard TOH ANOVAs

Standard TOH Pre Injury IQ ANOVA means and significance

TOH Standard Logit cat	*Pre IQ Mean*	*Pre IQ Std.Err.*	*Pre IQ -95.00%*	*Pre IQ +95.00%*	*N*
non learner	94.2510	3.327285	87.58297	100.9190	20
Learner	99.5679	2.812069	93.93235	105.2034	28
High scorer	105.1780	4.705491	95.74799	114.6080	10

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	481379.9	1	481379.9	2174.093	0.000000
TOH Standard logit	836.6	2	418.3	1.889	0.160872
Error	12177.9	55	221.4		

Standard TOH Current IQ ANOVA means and significance

TOH Standard Logit cat	*FSIQ Mean*	*FSIQ Std.Err.*	*FSIQ -95.00%*	*FSIQ +95.00%*	*N*
non learner	88.8333	3.593979	81.61461	96.0521	18
Learner	91.4074	2.934472	85.51335	97.3015	27
high scorer	103.0000	5.390969	92.17192	113.8281	8

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	368695.1	1	368695.1	1585.783	0.000000
TOH Standard logit	1153.7	2	576.9	2.481	0.093892
Error	11625.0	50	232.5		

Standard TOH GCS ANOVA means and significance

TOH Standard Logit cat	*GCSO_TOT Mean*	*GCSO_TOT Std.Err.*	*GCSO_TOT -95.00%*	*GCSO_TOT +95.00%*	*N*
non learner	7.28571	1.170579	4.916002	9.65543	14
Learner	10.59091	0.933799	8.700532	12.48129	22
high scorer	10.20000	1.958753	6.234712	14.16529	5

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	2487.658	1	2487.658	129.6765	0.000000
TOH Standard logit	96.976	2	48.488	2.5276	0.093199
Error	728.975	38	19.184		

Standard TOH age at onset ANOVA means and significance

TOH Standard Logit cat	*AGE Mean*	*AGE Std.Err.*	*AGE -95.00%*	*AGE +95.00%*	*N*
non learner	34.71429	2.763040	29.18346	40.24511	21
Learner	32.70000	2.311725	28.07258	37.32742	30
high scorer	29.30000	4.004025	21.28507	37.31493	10

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	51691.24	1	51691.24	322.4210	0.000000
TOH Standard logit	199.67	2	99.84	0.6227	0.540026
Error	9298.69	58	160.32		

Standard TOH Age at testing ANOVA means and significance

TOH Standard Logit cat	*Age at testing Mean*	*Age at testing Std.Err.*	*Age at testing -95.00%*	*Age at testing +95.00%*	*N*
non learner	32.64706	2.417982	27.78271	37.51141	17
Learner	31.61538	1.955199	27.68203	35.54874	26
high scorer	26.71429	3.768154	19.13374	34.29483	7

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
Intercept	34466.10	1	34466.10	346.7663	0.000000
TOH Standard logit	180.62	2	90.31	0.9086	0.410053
Error	4671.46	47	99.39		

Standard TOH Time since injury ANOVA means and significance

TOH Standard Logit cat	*Time Mean*	*Time Std.Err.*	*Time -95.00%*	*Time +95.00%*	*N*
non learner	39.11111	13.19212	11.27818	66.94405	18
Learner	50.23077	15.07451	19.18423	81.27731	26
high scorer	21.71429	8.87671	-0.00623	43.43480	7

	SS	*Degr. of Freedom*	*MS*	*F*	*P*
TOH Standard logit	4784.335	2	2392.168	0.562119	0.573706
Error	204269.8	48	4255.621		

Standard TOH Pre Injury Home Integration CIQ scale ANOVA means and significance

TOH Standard Logit cat	*HIS_PRE Mean*	*HIS_PRE Std.Err.*	*HIS_PRE -95.00%*	*HIS_PRE +95.00%*	*N*
non learner	5.095238	0.811980	3.468646	6.721830	21
Learner	6.333333	0.679352	4.972429	7.694238	30
high scorer	5.875000	1.315559	3.239619	8.510381	8

Standard TOH Pre Injury Social Integration CIQ scale ANOVA means and significance

TOH Standard Logit cat	SIS_PRE Mean	SIS_PRE Std.Err.	SIS_PRE -95.00%	SIS_PRE +95.00%	N
non learner	9.85714	0.400800	9.054245	10.66004	21
Learner	10.53333	0.335333	9.861580	11.20509	30
high scorer	11.12500	0.649370	9.824156	12.42584	8

Standard TOH Pre Injury Productive Activity Integration CIQ scale ANOVA means and significance

TOH Standard Logit cat	PS_PRE Mean	PS_PRE Std.Err.	PS_PRE -95.00%	PS_PRE +95.00%	N
non learner	5.523810	0.263100	4.996756	6.050863	21
Learner	5.833333	0.220125	5.392369	6.274298	30
high scorer	5.500000	0.426271	4.646076	6.353924	8

Standard TOH Pre Injury Total Integration CIQ scale ANOVA means and significance

TOH Standard Logit cat	CIS_PRE Mean	CIS_PRE Std.Err.	CIS_PRE -95.00%	CIS_PRE +95.00%	N
non learner	20.42857	1.053666	18.31782	22.53932	21
Learner	22.63333	0.881560	20.86736	24.39931	30
high scorer	22.25000	1.707134	18.83020	25.66980	8

	Test	Value	F	Effect df	Error df	P
Intercept	Wilks	0.031748	404.0998	4	53	0.000000
TOH Standard logit	Wilks	0.881614	0.8616	8	106	0.551310

Standard TOH Current Home Integration Scale ANOVA means and significance

TOH Standard Logit cat	HIS_NOW Mean	HIS_NOW Std.Err	HIS_NOW -95.00%	HIS_NOW +95.00%	N
non learner	6.571429	0.521139	5.527462	7.615395	21
Learner	7.433333	0.436016	6.559889	8.306778	30
high scorer	8.125000	0.844341	6.433582	9.816418	8

