Thinking Matters: The Profile of Executive Functioning Associated with Cannabis Use in Schizophrenia and its Functional Outcome Correlates

by

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I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary institution.

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Khrstin Highet
Abstract

Not only is there a high prevalence of cannabis use in schizophrenia, but long-term or heavy cannabis users are also considered to demonstrate deficits similar to the cognitive endophenotypes of the illness itself. The specific neurocognitive domain of executive function has particular clinical relevance as executive dysfunction has been found to be significantly associated with the functional outcomes of schizophrenia patients. The current study sought to examine the pattern of executive functioning in schizophrenia patients with cannabis use and its functional outcome correlates. Eleven measures guided by a hierarchical model of executive function were administered to 28 schizophrenic outpatients with cannabis use and 28 matched-controls with a similar cannabis use history. Premorbid IQ and ‘real-world’ functional outcome were also assessed. A series of ANCOVA’s revealed that patients with cannabis use demonstrated poorer performances on a number of executive function measures relative to controls. However, further analysis indicated that a significantly larger proportion of this sample showed performances that did not fall in the range of clinical impairment. Using multiple regression analyses, a retrospective memory and an interference control task were found to significantly contribute to ‘real-world’ functional outcome. A lack of clinical impairment in the executive functioning of a representative sample of schizophrenia patients with cannabis use may be suggestive of differential and subtle deficits in this subgroup. Retrospective memory and interference control abilities may also present as potential targets helping to better inform rehabilitation planning efforts for such patients. Evaluating different subgroups of schizophrenia from a neurocognitive viewpoint should be an important consideration for treating clinicians particularly when attempting to achieve more successful functional outcomes.
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LIST OF ABBREVIATIONS

Analysis of Covariance (ANCOVA)
Behavioral Assessment of the Dysexecutive Syndrome (BADS)
Brief Assessment of Cognition in Schizophrenia (BACS)
Brief Visual Memory Test – Revised (BVMT-R)
Cambridge Neuropsychological Test Automated Battery (CANTAB)
Cannabis Use Disorder (CUD)
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Independent Living Skills Inventory (ILSI)
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Neurocognitive Enhancement Therapy (NET)
Orbitofrontal Cortex (OFC)
Positive and Negative Syndrome Scale (PANSS)
Positron Emission Tomography (PET)
Prefrontal Cortex (PFC)
Premorbid Adjustment Scale (PAS)
Principal Components Analysis (PCA)
Standard Deviation (SD)
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Test of Grocery Shopping Skills (TGSS)
Trail Making Test (TMT)
UCSD Performance-based Skills Assessment (UPSA)
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Thinking Matters: The Profile of Executive Functioning Associated with Cannabis Use in Schizophrenia and its Functional Outcome Correlates

Substance use and its misuse have been associated with detrimental effects on cognition (Beatty, Katzung, Moreland, & Nixon, 1995; O’Malley, Adamse, Heaton, & Gawin, 1993). Cognitive impairment is also considered to be a core feature of the illness of schizophrenia (Bleuler, 1911, 1950; Green, 1996; Herman, 2004; Hoff, Riordan, O'Donnell, Morris, & DeLisi, 1992; Kraeplin, 1919, 1971; Saykin, Gur, Gur, Mozley, Mozley, Resnick, & Stafniak, 1991; Sharma & Antonova, 2003), and executive dysfunction is found to be particularly implicated (Pantelis, Barnes, Nelson, Tanner, Weatherley, Owen, & Robbins, 1997; Reichenberg & Harvey, 2007; Shallice, Burgess, & Frith, 1999). Executive function is considered an important cognitive domain as it has been strongly linked to the functional outcomes of patients (Greenwood, Landau, & Wykes, 2005; McClure, Bowie, Patterson, Heaton, Weaver, Anderson, & Harvey, 2007; Penadés, Boget, Catalán, Bernardo, Gastó, & Salamero 2003; Simon, Giacomini, Ferrero, & Mohr, 2012; Williams, Whitford, Flynn, Wong, Liddell, Silverstein et al., 2008). Not only are there high rates of substance abuse in patients with schizophrenia (Drake, Osher, & Wallach, 1991; Mueser, Yarnold, Levinson, Singh, Bellack, Kee et al., 1990; Regier, Farmer, Rae, Locke, Keith, Judd, & Goldwin, 1990), but cannabis is the most commonly used illicit drug among patients with the illness (Barnes, Mutsatsa, Hutton, Watt, & Joyce, 2006). Impaired cognitive function has also been found in cannabis abusers alone (Pope, Gruber, & Yurgelun-Todd, 1995). In addition, the widespread use of cannabis amongst individuals with schizophrenia has been found to be strongly related to the severity of symptoms, the course of their illness, and poor outcome (Caspari, 1999; Grech, Van Os, Jones, Lewis, & Murray, 2005; Linszen, Dingemans, & Lenior, 1994). Therefore, examining the relative differences in the
executive functioning of schizophrenia patients with cannabis use has important clinical significance when considering treatment targets for comorbid patients and ultimately more successful functional outcomes. Considering the high rates of cannabis use in this particular clinical population, both the neuropsychological and functional outcome correlates of cannabis use and schizophrenia will be specifically examined.

Part A

The Issue of Comorbid Substance Use and Schizophrenia

There is a high prevalence of substance use and misuse in individuals with first-episode psychosis (Cantwell, Brewin, Glazebrook, Dalkin, Fox, Medley, & Harrison, 1999). In addition, amongst those with psychotic disorders approximately 52% of patients are not only found to have comorbid diagnoses, but the most common of these diagnoses is substance use disorder (Stratowski, Maurico, Stoll, Faedda, Mayer, Kolbrener et al., 1993). Substance abuse is also the most prevalent comorbid condition associated with the illness of schizophrenia (Cuffel, Heithoff, & Lawson, 1993). Evidence from community studies suggests that schizophrenia patients in particular, are more prone to comorbid substance use disorders than the general population and that the rate of substance abuse has been found to be 4.6 times higher than those without the illness (Regier et al., 1990). The estimated lifetime prevalence rates of substance abuse in this clinical population are reported to approximate 50% and the prevalence rates relating to recent or current substance use range from 20% to 40% (Drake et al., 1991; Mueser et al., 1990). Not only are substance abuse prevalence rates high in this population, but substance use in schizophrenia is associated with the greater utilisation of services as well as higher service costs (Bartels, Teague, Drake, Clark, Bush, & Noordsy, 1993).
In comparison to other types of psychiatric patients or healthy individuals, it has been found that schizophrenia patients in particular are more likely to use cannabis than other drugs of abuse (Degenhardt, Hall, & Lynskey, 2003; Warner, Taylor, Wright, Sloat, Springett, Arnold, & Weinberg, 1994). With lifetime use reported to be as high as 64.4%, cannabis is the most commonly used illicit drug reported among patients with schizophrenia (Barnes et al., 2006). More specific to the Australian population, approximately 25% of a nationally represented sample of individuals with psychotic disorders in contact with services, were found to have reported a lifetime history of cannabis abuse (Hall, Teesson, Lynskey, & Degenhardt, 1999). Twenty-four percent of these patients were reported to be daily or near-daily users. Data from an Australian survey also showed that cannabis dependence was associated with an 11-fold higher odds of screening positively for schizophrenia or schizoaffective disorders (Degenhardt et al., 2003). Green and colleagues (2005) have considered that the variation in prevalence findings across studies is contributed to by a number of factors. These include age, the percentage of male representation in studies, the methods used as well as the clinical experience of researchers in applying diagnostic criteria to individuals with psychoses, the variation in specificity of diagnostic inclusion criteria, and the variance in the nature of the interviews used to collect information and the method of data collection (e.g., self-report versus sample analysis). Such variability in factors across studies makes prevalence rates more difficult to precisely define. However, the general consensus suggests that cannabis use and its misuse is a commonality amongst this particular clinical population.

In a meta-analysis of studies examining cannabis use in schizophrenia occurring between 1996 and 2008, a median current prevalence rate of 16.0% was reported and a median lifetime prevalence rate was estimated to be 27.1% (Koskinen, Löhönen,
Koponen, Isohanni, & Miettunen, 2010). It was found that the median rate of cannabis use disorders (CUD’s) was higher in first-episode patients compared to long-term patients, with rates for current CUD’s being 28.6% and 22.0% respectively, and lifetime prevalence rates being 44.4% and 12.2% respectively. The overall findings of the meta-analysis indicated that approximately 1 in 4 schizophrenia patients in the included studies had a diagnosis of CUD. The reviewed studies also suggest that countries such as Australia are an example of a country that evidences a high consumption of cannabis not only in schizophrenia patients, but also in the general population. Data from the Low Prevalence arm of the Australian National Survey of Mental Health and Wellbeing which targeted a sample of 970 individuals diagnosed with psychosis, showed that 26.5% of schizophrenia patients had a comorbid lifetime diagnosis of cannabis abuse or dependence (Kavanagh, Waghorn, Jenner, Chant, Carr, Evans, et al., 2004). Cannabis was also found to be the most frequently used drug with 40.9% of the overall sample using this particular illicit substance. In a review of population-based studies, it has been reported that cannabis use appears to overall be associated with a two-fold increase in the relative risk for later schizophrenia or schizophreniform disorders when compared to the general population (Arseneault, Cannon, Witton, & Murray, 2004).