Standard TOH Current Social Integration Scale ANOVA means and significance

TOH Standard Logit cat	SIS_NOW Mean	SIS_NOW Std.Err.	SIS_NOW -95.00%	SIS_NOW +95.00%	N
non learner	5.600000	0.505955	4.588280	6.611720	20
Learner	6.958333	0.461872	6.034764	7.881903	24
high scorer	8.350000	0.505955	7.338280	9.361720	20

Standard TOH Current Productive Activity Scale ANOVA means and significance

TOH Standard Logit cat	PS_NOW Mean	PS_NOW Std.Err.	PS_NOW -95.00%	PS_NOW +95.00%	N
non learner	3.000000	0.458727	2.081059	3.918941	21

Learner	3.866667	0.383799	3.097825	4.635508	30
high scorer	3.500000	0.743223	2.011145	4.988855	8

Standard TOH Current Total Integration Scale ANOVA means and significance

TOH Standard Logit cat	CIS_NOW Mean	CIS_NOW Std.Err.	CIS_NOW -95.00%	CIS_NOW +95.00%	N
non learner	12.71429	1.325913	10.05816	15.37041	21
Learner	16.30000	1.109338	14.07773	18.52227	30
high scorer	14.87500	2.148224	10.57159	19.17841	8

	Test	Value	F	Effect df	Error df	P
Intercept	Wilks	0.109806	107.4176	4	53	0.000000
TOH Standard logit	Wilks	0.760250	1.9463	8	106	0.060500

Standard TOH Change in Home Integration Scale ANOVA means and significance

TOH Standard Logit cat	Home Difference Mean	Home Difference Std.Err.	Home Difference -95.00%	Home Difference +95.00%	N
non learner	-1.95238	0.556115	-3.06641	-0.83835	21
Learner	-1.26667	0.465279	-2.19873	-0.33460	30
high scorer	-2.87500	0.901009	-4.67994	-1.07006	8

Standard TOH Change in Social Integration Scale ANOVA means and significance

TOH Standard Logit cat	Social Difference Mean	Social Difference Std.Err.	Social Difference -95.00%	Social Difference +95.00%	N
non learner	-3.28571	0.612363	-4.51242	-2.05900	21
Learner	-3.10000	0.512339	-4.12634	-2.07366	30
high scorer	-3.00000	0.992141	-4.98750	-1.01250	8

Standard TOH Change in Productive Activity Scale ANOVA means and significance

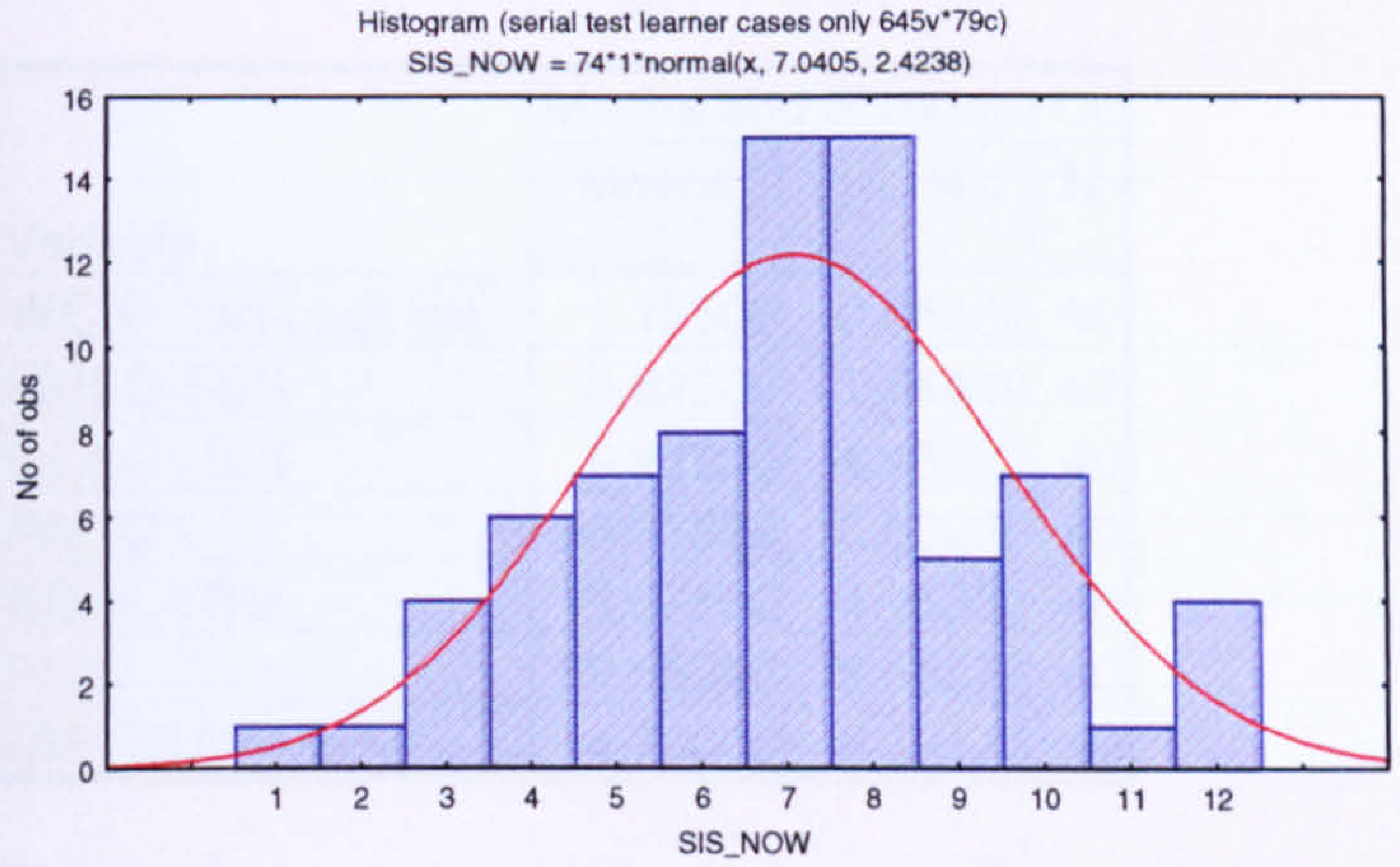
TOH Standard Logit cat	Productive difference Mean	Productive difference Std.Err.	Productive difference -95.00%	Productive difference +95.00%	N
non learner	2.52381	0.461258	3.44782	1.59980	21
Learner	1.96667	0.385916	2.73975	1.19358	30
high scorer	2.00000	0.747324	3.49707	0.50293	8