It is considered that many young people in Australia use cannabis and that this use usually occurs during late adolescence and early adulthood, which is a period of development considered to be where the risk of psychoses is at its peak (Hall, Degenhardt, & Teesson, 2004). Australian survey data suggests that the age of cannabis use initiation now occurs at an earlier age in young people, compared to the age of cannabis use onset reported in the 1980’s (Degenhardt, Lynskey, & Hall, 2000). It is reasonable to consider that if the onset of psychosis symptoms occurs around this time in development; consequently, so does a diagnosis of the illness. However, research
findings have suggested a more direct link between earlier age of cannabis use onset and increased risk of the development of psychosis. Arsenault and colleagues (2002) examined the relationship between cannabis use in adolescence and psychosis in young adulthood. Results of their study not only demonstrated a significant relationship between cannabis use by the age of 15 and an increased risk of reported psychotic symptoms by the age of 26, but also the specificity of effects of this particular substance on such symptoms. In other words, no significant relationship was found between psychotic disorders and other drugs of abuse. In addition to this, no relationship was demonstrated between depression and cannabis use. An interaction between age of cannabis use onset and psychosis risk was also found, showing earlier cannabis use onset being significantly related to psychosis. In line with these findings, results from a meta-analysis indicated that the age of psychoses onset in cannabis users is 2.7 years earlier in comparison to non-cannabis using individuals (Large, Sharma, Compton, Slade, & Nielssen, 2011). It has also been shown that earlier initiation of cannabis abuse is associated with the onset of high-risk symptoms for psychosis at a younger age (Dragt, Nieman, Becker, van de Fliert, Dingemans, de Haan et al., 2010). In light of the research evidence, it appears that earlier age of cannabis use onset has a significant association with earlier age of illness onset. In addition, not only is cannabis use in schizophrenia highly prevalent around the world, as well as within Australia, but that the age of cannabis use onset has become younger over the years which places such individuals at greater risk considering the abovementioned relationships.

Studies investigating the subjective effects of substances based on the self-report of users, suggest that patients with schizophrenia use drugs such as cannabis to help self-medicate. Cannabis has been reported to be used in order to relieve negative affect, ‘to increase pleasure’, ‘to get high’, ‘to relax’, ‘to satisfy curiosity’, ‘to give more
interests’, as well as to ‘get along with the group’ (Addington & Duchak, 1997; Goswami, Mattoo, Basu, & Singh, 2004). However, despite the many reported reasons for using cannabis by individuals with schizophrenia, extensive research has demonstrated that there are also many detrimental consequences that are associated with cannabis use in this particular patient population. While it has been proposed that cannabis may help to relieve negative symptoms (Dixon, Haas, Weiden, Sweeney, & Frances, 1991; Peralta & Cuesta, 1992), it has been also reported to have a negative impact on the symptom dimensions of the illness and its course (Linszen et al., 1994). More specifically, the research examining substance abuse and outcome in schizophrenia has suggested that cannabis use is associated with an increase in positive symptoms and significantly more and earlier psychotic relapses (Linszen et al., 1994). This association is also found to be stronger among heavy cannabis users. Those with a history of cannabis use have significantly more rehospitalisations, poorer psychosocial functioning, as well as increased ratings of thought disorder and hostility (Caspari, 1999). Moreover, not only is there a significant association between increased cannabis use and increased severity of positive symptoms, but also a more continuous course of the illness itself (Grech et al., 2005). While substance use in schizophrenia has been found to be associated with generally fewer negative symptoms, more social contacts and better functioning in social-leisure areas, issues in relation to interpersonal relationships and family dynamics are still reported to be associated with cannabis use in schizophrenia (Salyers & Mueser, 2001). Therefore, given the high rates of comorbidity between schizophrenia and substance abuse, as well as considering the vast detrimental clinical effects that can be associated with the misuse of substances in psychotic disorders, further insight into the implications of substance abuse in schizophrenia are of particular relevance when considering the management of such
individuals. The following section provides an overview of the literature examining the individual relationships between cannabis use and cognition, and schizophrenia and cognition. More specifically, the relationships between cannabis use, schizophrenia and the neurocognitive domain of executive function. The role of this neurocognitive domain and its clinical relevance to patients with schizophrenia will then be outlined, particularly in relation to the functional outcome of such individuals. Lastly, the challenges associated with the assessment of executive function and the ecological validity of traditional psychometric measures will be discussed.

The Relationship Between Cannabis Use, Schizophrenia and Cognition

In addition to the many clinical implications associated with cannabis use in schizophrenia, cognitive functioning has also been found to be significantly affected. Cognition involves mental processes that enable day-to-day functioning in humans spanning over a range of personal, social and/or occupational domains (Sharma & Antonova, 2003). Research has found deleterious cognitive impairments associated with cannabis abuse (for review, see Pope, Gruber, & Yurgelun-Todd, 1995), as well as substantial cognitive impairments have also been demonstrated in schizophrenia patients without a substance abuse history (Hoff et al., 1992; Saykin, Shtasel, Gur, Kester, Mozley, Stafiniak, & Gur, 1994). Therefore, given the high rates of cannabis use in schizophrenia and its association with poor outcome, a better understanding of the relationship between cannabis use, schizophrenia and cognition is warranted. In order to be able to fully evaluate the clinical significance of the relationship between dual-diagnosis and cognition, it is important to firstly review the individual relationships between cannabis use, schizophrenia and cognition separately.

Cognitive impairments associated with cannabis use. Cannabis consumption in otherwise healthy subjects has been demonstrated to be accompanied by cognitive
deficits similar to the cognitive endophenotypes found in schizophrenia patients (for review, see Solowij & Michie, 2007). It has been found that early onset, higher dose, higher frequency of use and duration of use are considered as risk factors when examining the relationship between patterns of cannabis use and the extent of cognitive impairment (Bolla, Brown, Eldreth, Tate, & Cadet, 2002; Harvey, Sellman, Porter, & Frampton, 2007; Pope, Gruber, Hudson, Cohane, Huestis, & Yurgelun-Todd, 2003). Evidence has also suggested that the cognitive impairments associated with cannabis use not only persist beyond the acute intoxication state, but that worse cognitive performance has been found to be specifically associated with cumulative years of use (Solowij, Stephens, Roffman, Babor, Kadden, Miller et al., 2002). While there has been an increase in the empirical evidence suggesting that the deficits demonstrated in cannabis users have been shown to persist beyond the acute effects of intoxication, the findings related to the recovery of such functions following cannabis use abstinence is inconsistent (Solowij & Battisti, 2008; Solowij & Michie, 2007).

Frontal lobe function, particularly prefrontal, superiorfrontal and central areas, have been found to be negatively affected by long-term cannabis use (Lundqvist, Jönsson, & Warkentin, 2001). The frontal lobe of the brain is a structure thought to be associated with attentional abilities, the facilitation of memory functions and retrieval strategies, and the support of higher-level cognitive functions (Lezak, Howieson, & Loring, 2004). Such higher-level cognitive abilities, otherwise known as the executive functions, are considered to be crucial in decision-making processes where one is faced with novel or unfamiliar situations (Crean, Crane, & Mason, 2011). Patients with prefrontal cortex (PFC) lesions in the ventromedial sector and individuals with substance dependence have been found to show similar behaviours where they not only have reduced awareness of their difficulties, but also demonstrate a tendency to choose
a course of action that presents themselves with rewards of an immediate nature and ignore the risk of future negative consequences (Bechara, 2001; Bechara, Dolan, Denburg, Hindes, Anderson, & Nathan, 2001; DiClemente, 1993). In a study conducted by Bechara and Martin (2004), it was found that individuals with substance dependence who demonstrated decision-making impairments also showed severe deficits in working memory performance. However, the pattern of results found were suggestive of deficits in the ‘executive’ process of working memory (i.e., switching and response inhibition components) in comparison to the memory storage aspect of the task. While it was found that overall as a group, individuals with substance dependence showed poor performance on measures of decision-making and working memory, not every subject demonstrated impaired performances. The authors concluded that the different pattern of deficits across individuals with substance dependence may be a result of such individuals demonstrating any one, or a combination, of a number of different mechanisms which are thought to be involved in decision-making processes and inhibitory control supported by the PFC region. As executive dysfunction can result in self-monitoring difficulties, reduced ability to modify or control inappropriate behaviours, as well as impact rational decision-making processes, it is also considered that executive dysfunction may result in the perpetuation of addictive behaviour (Bolla, Cadet, & London, 1998). It is postulated that such decision-making deficits could be potentially attributable to the cumulative effects of heavy substance use, but may also result in the continuation of substance use and unsuccessful abstinence attempts (Bolla, Eldreth, London, Kiehl, Mouratidis, Contoreggi et al., 2003; Paulus, Tapert, & Schuckit, 2005). In addition, reduced decision-making abilities may make an individual more susceptible to the commencement of substance use and further, becoming a substance abuser. Therefore, it appears that executive functions may play an important
role in the engagement as well as maintenance of substance abuse; consequently, the following discussion will specifically focus on the effects of cannabis use in relation to this particular neurocognitive domain.

The role of executive function. Due to previous neuroanatomical research findings suggesting associations between impairments in executive function and frontal lobe pathology, the use of the term ‘executive function’ was traditionally equated with the term ‘frontal lobe function’ (Benton & Hamsher, 1976; Fuster, 1989; Katz, Tadmor, Felzen, & Hartman-Maeir, 2007; Luria, 1973; Milner, 1963; Roberts, Robbins, & Weiskrantz, 1998; Stuss & Benson, 1986). However, the use of the functional definition of ‘executive function(s)’ over the more anatomical-based definition of ‘frontal functions’ became increasingly more emphasised over the years. This was largely due to the number of regions in the brain that were postulated to be implicated in such cognitive processes which included those falling outside of the frontal lobes alone (Baddeley, 1996). Executive functions are conceptualised as higher-order cognitive processes which are considered pertinent to forming intentions, planning and organisation, the translation of a plan into purposive action, and self-monitoring and self-regulation (Lezak et al., 2004). The term ‘executive function’ is an umbrella term that has been used to describe, ‘capacities that enable a person to engage successfully in independent, purposive and self-serving behaviour’ (Lezak et al., 2004, p. 35).

While it is agreed that executive functions are considered to be complex, as well as highly important to adaptive human behaviour, there are an array of definitions for this particular neurocognitive construct (Jurado & Rosselli, 2007; Lyon & Krasnegor, 2001). Executive function is considered to be a multidimensional construct referring to a number of ‘higher-order cognitive processes including initiation, planning, hypothesis generation, cognitive flexibility, decision making, regulation, judgement, feedback
utilization, and self-perception that are necessary for effective and contextually appropriate behavior’ (Spreen & Strauss, 1998, p. 171). Such functions have been considered to be supported by the dorsolateral prefrontal cortex (DLPFC) and referred to as the ‘cold’ components of executive functioning due to their corresponding processes involving relatively ‘mechanistic’ or logically-driven abilities (Grafman & Litvan, 1999). Those executive functions thought to be supported by the ventromedial prefrontal cortex (VPFC) are considered to reflect those cognitive processes that are more emotionally-driven. These include the experience of reward and punishment, decision-making processes related to interpersonal and social behaviour, and the interpretation of complex emotions, and are often referred to as ‘hot’ components of executive functioning (Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Tranel, Damasio, & Damasio, 1996; Damasio, 1995; Grafman & Litvan, 1999).

Executive functions are also thought to act as those cognitive processes which are considered vital for success in the ‘Instrumental Activities of Daily Living’ (IADLs) (Chevignard, Taillefer, Picq, Poncet, Noulhiane, & Pradat-Diel, 2008; Shallice & Burgess, 1991). Such activities may involve a range of domestic and community activities, occupational activities, interpersonal and social behaviours, and the temporal organisation of daily activities as a whole (Chevignard et al., 2008). Research investigating the effects of executive function impairments have found that such deficits may have a negative impact on an individual’s activities of everyday life such as ‘real-world’ planning abilities (e.g., financial management), the ability to attend to educational and work pursuits, independent living, or even the development and/or maintenance of social relationships and understanding of social rules (Goel, Grafman, Tajik, Gana, & Danto, 1997; Grafman, Schwab, Warden, Pridgen, Brown, & Salazar, 1996; Green, 1996; Green, Kern, Braff, & Mintz, 2000).
Executive function deficits associated with cannabis use. When considering the more long-term effects of cannabis use in the literature, tasks that employ executive control abilities have at least in some way been shown to be affected (Grant, Gonzalez, Carey, Natarajan, & Wolfson, 2003; Pope, Gruber, Hudson, Huestis, & Yurgelun-Todd, 2001). The impact of cannabis use on executive functioning can be evaluated by its acute, residual and long-term effects. However, it is acknowledged that any neurocognitive deficits observed following a relatively minimal period of abstinence may be associated with drug residues in the brain or even the effects of drug withdrawal, therefore it is considered that the interpretation of such results would be difficult. With this in mind, the residual (7 hours to 20 days after last use) and longer-term (over 21 days after last use) effects are of greater interest and will be the focus of the following section. In addition, studies examining adolescent subjects were not included in the following review due to the consideration that the effects of cumulative cannabis use/longer lifetime-use potentially not being fully achieved in such samples. In relation to the specific effects of cannabis use on executive processes, the areas of attentional processing, working memory, inhibition and impulsivity, verbal fluency and decision-making will be discussed.

Attention. In relation to attentional abilities, no significant differences were found between current heavy cannabis users (i.e., those that used at least 5000 times in their lifetime and were daily users), individuals with a history of past heavy use (i.e., those that used at least 5000 times in their lifetime, but less than 12 times in the last 3 months), and control subjects with limited cannabis use experience (Pope et al., 2001, 2002). Subjects were assessed following 0, 1, 7 and 28 days of abstinence. Jager and colleagues (2006) not only assessed the cognitive performance of moderate cannabis users (i.e., median lifetime use of 1300 joints and median last year use of 350 joints) in
the area of attention, but also measured alterations of brain activity with functional Magnetic Resonance Imaging (fMRI) after one week of abstinence. Findings of the study were similar to Pope and colleagues’ results showing no significant differences in task performance compared to controls and, in addition to this, no significant differences in associated brain activity. Grant and colleagues (2012) examined the cognitive performances between cannabis users (with a $3.1 \pm 2.2$ times per week mean frequency of use within the past 12 months; $n = 16$) and controls ($n = 214$). However, the authors did not impose a specific abstinence period as they wished to evaluate cognition under normal circumstances in day-to-day life. Findings from their study also indicated that there were no significant differences between groups in performance on sustained attention (as measured by the Rapid Visual Information Processing task from the Cambridge Neuropsychological Test Automated Battery (CANTAB; Sahakian & Owen, 1992). Conversely, Solowij and colleagues (1991) found that long-term cannabis users (with a mean of 11.2 years of use, mean level of use of 4.77 days a week, and a mean consumption of 766 mg per week) demonstrated significantly poorer performance than controls on a selective attention task as well as a reduced ability to filter out irrelevant information, following a minimum 12-hour period of abstinence. In a later study, it was found that heavy cannabis users (i.e., those that used more than or equal to 3 days per week) had slower reaction times during cognitive tasks compared to not only controls, but to light cannabis users (i.e., those that used less than or equal to 2 days per week) following a minimum of 24 hours abstinence (Solowij, Michie, & Fox, 1995). Findings from the study also indicated that the ability for cannabis users to filter out irrelevant information was progressively impaired as a function of duration of use. In addition, both long-term (with a mean of 23.9 years of regular use) and short-term cannabis (with a mean of 10.2 years of regular use) users were found to make more errors on a speed of
comprehension task following a minimum 12-hour period of abstinence in comparison to controls (Solowij et al., 2002). Slower processing rates were also demonstrated in long-term cannabis users compared to short-term cannabis users (Solowij et al., 2002). Verdejo-García et al. (2013) examined whether genetic polymorphisms moderated the effects of cannabis use on executive function. The study included 86 cannabis users (with daily use of cannabis of >7 joints per week and for a minimum duration of 3 years) and 58 non-drug using controls. Both groups were genotyped and matched for genetic makeup, sex, age, education and Intelligence Quotient (IQ). The authors found no significant differences between users and controls in sustained attention performance (as measured by the Rapid Visual Information Processing test; CANTAB) following a 72-hour abstinence period. Further findings from the study suggested that certain genotypes of the COMT and SLC6A4 genes moderated the impact of cannabis use on executive functions. More specifically, results showed that cannabis users carrying the COMT val/val genotype exhibited lower accuracy of sustained attention than non-users of the same genotype. Research into the long-term effects of cannabis use on attentional abilities has also produced mixed findings. It was found that heavy cannabis users (with a mean consumption of 93.9 joints per week, a mean level of use of 7 days a week, and a mean of 5.3 years duration of use) who were abstinent for a period of approximately 28 days were found to demonstrate deficits in reaction time (Bolla et al., 2002). In addition, results from Solowij’s (1995) study found significant deficits in the ability to process irrelevant information in ex-cannabis users who were abstinent from a minimum of 6 weeks to an average of 2 years. However, in a study examining monozygotic twins, no impairments in attention or concentration were reported in cannabis-using twins who were abstinent for a minimum period of 1 year, in
comparison to non-using co-twins (Lyons, Bar, Panizzon, Toomey, Eisen, Xian, & Tsuang, 2004).

**Working memory.** Findings from Scholes & Martin-Iverson’s (2010) study showed that cannabis users (n=36; with a median total duration of cannabis use of 10 years and a median of 2 usage times per day) showed no significant differences from controls (n=35) on Letter-Number Sequencing (LNS; Wechsler Memory Scales – Third Edition (WMS-III); Wechsler, 1997), Spatial Span (WMS-III; Wechsler, 1997), and overall working memory (i.e., the summed score of LNS and Spatial Span). Cannabis users were instructed to not alter their pattern of cannabis use on the day of testing and therefore a set abstinence period was not imposed. This was considered by the authors to reduce the likelihood of abstinence syndrome. Of the cannabis users, 21 were daily/nearly daily users; 12 were weekly users; one was a monthly user and two used cannabis less than monthly. Sixteen of these users reported using other drugs in the last month. A similar pattern of results were also found regarding spatial working memory performance (measured by the Spatial Working Memory task from the CANTAB) in Grant and colleagues’ (2012) study. However, results also showed that cannabis users demonstrated significant impairments on the One Touch Stockings of Cambridge Task (from the CANTAB) relative to controls. While the test developers indicate that working memory is assessed by this task, spatial planning abilities are also tapped into by this measure. In addition, Gruber et al. (2012) found no significant differences between controls and marijuana users on tasks of visuospatial construction and working memory (measured by the Rey-Osterrieth Complex Figure test: for test description, see Lezak et al., 2004), as well as attention and working memory (measured by Digit Span). No significant differences in working memory (measured by Digit Span) were found between cannabis users (categorised as heavy and light) and a control group following a
minimum period of 19 hours abstinence (Pope & Yurgelun-Todd, 1996). Additional studies have replicated similar findings when assessing working memory with auditory/verbal tasks including computation span, omitted numbers, and a spatial task (e.g., a modified Sternberg item recognition task) (Fisk & Montgomery, 2008; Jager et al., 2006; Solowij et al., 2002). In a fMRI study, it was found that cannabis users demonstrated greater and more distributed brain activation during the performance of a spatial working memory task (measured by a perception task and a short-delay response task) in comparison to control subjects following 6-36 hours after last cannabis use (Kanayama, Rogowska, Pope, Gruber, & Yurgelun-Todd, 2004). Thames and colleagues (2014) examined neurocognitive performances across recent users (n=68; those who reported use in the last 4 weeks), past users (n=41; those who used more than 28 days prior to testing) and non-users (n=49). Results indicated that recent users performed more poorly than past users and non-users in attention/working memory (a composite score of performance on the Trail Making Test – Part A, Reitan, 1958; Stroop Test [colour and word conditions], Golden, 1978; and the Letter-Number Sequencing test from the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV); Wechsler, 2008). However, it is noted that the criteria of what constituted a user regarding frequency, amount and duration of use was not reported by the authors.