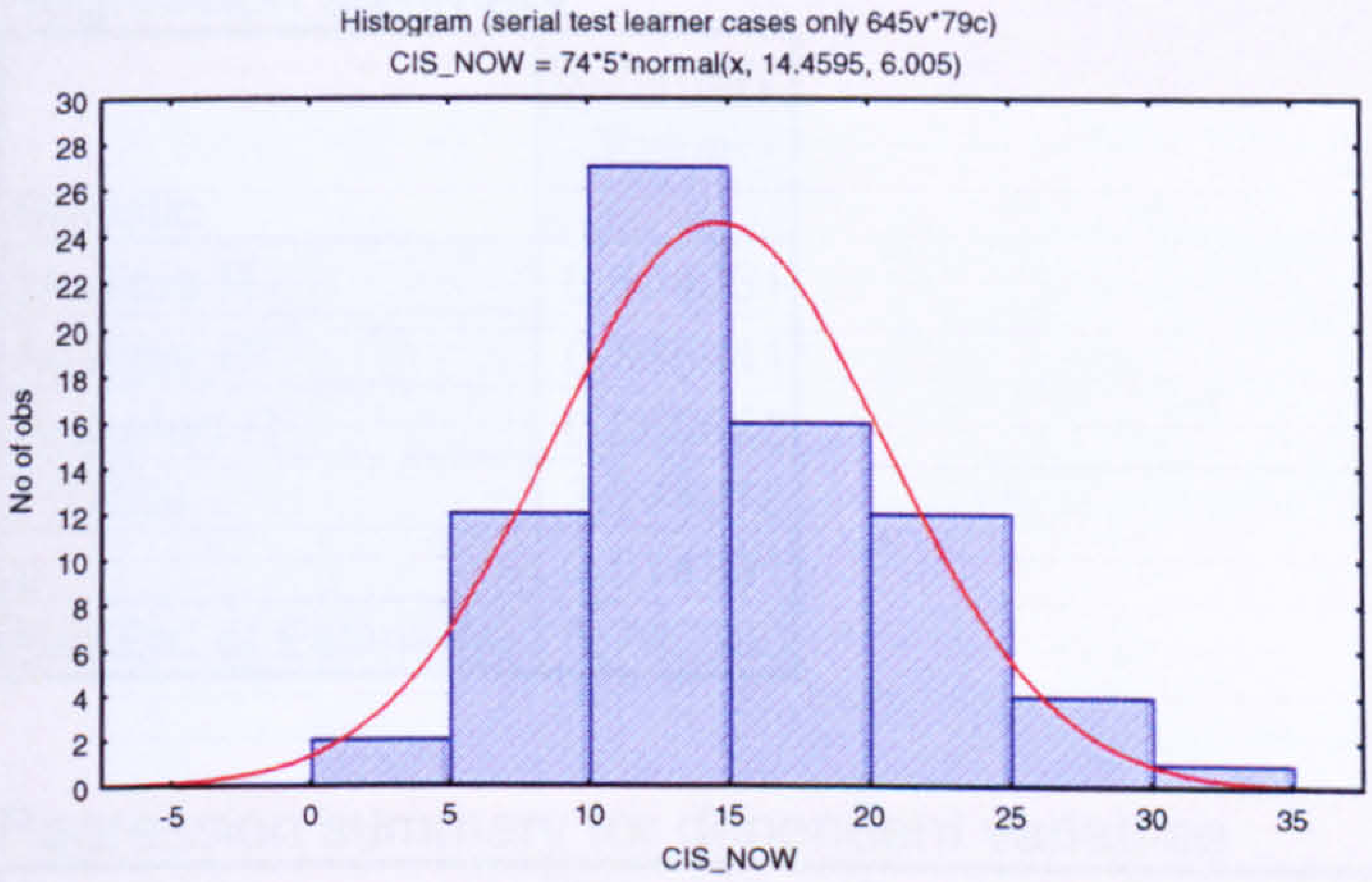
Standard TOH Change in Total Integration Scale ANOVA means and significance