Inhibition and impulsivity. Results from Pope and Yurgelun-Todd’s (1996) study indicated that heavy cannabis users (with a median use of 29 days in the past 30 days) demonstrated significantly greater perseverations on a card sorting measure (i.e., Wisconsin Card Sorting Task (WCST); Heaton, 1981), in comparison to light users (with a median use of 2 days in the past 30 days) following a minimum period of 19 hours of abstinence. Solowij and colleagues (2002) found that performance differences between task trials on the Stroop test suggested that cannabis users had greater
vulnerability to task complexity and increased demands following a minimum of 12 hours abstinence relative to controls. In addition, there was also an inverse relationship between the number of task items completed and duration of cannabis use. In the same study, there were no significant differences between groups on WCST performance. Gruber et al. (2012) examined the relationship between age of onset of marijuana use and executive function performance in 34 chronic, heavy marijuana smokers (with a mean frequency of 19.24 ±19.58 smokes per week; mean amount of 10.86 ± 14.95 grams per week; and mean duration of 7.24 ± 7.30 years) and 28 non-using controls following a minimum 12-hour abstinence period. From the results of the study, significantly poorer performances were found on the WCST, as well as in both the Word Reading and Interference condition of the Stroop test. Findings also suggested that early onset marijuana users were significantly more impaired than late onset users on both measures. However, Battisti et al. (2010) conducted a neurophysiological measure study using event-related potentials (ERP’s) to examine discrete cognitive events. Event-related brain potentials to neutral, congruent, and incongruent trials were compared between 21 cannabis users (with a mean of 16.4 years of nearly daily use) and 19 non-using controls following at least a 12 hour abstinence period. Results of the study indicated that chronic cannabis use produced changes in accuracy and brain activity associated with performance on the Stroop task during the unintoxicated state. It was shown that users displayed increased errors on colour-incongruent trials (e.g., “RED” printed in blue ink) suggesting more susceptibility to the colour-naming interference effect. However, no significant differences were found between users and controls on colour-congruent (“RED” printed in red ink) or neutral trials (e.g., “*****” printed in green ink). Further, earlier age of cannabis use onset was found to significantly predict accuracy on incongruent trials. Results imply that users may have
difficulty suppressing more automatic responses. Attentional inhibition dysfunction (assessed by a visuospatial negative priming task) was demonstrated in current cannabis users in comparison to past cannabis users and controls following a minimum 48-hour abstinence period in a study conducted by Skosnik, Spatz-Glenn, and Park (2001). The authors proposed that as current cannabis users had significantly faster reactions times when performing a simple detection task, the demonstrated deficit was not the result of visual inattention, but instead reflective of increased disinhibition. Poorer performances demonstrated by cannabis users have also been reported in other studies using the WCST (Bolla et al., 2002; Pope, Yurgelun, & Todd, 1996; Pope et al., 2001, 2002; 2003). Conversely, findings from Lyons and colleagues’ (2004) study did not indicate reduced performance on the WCST by users. Other studies have also reported no effects on inhibition or impulsivity to be associated with cannabis use (Gruber & Yurgelun-Todd, 2005; Hermann, Sartorius, Welzel, Walter, Skopp, Ende, & Mann, 2007; Whitlow, Liguori, Brooke Livengood, Hart, Mussat-Whitlow, Lamborn et al., 2004). Additionally, when inhibition was measured using the Stroop test, no significant differences were reported between cannabis users and controls (Lyons et al., 2004; Pope & Yurgelun-Todd, 1996; Pope et al., 2001, 2002, 2003). It is possible that differences in results could possibly be due to the WCST and Stroop test measuring different underlying executive function subdomains. While both have been used as measure of inhibition and impulsivity, the WCST is also thought to be a measure of cognitive flexibility and abstraction ability (Milner, 1963), whereas the Stroop test also measures sustained attention with or without interference (MaCleod, 1991). In Verdejo-García et al.’s (2013) study no differences were found between users and controls in monitoring/shifting (as measured by the CANTAB Intradimensional/Extradimensional...
set-shifting task). However, it was found that users carrying the COMT val allele committed more monitoring/shifting errors than users carrying the met/met genotype.

*Verbal fluency.* While verbal fluency tasks do not traditionally fall into the category of being solely a frontal lobe executive function task due to also tapping into functions of the temporal lobe (Raskin & Rearick, 1996), verbal fluency tasks are thought to load heavily on executive function (Rabbitt, 1997). It is also considered a well established measure of executive functioning and has been commonly used to assess the integrity of the pre-frontal region (Kolb & Whishaw, 1985; Parkin & Java, 1999; Warkentin & Passant, 1997). In addition, due to the tendency of verbal fluency measures heavily relying on processes involving strategic searching, such tests are deemed to be some of the most sensitive and best validated measures of dysfunction in the frontal lobe (Benton, 1968; Bryan & Luszcz, 2000; Lezak, 1995; Parker & Crawford, 1992; Stuss & Benson, 1986). Following a minimum 12-hour abstinence period, Gruber et al. (2012) found no significant differences between marijuana users and controls in verbal fluency performance (as measured by the Controlled Oral Word Association Test (COWAT; Benton, Hamsher, & Sivan, 1983). In Pope and Yurgelun-Todd’s (1996) study, no significant differences were found between light and heavy cannabis users on verbal fluency following a minimum 19-hour abstinence period. However, a significant interaction was found between Verbal Intelligence Quotient (VIQ) and cannabis-use status indicating that out of those subjects with the lowest VIQ’s, the heavy users demonstrated reduced verbal fluency in comparison to light users. In addition, those subjects with average to high VIQ scores demonstrated no verbal fluency deficits. Findings from Fisk and Montgomery’s (2008) study showed no significant differences in verbal fluency (both letter and semantic) between cannabis users and controls following a minimum of 24 hours abstinence. Both recent (i.e., had
used in the last 7 days) and abstinent cannabis users (i.e., had not used in the last 7 days) were found to demonstrate deficits in verbal fluency (phonemic verbal fluency) following a minimum 24-hour abstinence period compared to controls (McHale & Hunt, 2008). Pope and colleagues (2003) reported a significant difference between groups in verbal fluency (COWAT - FAS) following a minimum of 28 days abstinence. In this study, the cannabis users were grouped according to age of onset (early and late). Cannabis users with early age of onset (i.e., those who commenced use before 17 years of age) were found to demonstrate significant verbal fluency deficits compared to the control group. However, the researchers’ earlier studies (2001, 2002) found no significant differences on this domain. Results from the more recent study suggest that age of onset may be an influencing factor (Pope et al., 2003).

**Decision-making.** In a study conducted by Whitlow and colleagues (2004) long-term, heavy cannabis users (i.e., those that were daily users for at least 25 out of 30 days and for at least 5 years duration) were found to demonstrate impaired performance on the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994), in comparison to controls (i.e., those who had a minimal use of 1-50 lifetime uses and did not use in the last year). Subjects in the user group were required to abstain for a minimum of 12 hours prior to testing. Findings from the study suggest that long-term, heavy cannabis users made decisions which led to larger immediate gains, but more losses overall in comparison to individuals with minimum cannabis use in their history. The authors concluded that long-term, heavy cannabis users may have a reduced ability to effectively weigh up costs and rewards and that this deficit may contribute to the continuation of their drug-use. However, it is also acknowledged by the researchers that such deficits may be the consequence of cannabis use, or may alternatively reflect the presence of pre-existing differences regarding genetics or behaviour. Additional
findings from Grant et al.’s (2012) study also indicated significant impairments in decision-making performance (as measured by the Cambridge Gamble Task from the CANTAB) in cannabis users. Bolla et al. (2005) examined brain activity using Positron Emission Tomography (PET) during the administration of the IGT. Not only did the authors find similar results where decision-making deficits were demonstrated in cannabis users (i.e., those who currently smoked at least 4 days a week, for at least 2 years duration) following a 25-day abstinent period, but cannabis users also showed different patterns of brain activation than non-users. More specifically, cannabis users showed less activation in the right dorsolateral prefrontal cortex (DLPFC) and right lateral orbitofrontal cortex (OFC), in addition to greater brain activation in the left cerebellum. One study, examined the relationship between cocaine and cannabis users (i.e., those that used at least 4 times a week, for at least 2 years duration) and IGT learning (Verdejo-García, Benbrook, Funderburk, David, Cadet, & Bolla, 2007). Results suggested that while both cocaine and cannabis users demonstrated worse performance on the total IGT net score than controls, the pattern of learning indicated that the cannabis-using group showed less learning than the cocaine-using group. Dose-related measures of cannabis use (i.e., joints per week), were also found to predict IGT performance where the heavier the use, the lower the performance demonstrated. Contrastingly, Quednow and colleagues (2007) did not find IGT decision-making deficits in chronic cannabis users who had been abstinent for a mean of 7 days. The chronic cannabis users in this study (with a mean consumption of 3.89 times a week and 6.55 years duration of use) did report using other drugs of abuse in their history, but were included in the study as long as they were deemed to not have substantially used amphetamine derivatives like MDMA or have substantial previous use of cocaine. In Verdejo-García et al.’s (2013) study, a significant difference was found between groups
on the IGT (block 3), which is considered to index the learning phase of the task. In addition, users carrying the 5-HTTLPR s/s genotype had worse decision-making skills than s/s non-users.