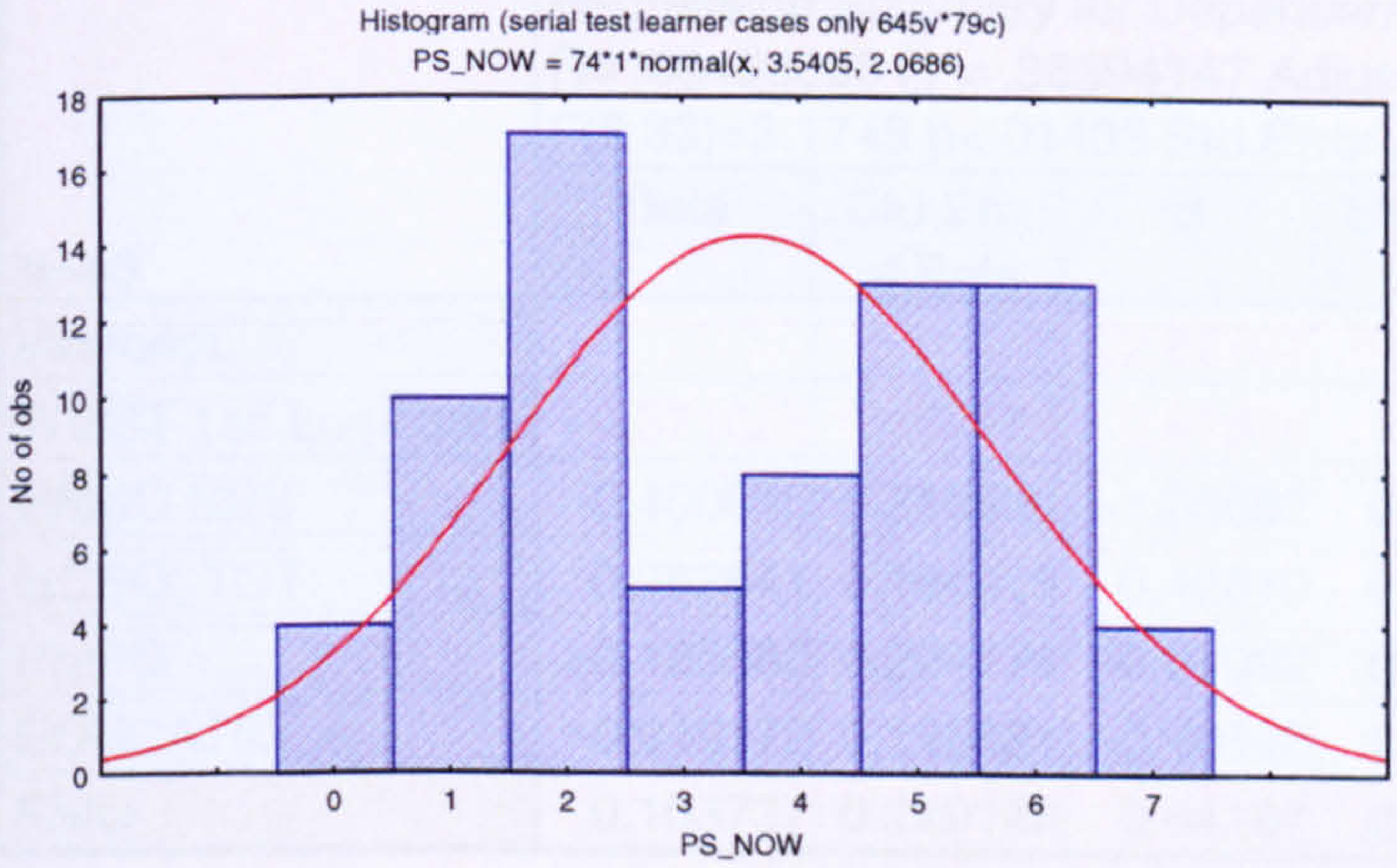
TOH Standard Logit cat	CIQ difference Mean	CIQ difference Std.Err.	CIQ difference -95.00%	CIQ difference +95.00%	N
non learner	7.71429	1.283340	10.2851	5.14345	21
Learner	6.33333	1.073719	8.4843	4.18241	30
high scorer	7.37500	2.079249	11.5402	3.20976	8

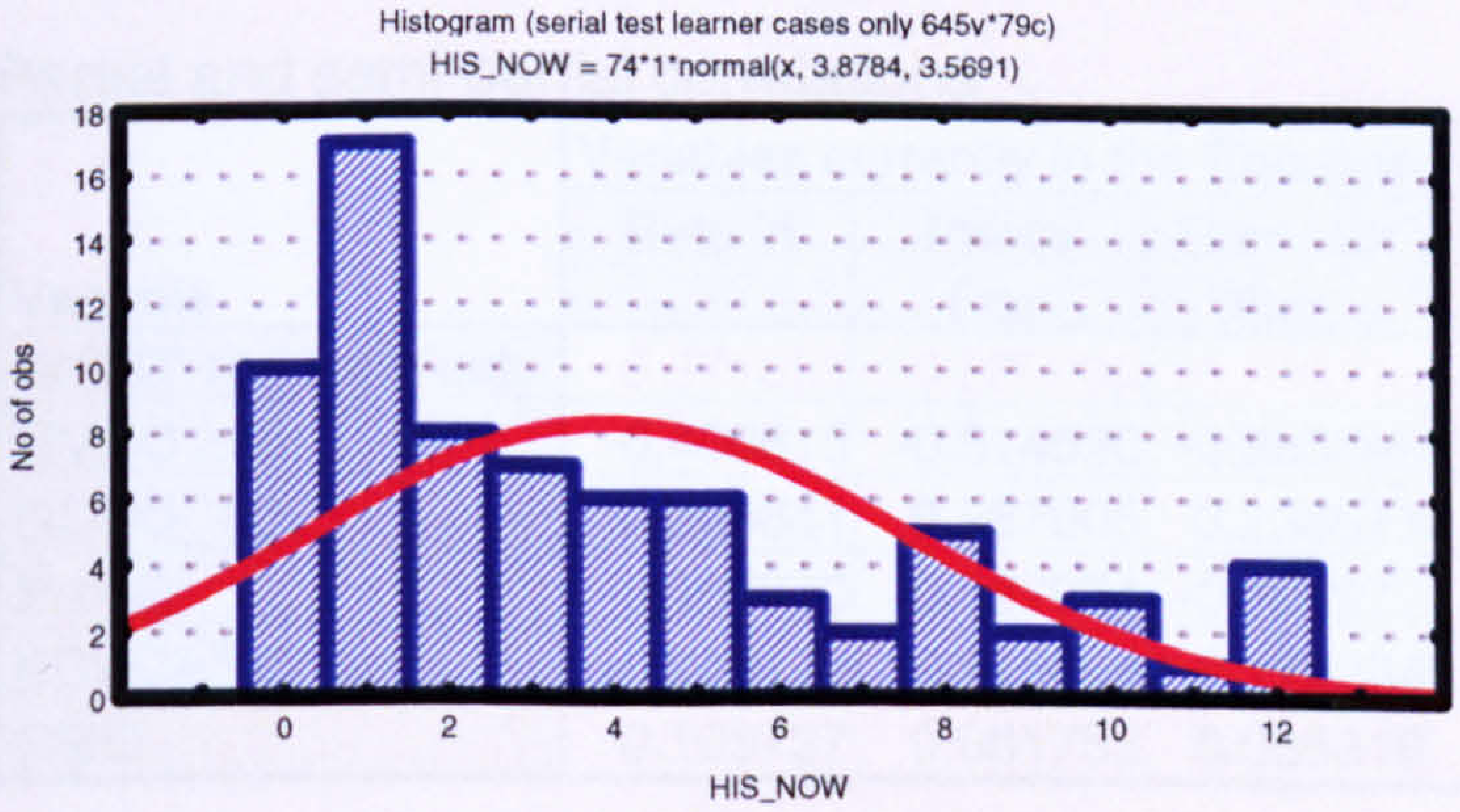
	Test	*Value*	*F*	*Effect df*	*Error df*	*P*
Intercept	Wilks	0.437507	17.03523	4	53	0.000000
TOH Standard logit	Wilks	0.832174	1.27475	8	106	0.264454

Appendices 26: Histograms for all CIQ scales conducted for the multiple regression









Appendices 27: Statistics for outcome multiple regressions

Multiple Regression CIQ

Variable	Means and Standard De		
	Means	Std.Dev.	N
WCST 1sd Logit cat	1.12500	0.88252	40
HMSO SES	3.62500	1.44449	40
GCSO_TOT	9.27500	4.48923	40
Pre IQ	95.37875	15.60259	40
EDUCATIO	13.67500	4.15339	40
FSIQ	89.65000	16.65879	40
CIS_NOW	14.70000	6.69175	40

Regression summary

Statistic	Summary
	Value
Multiple R	0.604931
Multiple R²	0.365941
Adjusted R²	0.250658
F(6,33)	3.174278
p	0.014331
Std.Err. of Estimate	5.792680

Regression summary for dependent variables

N=40	Regression Summary for Dependent Variable: CIS_NOW (serial R= .60493096 R²= .36594147 Adjusted R²= .25065810 F(6,33)=3.1743 p<.01433 Std.Error of estimate: 5.7927					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(33)	p-level
Intercept			22.85487	10.85440	2.10559	0.042933
WCST 1sd Logit cat	0.371655	0.168179	2.81808	1.27522	2.20987	0.034161
HMSO SES	-0.400815	0.210530	-1.85682	0.97530	-1.90384	0.065682
GCSO_TOT	0.283841	0.164916	0.42310	0.24583	1.72113	0.094592
Pre IQ	-0.165360	0.224779	-0.07092	0.09640	-0.73566	0.467137
EDUCATIO	-0.249172	0.193621	-0.40146	0.31195	-1.28691	0.207080
FSIQ	0.103737	0.220149	0.04167	0.08843	0.47121	0.640591

Partial and semi-partial correlations

Variable	Variables currently in the Equation; DV: CIS_NOW (serial test learner cases on						
	Beta in	Partial Cor.	Semipart Cor.	Tolerance	R-square	t(33)	p-level
WCST 1sd Logit cat	0.371655	0.359039	0.306319	0.679313	0.320687	2.20987	0.034161
HMSO SES	-0.400815	-0.314590	-0.263899	0.433500	0.566500	-1.90384	0.065682
GCSO_TOT	0.283841	0.287005	0.238573	0.706468	0.293532	1.72113	0.094592
Pre IQ	-0.165360	-0.127024	-0.101972	0.380280	0.619720	-0.73566	0.467137
EDUCATIO	-0.249172	-0.218604	-0.178384	0.512520	0.487480	-1.28691	0.207080
FSIQ	0.103737	0.081753	0.065316	0.396443	0.603557	0.47121	0.640591

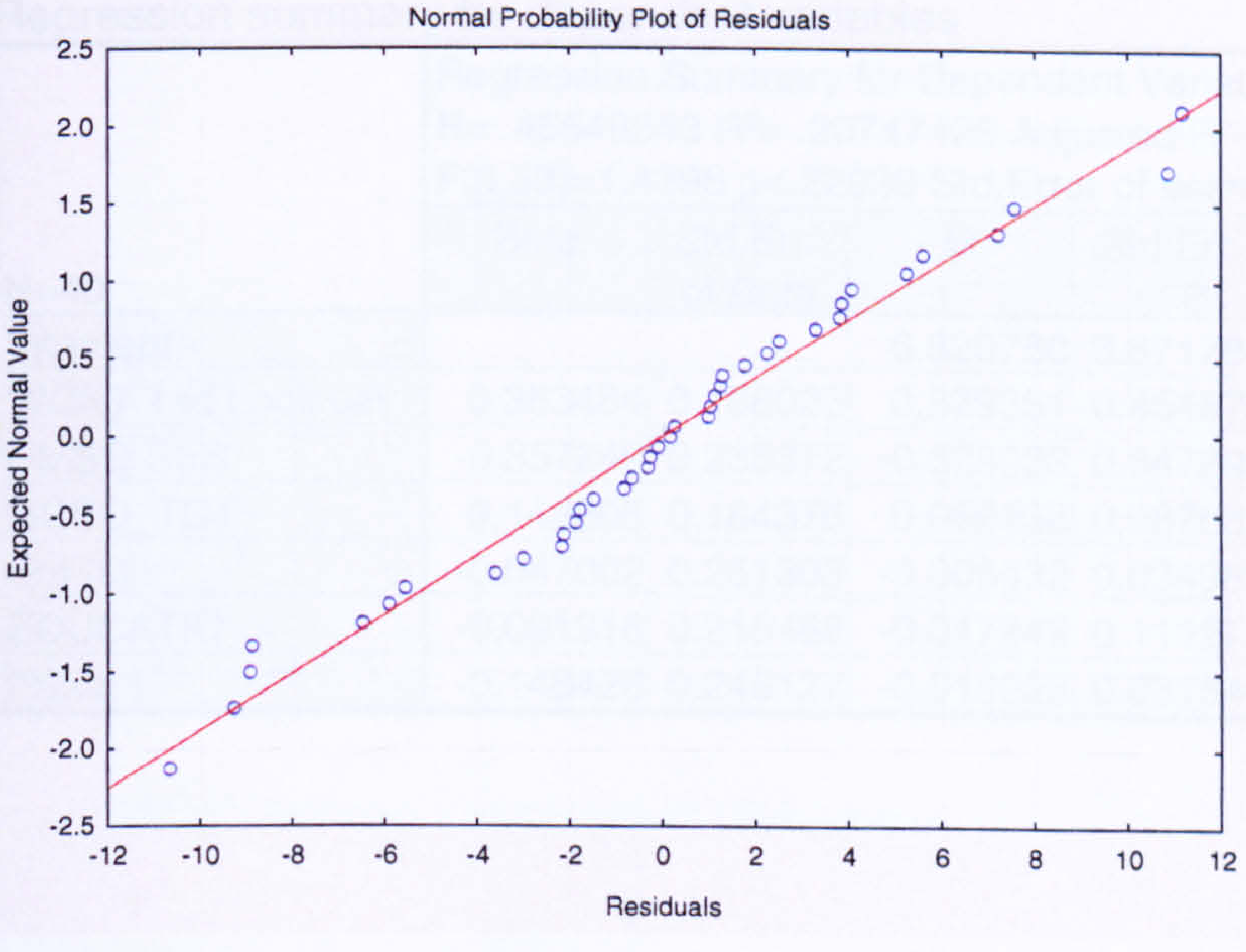
Regression summary for dependent variables with one outlier removed