The abovementioned studies indicate that the cognitive impairments associated with cannabis use are demonstrated across a range of important executive function processes. However, differences in findings across studies could be attributed to variability in sample characteristics, abstinence periods and differences in frequency, severity/quantity, or duration of use/cumulative amount. In addition, results indicating no significant differences suggest that while some of the measures mentioned above may be sensitive enough to tap into the neurocognitive domain of interest, they may not support the specificity of the measures to solely detect deficits in that specific domain. In other words, such measures may not serve as specific markers for deficits in the associated domain in question. In addition, differences in the actual tests used to assess specific domains may have impacted the consistency of the findings. It would also not be surprising that multiple brain regions and connections would be involved in a neurocognitive process as complex as executive function and thus, isolating the domain by a single psychometric task presents another concern. While the findings suggest that some executive function impairments related to cannabis use have been found to improve following the discontinuation of cannabis use (Pope et al., 2001, 2002, 2003), deficits have been also shown to persist following cannabis use cessation (Bolla et al., 2005). It is also proposed that the specific factors of age of cannabis use onset, duration and amount of cannabis use may play a part in the manifestation of differing executive functioning impairments (Grant et al., 2003; Pope et al., 2003; Solowij, 1995; Solowij et al., 2002). Considering the differences in findings across studies, it is thought that the more precise and adequate assessment of executive function abilities, as well as of such
cannabis use parameters, is crucial in order to ensure that the measures used are sensitive enough to detect impairment if it indeed exists.

**Cognitive impairments associated with schizophrenia.** In 1896, the first clinical account of schizophrenia was made by Kraepelin and was termed ‘dementia praecox’ (Kraepelin, 1919, 1971, cited in Sharma & Antonova, 2003). Cognitive impairment was emphasized to be a core part of the illness and that such impairments comprised of deficits in attention, problem-solving, motivation, learning and memory (Sharma & Antonova, 2003). In 1911, Bleuler used the term ‘schizophrenia’ and also conceived cognitive impairment as being a fundamental aspect of the illness (Bleuler, 1911, 1950, cited in Sharma & Antonova, 2003). Through extensive research over the years, it is now universally recognised that cognitive impairment is a central and enduring feature of the illness and that such deficits have greater predictive ability of functional outcome than clinical symptoms (Green, 1996). More contemporary understandings of the illness indicate that cognitive impairments are more specifically demonstrated in the domains of sustained attention, language skills, executive functions, verbal learning and memory (Bilder, Lipschutz-Broch, Reiter, Geisler, Mayerhoff, & Lieberman, 1992; Riley, McGovern, Mockler, Doku, O’Ceallaigh, Fannon, & Sharma, 2000).

The cognitive impairment associated with schizophrenia is not thought to be the result of symptomatology, nor the effects of antipsychotic medication (Green, 2006). Research has suggested that the cognitive impairments associated with schizophrenia are present prior to the onset of clinical symptomatology and show relative stability across the course of the illness (Finkelstein, Cannon, Gur, Gur, & Moberg, 1997; Gold, 2004). Cognitive dysfunction in schizophrenia has also been found to be related to, but distinct from, negative symptoms (Harvey, Lombardi, Leibman, White, Parrella,
Impairments have also been observed to already be present in first-episode patients with schizophrenia (Hutton, Puri, Duncan, Robbins, Barnes, & Joyce, 1998). In addition, cognitive deficits have not only been found in patients with schizophrenia prior to illness onset, but there is evidence of similar deficits in their first degree relatives (Cornblatt, Obuchowski, Schnur, & O’Brien, 1998). The cognitive impairments found in first-episode patients with schizophrenia are also considered to be important predictors of long-term outcome (Green, Kern, & Heaton, 2004).

A wide range of cognitive impairments have been associated with the illness of schizophrenia. While deficits in global performance have been described (Braff, Heaton, Kuck, Cullum, Moranville, Grant, & Zisook, 1991), as well as broad deficits spanning across a number of cognitive domains (Heinrichs & Zakzanis, 1998), other findings have shown selective cognitive deficits which are deemed over-and-above general cognitive impairment (Saykin et al., 1991, 1994). Meta-analytic, epidemiological and twin-study findings suggest that the most severe impairments are consistently observed in the domains of episodic memory and executive function (Reichenberg & Harvey, 2007). Therefore, considering the postulated relationship between executive function and substance abuse maintenance, this neurocognitive domain in particular will once again be focussed on in the following section.

Many pathophysiological accounts of schizophrenia suggest that the illness results from neural network dysfunction where the PFC is considered an intrinsic part of these networks (Reichenberg & Harvey, 2007). The most prevalent findings from brain-imaging studies are impairments in frontal lobe functions and ‘hypofrontality’ associated with the illness of schizophrenia (Davidson & Heinrichs, 2003). It is also found that medication variables are not significant contributors to these
pathophysiological differences (Davidson & Heinrichs, 2003). It has been reported that the similar pattern of deficits demonstrated between individuals with schizophrenia and frontal lesion patients not only suggest frontostriatal circuitry disturbance, but that there are even greater impairments in executive functioning among schizophrenia patients than those individuals with frontal lobe lesions (Pantelis et al., 1997).

It has been argued that executive function deficits are a commonality across the cognitive deficits seen in the illness of schizophrenia (Shallice et al., 1999). The study of executive functions in schizophrenia is of great importance considering deficits in this domain have been associated with psychosis proneness (Franke, Maier, Hain, & Klinger, 1992). Schizophrenia patients also demonstrate profound impairments in executive function at the beginning of their illness and that such deficits are thought to mainly involve planning and strategy use, but not attentional set-shifting (Hutton et al., 1998). Such impairments are found to progress over the course of the illness. Findings have also suggested that schizophrenia patients demonstrate a distinctive pattern of decision-making impairment on specific cognitive tasks with which performance is also dependent on executive function (Shurman, Horan, & Neuchterlein, 2005). Once again, such evidence is suggestive of specific frontal lobe function abnormalities, supporting the notion that the cognitive impairments associated with the illness are related to frontostriatal dysfunction (Robbins, 1990).

Results from Katz et al.’s (2007) study suggested that while schizophrenia patients demonstrated executive deficits, those patients in the more chronic stages of the illness demonstrated worse executive function performance in comparison to those in a more acute phase. Such deficits have been shown to be associated with treatment-refractory symptoms, such as negative symptoms (Kerns & Berenbaum, 2002; Voruganti, Heslegrave, & Awad, 1997), as well as with poor functional outcome
Impaired performances have been specifically demonstrated on ‘traditional’ executive functions measures such as the Wisconsin Card Sorting Test (WCST), tests of verbal fluency, and the Trail Making Test (TMT) (Chen, Chen, Chan, Lam, & Lieh-Mak, 2000; Chen, Lam, Chen, Nguyen, & Chan, 1996; Franke, Maier, Hardt, Frieboes, Lichterman, & Hain, 1993; Goldberg, Torrey, Berman, & Weinberger, 1994; Hutton et al., 1998; Zalla, Joyce, Szöke, Schürhoff, Pillon, Komano et al., 2004). However, the extent of impairment on such measures has been found to vary among individuals with schizophrenia depending on illness presentation. For example, findings have suggested that there is a poor correlation between positive symptoms and reduced performance on executive function measures (Morris, Rushe, Woodruffe, & Murray, 1995). Some authors report that negative symptoms have been found to be significantly correlated with the severity of executive dysfunction (Voruganti et al., 1997). However, in a study by Rodriguez-Jimenez and colleagues (2008), it was found that while those schizophrenia patients who performed poorly on the WCST also exhibited more negative symptoms, there was no association found between WCST performance and negative symptoms in dually-diagnosed schizophrenia patients with substance use disorders. No significant association between neuroleptic medication and executive functioning impairment in schizophrenia has also been found (Verdoux, Magnin, & Bourgeois, 1995). Therefore, it is possible that there may be certain subgroups among the schizophrenia population that may comprise of individuals with differing illness pathology and possibly different executive abilities. Due to the high prevalence of
substance use, more specifically cannabis use, in schizophrenia, investigation into the
neurocognitive abilities of such a subgroup is of particular interest.

The importance of executive function to individuals with schizophrenia. The
illness of schizophrenia has significant economic implications and it is considered as the
most costly of the psychiatric disorders (Capri, 1994; Knapp, 1997; Torrey, 2002).
Functional impairment in particular has been identified as one the primary factors
contributing to the illness’ high cost (Kenny & Meltzer, 1991). In an extensive review
of the measurement of outcome in schizophrenia, Green (1996) defined functional
outcome as ‘the result of competence in a large number of constituent social and
instrumental role tasks’ (p. 323). Research findings have shown that cognitive
impairments account for significant variance in functional status measures (Green,
1996). Both cross-sectionally (Green, 1996) and longitudinally (Green, Kern, & Heaton,
2004), the cognitive impairments found in schizophrenia have been shown to be
associated with impairments in everyday functioning. Past research has found that
cognition is a stronger predictor of functional outcome than symptomatology (Harvey,
Howanitz, Parrella, White, Davidson, Mohs, & Davis, 1998; Harvey, Napolitano, Mao,
& Gharabawi, 2003; Kurtz, Moberg, Ragland, Gur, & Gur, 2005; Perlick, Rosenheck,
Kaczynski, Bingham, & Collins, 2008; Velligan, Mahurin, Diamond, Hazleton, Eckert,
& Miller, 1997). Therefore, in order for rehabilitation efforts to be more precise and
thus ultimately have a higher success rate, identifying the specific cognitive domains
found to be particularly associated with successful independent living is crucial.

Current treatments targeting functional impairments typically involve
behavioural techniques aimed at social, occupational, self-care and independent living
skills training (Sharma & Antonova, 2003). However, despite the levels of residential
independence demonstrated in schizophrenia outpatients (i.e., those that reside in the
community), widespread functional impairments are still evidenced (Auslander, Lindamer, Delapena, Harless, Polichar, Patterson et al., 2001). It has been postulated that one of the main reasons for the lack of improvement in the functional outcome of patients with schizophrenia is the lack of success in sufficiently treating those features of schizophrenia which are considered strong predictors of functional outcome, such as negative symptoms and cognitive impairment (Harvey, Green, Keefe, & Velligan, 2004). Therefore, there appears to possibly be a mediating factor in influencing the effectiveness of such approaches and it is cognitive impairment that is considered to be this link (Green, 1996; Green et al., 2000).