	Regression Summary for Dependent Variable: CIS_NOW (serial R= .65001061 R²= .42251380 Adjusted R²= .31423514 F(6,32)=3.9021 p<.00490 Std.Error of estimate: 5.5774					
N=39	Beta	Std.Err. of Beta	B	Std.Err. of B	t(32)	p-level
Intercept			22.77258	10.45110	2.17897	0.036809
WCST 1sd Logit cat	0.375808	0.160907	2.86835	1.22812	2.33556	0.025944
HMSO SES	-0.429802	0.204041	-1.98304	0.94141	-2.10645	0.043098
GCSO_TOT	0.282131	0.158374	0.42165	0.23669	1.78142	0.084337
Pre IQ	-0.253576	0.222400	-0.10818	0.09488	-1.14018	0.262674
EDUCATIO	-0.245831	0.186883	-0.39512	0.30038	-1.31542	0.197715
FSIQ	0.214503	0.213720	0.08906	0.08874	1.00366	0.323071

Partial and semi-partial correlations with one outlier removed

	Variables currently in the Equation; DV: CIS_NOW (serial test learner cases or						
Variable	Beta in	Partial Cor.	Semipart Cor.	Tolerance	R-square	t(32)	p-level
WCST 1sd Logit cat	0.375808	0.381626	0.313753	0.697016	0.302984	2.33556	0.025944
HMSO SES	-0.429802	-0.348962	-0.282974	0.433467	0.566533	-2.10645	0.043098
GCSO_TOT	0.282131	0.300372	0.239311	0.719488	0.280512	1.78142	0.084337
Pre IQ	-0.253576	-0.197584	-0.153168	0.364858	0.635142	-1.14018	0.262674
EDUCATIO	-0.245831	-0.226493	-0.176710	0.516715	0.483285	-1.31542	0.197715
FSIQ	0.214503	0.174696	0.134829	0.395095	0.604905	1.00366	0.323071

Normal probability plot



Multiple regression Productive Activity

Means and standard deviation

	Means and Standard De		
Variable	Means	Std.Dev.	N
WCST 1sd Logit cat	1.12500	0.88252	40
HMSO SES	3.62500	1.44449	40
GCSO_TOT	9.27500	4.48923	40
Pre IQ	95.37875	15.60259	40
EDUCATIO	13.67500	4.15339	40
FSIQ	89.65000	16.65879	40
PS_NOW	3.57500	2.13503	40

Regression summary

	Summary
Statistic	Value
Multiple R	0.455493
Multiple R²	0.207474
Adjusted R²	0.063379
F(6,33)	1.439838
p	0.229394
Std.Err. of Estimate	2.066260

Regression summary for dependent variables

	Regression Summary for Dependent Variable: PS_NOW (serial te R= .45549343 R²= .20747426 Adjusted R²= .06337867 F(6,33)=1.4398 p<.22939 Std.Error of estimate: 2.0663					
N=40	Beta	Std.Err. of Beta	B	Std.Err. of B	t(33)	p-level
Intercept			6.820760	3.871784	1.76166	0.087390
WCST 1sd Logit cat	0.363484	0.188025	0.879351	0.454875	1.93317	0.061833
HMSO SES	-0.357249	0.235372	-0.528033	0.347893	-1.51781	0.138586
GCSO_TOT	0.146005	0.184376	0.069438	0.087687	0.79189	0.434082
Pre IQ	-0.047002	0.251303	-0.006432	0.034388	-0.18703	0.852780
EDUCATIO	-0.091916	0.216468	-0.047249	0.111274	-0.42462	0.673872
FSIQ	-0.148426	0.246127	-0.019023	0.031544	-0.60305	0.550600

Multiple Regression for Social Integration

Means and standard deviation

Variable	Means and Standard De Means	 Std.Dev.	 N
WCST 1sd Logit cat	1.10256	0.88243	39
HMSO SES	3.64103	1.45976	39
GCSO_TOT	9.17949	4.50656	39
Pre IQ	95.25744	15.78744	39
EDUCATIO	13.61538	4.19031	39
FSIQ	88.92308	16.22114	39
SIS_NOW	7.10256	2.69302	39

Regression summary

Statistic	Summary Value
Multiple R	0.608450
Multiple R²	0.370211
Adjusted R²	0.255704
F(6,33)	3.233089
p	0.013074
Std.Err. of Estimate	2.298285

Regression summary for dependent variables

N=40	Regression Summary for Dependent Variable: SIS_NOW (serial R= .60844996 R²= .37021136 Adjusted R²= .25570433 F(6,33)=3.2331 p<.01307 Std.Error of estimate: 2.2983					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(33)	p-level
Intercept			10.57992	4.306555	2.45670	0.019451
WCST 1sd Logit cat	0.319703	0.167612	0.96505	0.505954	1.90740	0.065205
HMSO SES	-0.357978	0.209820	-0.66020	0.386958	-1.70612	0.097381
GCSO_TOT	0.202972	0.164359	0.12045	0.097533	1.23493	0.225577
Pre IQ	-0.468282	0.224021	-0.07995	0.038249	-2.09035	0.044369
EDUCATIO	-0.128900	0.192968	-0.08268	0.123769	-0.66799	0.508786
FSIQ	0.379595	0.219407	0.06070	0.035086	1.73010	0.092957

Regression summary with outlier removed

Statistic	Summary Value
Multiple R	0.657747
Multiple R²	0.432631
Adjusted R²	0.326249
F(6,32)	4.066774
p	0.003849
Std.Err. of Estimate	2.210495

Regression summary with dependent variables with outlier removed

N=39	Regression Summary for Dependent Variable: SIS_NOW (serial R= .65774658 R²= .43263056 Adjusted R²= .32624879 F(6,32)=4.0668 p<.00385 Std.Error of estimate: 2.2105					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(32)	p-level
Intercept			10.54696	4.142088	2.54629	0.015901
WCST 1sd Logit cat	0.322818	0.159491	0.98519	0.486741	2.02405	0.051381
HMSO SES	-0.385265	0.202246	-0.71075	0.373111	-1.90493	0.065810
GCSO_TOT	0.200586	0.156981	0.11987	0.093808	1.27778	0.210521
Pre IQ	-0.556202	0.220443	-0.09488	0.037603	-2.52311	0.016798
EDUCATIO	-0.124699	0.185239	-0.08014	0.119049	-0.67318	0.505667
FSIQ	0.479973	0.211840	0.07968	0.035169	2.26574	0.030369

Partial and semi-partial correlation with outlier removed

Variable	Variables currently in the Equation; DV: SIS_NOW (serial test learner cases on						
	Beta in	Partial Cor.	Semipart Cor.	Tolerance	R-square	t(32)	p-level
WCST 1sd Logit cat	0.322818	0.336889	0.269513	0.697016	0.302984	2.02405	0.051381
HMSO SES	-0.385265	-0.319139	-0.253652	0.433467	0.566533	-1.90493	0.065810
GCSO_TOT	0.200586	0.220330	0.170142	0.719488	0.280512	1.27778	0.210521
Pre IQ	-0.556202	-0.407345	-0.335966	0.364858	0.635142	-2.52311	0.016798
EDUCATIO	-0.124699	-0.118168	-0.089637	0.516715	0.483285	-0.67318	0.505667
FSIQ	0.479973	0.371815	0.301695	0.395095	0.604905	2.26574	0.030369

Multiple regression home integration score
Means and standard deviation

Variable	Means and Standard De		
	Means	Std.Dev.	N
WCST 1sd Logit cat	1.12500	0.88252	40
HMSO SES	3.62500	1.44449	40
GCSO_TOT	9.27500	4.48923	40
Pre IQ	95.37875	15.60259	40
EDUCATIO	13.67500	4.15339	40
FSIQ	89.65000	16.65879	40
HIS_NOW	4.10000	4.04335	40

Regression summary

Statistic	Summary Value
Multiple R	0.449829
Multiple R²	0.202346
Adjusted R²	0.057318
F(6,33)	1.395221
p	0.245846
Std.Err. of Estimate	3.925766

Regression summary with dependent summary

	Regression Summary for Dependent Variable: HIS_NOW (serial t R= .44982891 R^2= .20234604 Adjusted R^2= .05731805 F(6,33)=1.3952 p<.24585 Std.Error of estimate: 3.9258					
N=40	Beta	Std.Err. of Beta	B	Std.Err. of B	t(33)	p-level
Intercept			4.630848	7.356150	0.62952	0.533343
WCST 1sd Logit cat	0.216183	0.188632	0.990460	0.864234	1.14606	0.260015
HMSO SES	-0.210032	0.236133	-0.587914	0.660974	-0.88947	0.380191
GCSO_TOT	0.266828	0.184971	0.240327	0.166600	1.44254	0.158575
Pre IQ	0.061215	0.252115	0.015864	0.065335	0.24281	0.809657
EDUCATIO	-0.263388	0.217168	-0.256410	0.211414	-1.21283	0.233805
FSIQ	0.011507	0.246922	0.002793	0.059932	0.04660	0.963112

Appendices 28: Mean scores and significances for all ANOVAs etc for the Cognitive Profiles for Study 4

WCST 1sd Logit cat; Unweighted Means (serial test learner cases only)
Current effect: F(2, 56)=2.4725, p=.09354
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	VisualIMM% Mean	VisualIMM% Std.Err.	VisualIMM% -95.00%	VisualIMM% +95.00%	N
1	non learner	10.97059	7.456292	-3.96616	25.90734	17
2	learner	24.62500	6.874362	10.85400	38.39600	20
3	high scorer	33.00000	6.554447	19.86987	46.13013	22

Brown-Forsythe Test of Homog. of Variances (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
VisualIMM%	3712.923	2	1856.461	30724.26	56	548.6476	3.383705	0.040993

WCST 1sd Logit cat; Unweighted Means (serial test learner cases only)
Current effect: F(2, 56)=2.4725, p=.09354
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	VisualIMM% Mean	VisualIMM% Std.Err.	VisualIMM% -95.00%	VisualIMM% +95.00%	N
1	non learner	10.97059	7.456292	-3.96616	25.90734	17
2	learner	24.62500	6.874362	10.85400	38.39600	20
3	high scorer	33.00000	6.554447	19.86987	46.13013	22

WCST 1sd Logit cat; Unweighted Means (serial test learner cases only)
Current effect: F(2, 56)=1.7509, p=.18300
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	visual delayed Mean	visual delayed Std.Err.	visual delayed -95.00%	visual delayed +95.00%	N
1	non learner	11.23529	6.687962	-2.16230	24.63289	17
2	learner	19.70000	6.165996	7.34803	32.05197	20
3	high scorer	27.86364	5.879047	16.08649	39.64078	22

Brown-Forsythe Test of Homog. of Variances (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
visual delayed	1693.489	2	846.7443	34446.36	56	615.1136	1.376566	0.260853

WCST 1sd Logit cat; Unweighted Means (serial test learner cases only)
Current effect: F(2, 56)=1.7509, p=.18300
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	visual delayed Mean	visual delayed Std.Err.	visual delayed -95.00%	visual delayed +95.00%	N
1	non learner	11.23529	6.687962	-2.16230	24.63289	17
2	learner	19.70000	6.165996	7.34803	32.05197	20
3	high scorer	27.86364	5.879047	16.08649	39.64078	22

Analysis of Variance (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
CT attention	13879.24	2	6939.620	33041.74	42	786.7081	8.821086	0.000633

Brown-Forsythe Test of Homog. of Variances (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
CT attention	2830.467	2	1415.234	18426.51	42	438.7264	3.225777	0.049748

WCST 1sd Logit cat; Unweighted Means (serial test learner cases only)
Current effect: F(2, 42)=8.8211, p=.00063
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	CT attention Mean	CT attention Std.Err.	CT attention -95.00%	CT attention +95.00%	N
1	non learner	10.28571	7.496228	-4.84229	25.41371	14
2	learner	28.75000	8.096852	12.40989	45.09011	12
3	high scorer	51.42105	6.434725	38.43525	64.40685	19