Specific cognitive domains have been found to be closely related to functional outcome (Green & Neuchterlein 1999; Green et al., 2000). It has been found that the utilisation of complex and higher-order cognitive abilities (i.e., executive functions) which include flexibility with set-shifting, reasoning, decision-making, planning and working memory are related to successful treatment outcomes (Gordon, Kennedy, & McPeake, 1988; O’Leary, Donovan, Chaney, & Walker, 1979; Weinstein & Shaffer, 1993). Among the range of cognitive deficits which have been most commonly found in individuals with schizophrenia, it is acknowledged that executive functions play a crucial role when considering outcome (Simon et al., 2003). Through extensive reviews in the area of cognition in schizophrenia, performance on measures assessing executive functioning was consistently found to be associated with poor community outcomes in particular (i.e., independent living) (Green, 1999; Green et al., 2000). In addition, Penadés and colleagues (2003) examined the effects of cognitive rehabilitation strategies (i.e., the cognitive differentiation and social perception cognitive modules from the Integrated Psychological Therapy program, implemented in 24 group sessions over a 12-week period), on cognition and functional outcome in patients with
schizophrenia. The authors found that changes in encoding and executive function were specifically associated with changes in functional outcome.

Several research studies have suggested that tests measuring executive functions are the best predictors of performance in activities of daily living, particularly when considering patients with schizophrenia (Dickenson & Coursey, 2002; Ihara, Berrios, & McKenna, 2003; Semkovska, Stip, Godbout, Pacquet, & Bedard, 2002). Results from a study conducted by McClure and colleagues (2007) indicated that two domains of functional capacity (i.e., social and living skills) had different neuropsychological correlates in schizophrenia. More specifically, it was found that both working and episodic memory, as well as verbal fluency abilities, were related to social competence. It was also found that processing speed, episodic memory and executive function were associated with everyday living skills. Katz et al.’s (2007) findings suggested that performance on executive function measures were more strongly related to performance in complex areas of daily living (which included social communication, IADLs, and occupational skills), in comparison to performance on a basic cognitive skill measure. It is also considered that executive function measures in general have better predictive ability regarding lack of insight in comparison to premorbid intellectual ability, IQ, memory, or language measures (Burgess, Alderman, Evans, Emslie, & Wilson, 1998).

It has been well established that cognitive impairment is a core feature of schizophrenia. In addition, executive dysfunction is not only particularly implicated in the illness of schizophrenia, but is also identified as an important predictor of functional outcome status. This neurocognitive domain has been considered as an area of importance especially when evaluating the independent living capacity of patients in the community. Therefore, if this particular domain is considered as a potential target for treatment, then the comprehensive assessment of this neurocognitive system has
significant clinical importance. Without obtaining knowledge with regard to which specific deficits are linked to ‘real-world’ functioning, efforts towards cognitive rehabilitation will continue to remain not only less clearly focused, but ultimately less successful in their utility. In the current study, executive functions are targeted due to their close connections to community functioning, as well as their association with negative symptoms which are also linked to functional outcome. Considering the relationship between executive function and illness presentation, as well as outcome, this particular neurocognitive domain has specific relevance in the examination of cognitive functioning in schizophrenia.

**Cognitive impairments associated with cannabis use and schizophrenia.**

Since previous research findings have suggested an association between cannabis use in schizophrenia and worsened illness prognosis, in addition to the reported adverse effects of cannabis use alone on cognitive function without the presence of psychotic illness, it would be reasonable to suggest that poorer cognitive function would be expected in schizophrenia patients with cannabis use. However, relatively few studies have specifically examined the relationship between cannabis use and cognitive functioning in the schizophrenia spectrum disorders, with mixed results being reported. The current literature review will further outline these studies. Once again, only neurocognitive effects associated with chronic or long-term use cannabis use will be focussed on in the following review.

Some studies have reported poorer performance amongst schizophrenia patients with cannabis use. Mata and colleagues (2008) examined the relationship between pre-illness cannabis abuse and cognitive performance in 61 cannabis-abusing and 71 non-abusing patients experiencing their first episode of schizophrenia-spectrum psychosis. The patients were grouped according to their cannabis abuse prior to illness onset and
cannabis abuse status was based on the criteria of at least weekly use during the
previous year. In their study, a cognitive battery was administered which included tasks
thought to utilise the DLPFC, such as a measure of working memory (assessed by Digit
Span - backwards condition), a measure of verbal fluency (measured by phonemic
fluency task – FAS), and a set-shifting task (measured by the TMT), as well as an OFC
related task designed to measure decision-making capacity (e.g., IGT). Findings from
their research showed no significant differences between patients who had abused
cannabis before their psychosis onset and patients who had not abused cannabis before
their psychosis onset on any of the DLPFC related tasks. However, results also showed
that those patients who had abused cannabis before their psychosis onset demonstrated
poorer total performance and lower improvement in performance on the IGT. The
authors suggested a possible explanation for the findings is that decision-making
differences between cannabis abusers and non-abusers may reflect a pre-existing
condition that led abusers to make costly decisions in the gambling task.

In a recent study conducted by Sánchez-Torres and colleagues (2013), the
relationship between lifetime cannabis use (over 10 years of follow-up) and current
cognitive performance was examined in a sample of 42 patients with schizophrenia, 35
of their unaffected siblings, and 42 healthy control subjects. Drug abuse was assessed in
patients and siblings longitudinally using the Composite International Diagnostic
Interview (World Health Organisation, 1993). The controls were only assessed at
follow-up and reported current consumption. A lifetime estimate of consumption was
determined for all participants (using information from subject reports, family and
charts) and subjects were given a rating from 0 (no consumption) to 5 (every-day
consumption). In the patient group, longitudinal cannabis consumption was found to
have a negative relationship with performance in a social cognition task (assessed by the
Managing Emotions section of the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Mayer, Salovey, Caruso, 2009). The investigators did not find a significant relationship between cannabis use in the patient group for the three time points and the composite scores for processing speed, attention, declarative memory, working memory and executive function. In the unaffected sibling group, a significant negative correlation between cannabis use at baseline 10 years prior to assessment, current use and the declarative memory composite score (assessed by the Spanish version of the California Verbal Learning Test, the Test de Aprendizaje Verbal Espan˜a–Complutense (TAVEC; Benedet & Alejandre, 1998) and the Brief Visual Memory Test-Revised (BVMT-R; Benedict, 1997)) was found. However, while cannabis use was not found to predict cognitive performance in the healthy control group, a negative association between lifetime cannabis and tobacco use together and processing speed and social cognition performance was found. Results indicated that longitudinal cannabis use was associated with poorer social cognition in patients and that current cannabis use was associated with poorer performance in working memory, particularly when low premorbid IQ and earlier age of illness onset was accounted for in the explanatory model.

Other research findings have suggested no differences in cognitive performance between cannabis-using and non-cannabis using patients with schizophrenia. Sevy and colleagues (2007) compared the performance of 14 schizophrenia patients with concurrent cannabis use disorders and 13 patients without concurrent substance use disorders on a number of measures of cognition as well as on a decision-making task (i.e., IGT), with that of 20 healthy normal subjects. Results of the study showed that both schizophrenia groups demonstrated more cognitive impairments and worse performance on the IGT, compared to healthy controls. However, no significant
differences on most of the cognitive tests (including the IGT) were found between schizophrenia patients with cannabis use disorders and schizophrenia patients without. While it is noted that the study conducted by Sevy and colleagues (2007) included subjects who also used substances other than cannabis, due to the inclusion of the IGT measure in their assessment of cognition (and its particular relevance to the neurocognitive construct of interest), the results of the study were deemed worthy of review.

Scholes and Martin-Iverson (2010) investigated the cognitive performances of 22 cannabis-using schizophrenia patients, 49 non-using schizophrenia patients, 36 otherwise healthy cannabis-using controls and 35 non-using healthy controls. Performances on tasks measuring attentional control (Stroop test), auditory working memory (LNS), spatial working memory (Spatial Span) and card-sorting/set-shifting and perseveration (WCST), were assessed. Results from the study showed that while both schizophrenia groups demonstrated significantly poorer performance across all tasks relative to controls, no significant differences in cognitive performance between cannabis-abusing schizophrenia and non-using schizophrenia patients were found. In other words, cannabis use in schizophrenia was not associated with further neurocognitive decrements. Scholes and Martin-Iverson’s findings also suggested that cannabis use in healthy individuals was not associated with deficits in the measures administered that resemble those deficits associated with schizophrenia. However, one exception to this finding was noted and this was increased perseveration demonstrated on the WCST. From these results, the authors concluded that cannabis use has subtle effects on the cognitive performance of both healthy individuals and patients with schizophrenia across a range of tasks.
Surprisingly and contrary to expectations, there has also been a number of studies showing superior cognitive performance amongst schizophrenia patients with cannabis use. Stirling and colleagues (2003, 2005) administered a neuropsychological battery to 69 patients at a 10-12 year follow-up. The patients in this study were recruited out of 112 individuals in 1987 who had experienced their first episode of psychosis within 2 years prior to this time. Those who had a history of cannabis use (categorised as ‘no use’ and ‘some use’) at the time of the onset of their illness were noted. Thirty-seven patients were assessed with a neurocognitive battery at onset, 24 were re-assessed at follow-up and an additional 25 from the parent sample were also assessed at follow-up. Findings from the study showed that patients with cannabis use demonstrated better performance on a verbal fluency task (COWAT – FAS), as well as on other neurocognitive measures such as design memory (Memory for Design; Graham & Kendall, 1960), visuospatial organisation (object assembly, block design, picture completion, picture arrangement), and recognition memory (face recognition) at follow-up. More specifically, after controlling for the effects of age of cannabis use onset significantly better performance on measures of memory, verbal fluency, sequencing, visuospatial organisation and recognition memory was found to be associated with a history of cannabis use. In addition to these findings, the 26 patients who reported a level of continued cannabis use at follow-up demonstrated significantly better performance in several of these domains in comparison to those who had not sustained their cannabis use at this time. It was suggested by the authors that while impairment in executive function may be present in first episode patients, they do not appear to deteriorate over 10-12 years. As both the patients with cannabis use and non-using patients were not able to be distinguished based on their performance on any of the premorbid adjustment measures or in relation to social/behavioural functions (as
assessed by the Premorbid Adjustment Scale (PAS); Cannon-Spoor, Potkin, & Wyatt, 1982), the authors concluded that their findings were not indicative of the presence of differences between groups related to premorbid social functioning. Results suggested that the cannabis-using group may represent a subgroup with a subtly different profile, characterised by relatively preserved neurocognition and fewer negative symptoms.