Analysis of Variance (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
CT WM	13073.48	2	6536.741	32635.10	42	777.0261	8.412512	0.000846

Brown-Forsythe Test of Homog. of Variances (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
CT WM	917.6580	2	458.8290	15356.59	42	365.6330	1.254889	0.295577

WCST 1sd Logit cat; Unweighted Means (serial test learner cases o
Current effect: F(2, 42)=8.4125, p=.00085
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	CTWM Mean	CTWM Std.Err.	CTWM -95.00%	CTWM +95.00%	N
1	non learner	16.57143	7.449957	1.53681	31.60605	14
2	learner	27.16667	8.046873	10.92742	43.40591	12
3	high scorer	55.00000	6.395007	42.09435	67.90565	19

Analysis of Variance (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
DS_ASS	44.55060	2	22.27530	407.3661	45	9.052579	2.460658	0.096793

Brown-Forsythe Test of Homog. of Variances (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
DS_ASS	1.451389	2	0.725694	174.0486	45	3.867747	0.187627	0.829569

WCST 1sd Logit cat; Unweighted Means (serial test learner cases o
Current effect: F(2, 45)=2.4607, p=.09679
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	DS_ASS Mean	DS_ASS Std.Err.	DS_ASS -95.00%	DS_ASS +95.00%	N
1	non learner	7.187500	0.752188	5.672516	8.70248	16
2	learner	9.071429	0.804122	7.451843	10.69101	14
3	high scorer	9.333333	0.709169	7.904993	10.76167	18

Analysis of Variance (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
VER_IQ	2119.023	2	1059.511	17626.91	60	293.7819	3.606456	0.033186

Brown-Forsythe Test of Homog. of Variances (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
VER_IQ	127.7885	2	63.89427	7894.434	60	131.5739	0.485615	0.617716

WCST 1sd Logit cat; Unweighted Means (serial test learner cases o
Current effect: F(2, 60)=3.6065, p=.03319
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	VER_IQ Mean	VER_IQ Std.Err.	VER_IQ -95.00%	VER_IQ +95.00%	N
1	non learner	80.73684	3.932201	72.87127	88.6024	19
2	learner	89.89474	3.932201	82.02916	97.7603	19
3	high scorer	94.68000	3.428013	87.82295	101.5370	25

Variable	Analysis of Variance (serial test learner cases only) Marked effects are significant at p < .05000							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
PER_IQ	5797.909	2	2898.955	15428.41	60	257.1401	11.27383	0.000070

Variable	Brown-Forsythe Test of Homog. of Variances (serial test learner cases only) Marked effects are significant at p < .05000							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
PER_IQ	276.9125	2	138.4563	4760.072	60	79.33453	1.745221	0.183353

Cell No.	WCST 1sd Logit cat; Unweighted Means (serial test learner cases o Current effect: F(2, 60)=11.274, p=.00007 Effective hypothesis decomposition					
	WCST 1sd Logit cat	PER_IQ Mean	PER_IQ Std.Err.	PER_IQ -95.00%	PER_IQ +95.00%	N
1	non learner	81.6316	3.678817	74.27285	88.9903	19
2	learner	92.9474	3.678817	85.58864	100.3061	19
3	high scorer	104.7200	3.207118	98.30481	111.1352	25

Variable	Analysis of Variance (serial test learner cases only) Marked effects are significant at p < .05000							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
LM Immediate SS	164.6572	2	82.32859	817.6413	64	12.77565	6.444182	0.002820

Cell No.	WCST 1sd Logit cat; Unweighted Means (serial test learner cases only) Current effect: F(2, 64)=6.4442, p=.00282 Effective hypothesis decomposition				
	WCST 1sd Logit cat	LM Immediate SS Mean	LM Immediate SS Std.Err.	LM Immediate SS -95.00%	LM Immedi +95.00
1	non learner	5.105263	0.820001	3.467122	6
2	learner	8.333333	0.779977	6.775150	9
3	high scorer	8.740741	0.687875	7.366552	1

Variable	Brown-Forsythe Test of Homog. of Variances (serial test learner cases only) Marked effects are significant at p < .05000							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
LM Immediate SS	14.20945	2	7.104723	437.1935	64	6.831149	1.040048	0.359334

Variable	Analysis of Variance (serial test learner cases only) Marked effects are significant at p < .05000							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
LM Delayed SS	31.37362	2	15.68681	599.1935	64	9.362399	1.675512	0.195319

Variable	Brown-Forsythe Test of Homog. of Variances (serial test learner cases only) Marked effects are significant at p < .05000							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
LM Delayed SS	17.75600	2	8.877999	393.2888	64	6.145137	1.444719	0.243398

WCST 1sd Logit cat; Unweighted Means (serial test learner cases only)
Current effect: F(2, 64)=1.6755, p=.19532
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	LM Delayed SS Mean	LM Delayed SS Std.Err.	LM Delayed SS -95.00%	LM Delayed SS +95.00%	N
1	non learner	6.368421	0.701967	4.966081	7.770762	19
2	learner	7.761905	0.667704	6.428013	9.095797	21
3	high scorer	7.962963	0.588860	6.786581	9.139345	27

WCST 1sd Logit cat; Unweighted Means (serial test learner cases only)
Current effect: F(2, 74)=1.6300, p=.20288
Effective hypothesis decomposition

Cell No.	WCST 1sd Logit cat	EDUCATIO Mean	EDUCATIO Std.Err.	EDUCATIO -95.00%	EDUCATIO +95.00%	N
1	non learner	12.31818	0.733575	10.85650	13.77986	22
2	learner	12.68000	0.688154	11.30882	14.05118	25
3	high scorer	13.93333	0.628196	12.68163	15.18504	30

Analysis of Variance (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
EDUCATIO	38.59593	2	19.29797	876.0794	74	11.83891	1.630046	0.202876

Brown-Forsythe Test of Homog. of Variances (serial test learner cases only)
Marked effects are significant at p < .05000

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
EDUCATIO	22.05048	2	11.02524	660.6248	74	8.927363	1.234994	0.296760