While better performances demonstrated by schizophrenia patients with cannabis use could be considered counterintuitive, other studies have also reported a similar pattern of results. Jockers-Scherübl and colleagues (2007) compared the cognitive functioning of 39 schizophrenia patients (19 cannabis abusers and 20 non-abusers) with 39 healthy control subjects (18 cannabis abusers and 21 non-abusers) following a minimum abstinence period of 28 days. The researchers excluded those patients with any drug abuse or dependence history other than that involving cannabis. The cannabis-abusing group in the study included only those individuals whom had consumed an average of at least 0.5g of cannabis per day for a minimum of 2 years prior to illness onset. Main effects of diagnostic group (i.e., schizophrenia vs. controls) indicated cannabis-using patients with schizophrenia demonstrated worse performance in most neurocognitive tests in comparison to cannabis-using controls. However, when only the main effect of age of cannabis use onset was considered, irrespective of diagnostic group, there was no significant difference found. A significant interaction between diagnostic group and age of onset was found for performance on a processing speed and working memory task (measured by the Digit Symbol Substitution Test (DSST): Wechsler, 1981) and performance on another measure of working memory (assessed by ‘other errors’ on the WCST). More specifically, control subjects with cannabis abuse who had commenced regular use at 16 years or younger demonstrated worse cognitive performance than those individuals whose age of cannabis use onset
was 17 years or older. Contrastingly, schizophrenia patients with cannabis abuse who commenced their abuse at the age of 16 years or younger performed better on the DSST, but demonstrated worse performance relative to controls when their cannabis abuse had started at 17 years or older. No significant difference in performance between control subjects and schizophrenia patients with early onset of regular cannabis abuse were also observed on this test. A similar pattern of results was observed on ‘other errors’ of the WCST. These results suggested that regular cannabis abuse commencing before the age of 17 (and prior to illness onset) was associated with better neurocognitive performance in patients with schizophrenia. However in the control group, early age of onset of regular cannabis abuse was found to be associated with worse performance. It was noted that once the authors made corrections to the alpha level in order to account for multiple statistical tests, the difference in performance remained significant for ‘other errors’ on the WCST (when age of onset was applied), but only approached significance for performance on the DSST. The authors considered that a possible explanation for the findings showing better performance by patients with cannabis abuse on such measures who commenced their cannabis use prior to the age of 17 (and also illness onset) may be potentially due to the latter measure not only assessing processing speed abilities. It is thought that the DSST in particular may also tap into a number of neurocognitive abilities including attention, sustained attention, psychomotor speed, working memory and other executive functions (Lezak et al., 2004). Therefore, it was considered by the authors that such a measure may be possibly more sensitive in detecting subtle differences that exist between groups. It is postulated that when there are slight deficits on a collection of neurocognitive abilities, the need to simultaneously integrate these abilities may consequently lead to overall impairments in performance becoming more evident. Therefore, the authors proposed that a possible explanation for the findings of
better performance on this test may suggest that those patients with cannabis abuse with an age of cannabis abuse onset prior to illness onset could possibly possess a better capacity to integrate several cognitive functions despite demonstrating poor performance in individual tests.

Coulston, Perdices and Tennant (2007) examined the relationship between neuropsychological performance and three different indices of cannabis use in 60 males with schizophrenia/schizoaffective disorder and 17 male healthy control subjects. Forty-four schizophrenia patients met the Diagnostic and Statistical Manual of Mental Disorders - Fourth Edition (DSM-IV; American Psychiatric Association, 2004) criteria for lifetime cannabis abuse/dependence. The indices used by the researchers included lifetime abuse/dependence (assessed according to the DSM-IV criteria of substance abuse/dependence), frequency of use, and recency of use. In line with the pattern of results of previous studies, findings indicated that cannabis use was associated with enhanced neurocognitive functioning in schizophrenia. More specifically, results showed that a larger proportion of those schizophrenia patients with lifetime cannabis abuse/dependence demonstrated performance classified in the normal range on one of the executive function measures administered (i.e., the TMT), in comparison to those without lifetime abuse/dependence. However, the actual component of the measure which was found to be significantly associated with better performance was that aspect of the test which assessed psychomotor speed. In this study, cognitive performance was classified as ‘impaired’, ‘normal’, and ‘above average’ based on scores derived from the control group. Subjects were deemed to demonstrate cognitive ‘impairment’ if performance fell 1.5 – 2.0 standard deviations or more below the mean of the control group (Sprenn & Strauss, 1998; Ruff & Allen, 1996, both cited in Coulston et al., 2007). In addition, above average performance was determined if scores were 0.5 standard
deviations or more above the mean of the control group. Intriguingly, high frequency cannabis use was found to be associated with better performance on Principal Component Analysis derived cognitive components of speed of information processing, divided attention, visual conceptual switching, and planning efficiency. However in contrast, a larger proportion of subjects categorised as medium frequency cannabis users fell in the ‘impaired’ range on the cognitive components of planning efficiency and complex information processing. It was noted that while premorbid IQ was not found to be significantly different between frequency groups, the medium frequency group had a mean premorbid IQ at almost half a standard deviation lower than the high and low frequency cannabis user groups. The cannabis use indices measuring recency (i.e., cannabis abuse/dependence in the past week; cannabis use at a non-dependent level in the past month, but prior to the past week; cannabis use at a non-dependent level prior to the past month), were also found to be associated with better performance on the cognitive components reflective of speed of information processing, complex information processing, psychomotor speed, inhibition accuracy, planning efficiency, planning and organisation, and complex perceptual organisation. Worse performance on a non-executive cognitive component of immediate memory was however, associated with the recency category of non-dependent cannabis use in the past week. In addition, cannabis use at a non-dependent level in the past week was associated with worse performance on the cognitive components of planning and organisation and complex information processing. As the cognitive components which were found to be associated with better performance, as well as with the cannabis use parameters of frequency and recency of use, were attention/processing speed and executive function domains, the authors postulated that cannabis use may possibly stimulate prefrontal neurotransmission.
Further evidencing the surprising observation of better neurocognitive performance, Schnell and colleagues (2009) investigated the residual impact of cannabis use and specific parameters of cannabis consumption on cognition in a sample of schizophrenia patients with a lifetime diagnosis of comorbid cannabis use disorder. The indices of cannabis use assessed included age of onset of use, the duration of regular use, time since last dose, average frequency of use (joints per month), and maximum frequency of use (joints per month). A cognitive test battery was administered to 34 schizophrenia patients and 35 currently abstinent schizophrenia patients with cannabis use disorder. The minimum period of abstinence from cannabis was 3 weeks. The schizophrenia patients with cannabis use disorder had poorer academic achievement and lower vocabulary scores. However, after potential confounds were accounted for schizophrenia patients with cannabis use disorder were found to demonstrate better performance in tests of verbal memory (measured by the Auditory Verbal Learning and Memory Test; Heubrock, 1992), working memory (LNS; Gold, Carpenter, Randolph, Goldberg, & Weinberger, 1997), and visuomotor speed and executive function (DSST; Tewes, 1991; TMT, Part B; Reitan 1958; Reitan & Wolfson, 1993), in comparison to schizophrenia patients without comorbid cannabis use disorder. Results of the study were in support of previous findings (Coulston et al., 2007; Jockers-Scherübl et al., 2007; Stirling et al., 2005). More frequent cannabis use was also associated with better performance in tasks of attention (Continuous Performance Test (CPT); Cornblatt, Risch, Faris, Friedman, & Erlenmeyer-Kimling, 1988) and working memory (LNS). In addition, DeRosse and colleagues (2010) compared lifetime measures of psychotic symptoms, as well as cognitive performance in 280 schizophrenia patients without a history of cannabis use disorder and 175 schizophrenia patients with a history of cannabis use (51 patients with comorbid cannabis abuse; 124 patients with cannabis
dependence). Similar results were found where schizophrenia patients with a history of cannabis use disorder demonstrated significantly better performances on measures of processing speed (TMT, Part A & B), verbal fluency (animal naming) and verbal learning and memory (California Verbal Learning Test). This group also had better Global Assessment of Functioning (GAF) scores than schizophrenia patients without a history of cannabis use disorder.

Rodríguez-Sánchez et al (2010) conducted a study amongst 107 first-episode patients with schizophrenia (47 cannabis users and 57 non-users) and 37 healthy controls. Patients were considered to be cannabis users if there had been at least weekly use during the year prior to program entry. The aim was to compare subjects on clinical features, cognitive performance and premorbid adjustment, both cross-sectionally and longitudinally. Results showed that cannabis users demonstrated better performance in attention (as measured by the CPT) and executive function (as measured by the TMT-B) at baseline and following 1 year of treatment. In addition, cannabis users were found to have better social premorbid adjustment, particularly during childhood and adolescence. They were also found to have earlier age of illness onset. Findings also indicated that the amount of cannabis consumed and duration of use was not associated with cognitive performance. While it was noted by the investigators that some patients regularly used other drugs of abuse in addition to their cannabis use, it was found that results relating to executive function performance remained significant after the omission of these subjects from analyses. The authors argued that the findings of the higher presence of positive symptoms at baseline, better premorbid adjustment and higher performance on frontal related cognitive functions suggest that cannabis users may represent a specific subgroup of patients with better overall premorbid abilities.
Leeson and colleagues (2011) aimed to explore the role of age of onset and cognition on outcomes in cannabis users with first-episode schizophrenia. In addition, the investigators aimed to evaluate the effect of cannabis use parameters such as dose and cessation. Ninety-nine patients were divided into 65 lifetime cannabis users (as defined by those who reported having used the drug at all during their lifetime) and 34 never-users. The cannabis-using group were further parsed into a high frequency group (i.e., those who reported either daily or almost daily use; \( n = 30 \)) and a low frequency group (i.e., those who reported use of either twice a week or less; \( n = 35 \)). Results of the study showed that cannabis users had better premorbid IQ and social function at psychosis onset. Cannabis users also demonstrated better performance in verbal learning (assessed by the Rey Auditory Verbal Learning Task), working memory span (Spatial Span) and planning (assessed by a task analogous to the Tower of London), but not on a working memory manipulation task (self-ordered search task from the CANTAB), in comparison to non-users. However, when premorbid IQ was entered into analyses as a covariate, these between group differences were no longer significant except for planning. It was found that premorbid IQ did not explain the between group difference in social functioning. Low frequency users were found to have significantly higher current IQ than high frequency users and cannabis users had an earlier age of illness onset than non-users. There was also a strong relationship found between age at first cannabis use and age of onset of both prodromal and psychotic symptoms. The authors concluded from their overall findings that cannabis use may trigger the onset of psychosis in individuals who otherwise have good prognostic features (i.e., higher intellectual and social functioning prior to psychosis onset). It was also considered that the cannabis-using patients in the study had higher ‘cognitive reserve’ not only as evidence by better premorbid abilities, but by also better social function demonstrated
over the first 15 months of illness. It was considered that the earlier age of illness onset in cannabis users may therefore be due to the toxic action of cannabis instead of it reflecting of a form of illness that is more severe in nature.

Yücel and colleagues (2010) conducted a meta-analysis of the research in the area examining the cognitive functioning of patients with established schizophrenia with and without comorbid cannabis use. Findings suggested that patients with history of cannabis use were found to have superior cognitive functioning. These particular results were predominantly influenced by those studies which included schizophrenia patients who had a lifetime history of cannabis use (defined elsewhere e.g., Schnell et al., 2009 as those that were assessed to have a lifetime diagnosis of comorbid CUD according to DSM-IV-TR), rather than current or recent use factors. In a second study conducted by the authors, the cognitive performance of 59 first-episode patients with psychosis with a cannabis use history was examined in comparison to 26 patients with first-episode psychosis patients without a history of cannabis use and 43 healthy non-using control patients. Findings showed that first-episode patients with a cannabis use history demonstrated better performance in the neurocognitive domains of visual memory (as measured by Visual Reproduction (Part I) from the Wechsler Memory Scale - Revised (WMS-R); Wechsler, 1987), working memory (as measured by ‘SWM-errors’ on Spatial Working Memory from the CANTAB), and planning and reasoning (as measured by the Tower of London; Shallice, 1982). In addition to these results, it was also found that earlier onset of cannabis use was associated with less cognitive impairment in comparison to a later age of cannabis use onset which is in support of previous findings (Jockers-Scherübl et al., 2007).

Rabin and colleagues (2011) also conducted their own meta-analysis, but instead only included studies that examined the direct effects of cannabis on cognition in
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schizophrenia, with no other substance use included. Similar findings were reported, denoting overall superior cognitive performance in schizophrenia patients associated with lifetime cannabis use in comparison to non-using patients. However, the authors noted that the magnitude of the effect sizes found were considered to be in the small to medium range (mean $d = .06 - .48$) which were also similar to the effect sizes reported in Yücel and colleagues’ (2010) meta-analysis. As it is considered that effect sizes of 0.50 or greater are deemed to be clinically significant (Lezak et al., 2004), it is possible that results of the meta-analysis may be reflective of variability in methodological design instead of between-group differences. Therefore, effect sizes of these magnitudes may serve to question the clinical significance of the found relationship between cannabis use and neurocognition in schizophrenia amongst these studies. In a recent study by the same authors (2013), the cognitive performance in schizophrenia as a function of cannabis use indices was examined. The study included 18 schizophrenia outpatients with current cannabis dependence and 29 patients with no current cannabis dependence. The latter group was then parsed into subgroups which included 21 patients with lifetime cannabis dependence and 8 patients with no lifetime dependence. Results indicated no significant differences in cognitive performance between patients with current cannabis dependence and no current cannabis dependence. However, never-dependent patients were found to demonstrate poorer reaction time on a measure of sustained attention, concentration, psychomotor speed, response inhibition and impulsivity (Continuous Performance Test II (CPT-II); Conners, 2000), than current and former dependent patients. These results remained significant after controlling for age. In current dependent patients, negative correlations were found between years of cannabis exposure and performance on the CPT-II, a measure used to assess working memory (Digit Span; Wechsler, 1997), another measure of executive function (WCST),
a measure of verbal memory (California Verbal Learning Test—Second Edition; Delis, Kramer, Kaplan, & Ober, 2000), and long delayed cued recall. It is important to note that the reported associations with years of cannabis use exposure were found on the Digit Span forwards condition only. There was no association between performance on tests of impulsivity and risky decision making (assessed by the Kirby Delayed Discounting Task; Kirby, Petry, & Bickel, 1999 and the IGT - Computerized version; Bechara et al., 1994) and cumulative cannabis use. Results of the study suggest that the cessation of cannabis use was not associated with worse or better performance. Also, while poorer reaction times were demonstrated by never-dependent patients, reduced performance on a range of cognitive tasks was found to be associated with cumulative use in current dependent patients suggesting that years of cannabis use exposure may be a more important contributing factor than cannabis use status.

The increasing picture of better cognitive performance associated with cannabis use in schizophrenia patients is not only counterintuitive, but rather unexpected considering the impact of cannabis use on cognition in otherwise healthy users. One possible explanation for these findings is that better cognitive functioning may serve to be a risk factor in patients with schizophrenia for the development of cannabis use disorders. In other words, this cohort of individuals may have higher social competence (i.e., as demonstrated by the ability to seek, obtain and maintain drug use) and therefore be reflective of more intact cognitive functions (DeRosse et al., 2010; Jockers-Scherübl et al. 2007; Leeson et al., 2011; Rodríguez-Sánchez et al., 2010). Arndt and colleagues (1992) found better premorbid adjustment in those individuals with schizophrenia who abused alcohol or cannabis. A two-stage model was proposed by the authors to attempt to explain substance abuse in these individuals. The authors postulated that those with better premorbid adjustment were more sociable in nature and thus would possibly be
exposed to more opportunities for substance use experimentation. Other authors have also suggested better premorbid abilities in substance-using schizophrenia patients, where such cohorts have been considered to reflect a relatively distinct group who differ from non-using patients in terms of premorbid social adjustment which is thought to be required in order to initiate and maintain drug-seeking behaviour (Wobrock, Sittinger, Behrendt, D’Amelio, Falkai, & Caspari, 2007). Similarly, in a study conducted by Kumra and colleagues (2005) which examined performances on measures of intellectual functioning in adolescent inpatients with schizophrenia and schizoaffective disorder, findings suggested that a better Full Scale Intelligence Quotient (FSIQ) and Verbal Intelligence Quotient (VIQ) was associated with a history of cannabis abuse/dependence. However, this perspective is contrary to previous findings which failed to identify significant differences in premorbid adjustment and social/behavioural functioning between groups (Coulston et al., 2007; Stirling et al., 2005). It is also noted that the sample in Kumra et al.’s (2005) study were adolescents.

**Limitations to Previous Research**

The results of the abovementioned studies cannot be adequately evaluated without reviewing the limitations in methodology across each study. In some studies, it was more difficult to establish the direct impact of cannabis on cognition because additional substances had also been used by patients and these had not been controlled for in analyses (Sevy et al., 2007; Yücel et al., 2010). Yücel and colleagues (2010) included studies in their meta-analysis as long as cannabis was the most preferred substance of the sample. Therefore, some cannabis-using groups also included patients who did not only use cannabis. However, it is noted that in studies which included other substance use one would assume that this would only serve to increase the likelihood of detecting poorer performance in the drug-using patient group, but surprisingly most
found better performances. It is considered that the inclusion of other substances may potentially make it more difficult to establish the precise contributing factors to this level of performance (i.e., whether superior performances are associated with cannabis use related brain functioning per se, or are just simply associated with the neurocorrelates of substance use in schizophrenia in general). It is acknowledged that this issue is considered to be practically unavoidable, or at least in part a contributing factor, making the recruitment of larger, more specific patient sample groups more difficult to achieve. Some studies also only examined the effects of cannabis use prior to the first psychotic episode and failed to investigate the effects of continuing cannabis use after illness onset (Jockers-Scherübl et al., 2007; Mata et al., 2008).

Such inconsistent findings in the existing literature may also be explained by the level of variability in population characteristics between the studies. One source of this variability in sampling includes the types of patients used. Reported better performances amongst cannabis-using patients have involved a relatively young sample (Coulston et al., 2007). It was considered that the effects of cumulative substance use may not be fully developed in the tested sample and therefore, the effects associated with longer lifetime cannabis use could not be established. Another possibility is that the deficits found may be a reflection of age-related cognitive decline, as there is increasing evidence in the literature suggesting age-related deficits in executive functioning (Fisk & Sharp, 2004; Fisk & Warr, 1996; Fristoe, Salthouse, & Woodard, 1997; Salthouse & Babcock, 1991; Van der Linden, Beerten, & Pesenti, 1998). In other words, the neurocognitive performances observed in these previous studies may not be directly related to the effects of cannabis use, but instead a function of age differences. In Rabin and colleagues’ (2013) study, never-dependent patients were found to be significantly older than current-dependent and former-dependent patients. In addition, never-
dependent patients were found to have a significantly older age of diagnosis than former-dependent patients. Similar differences in age of diagnosis between never-dependent and current-dependent patients approached significance.

Further, the way in which cannabis users were classified or identified also varied between studies. For example, some studies have utilised a binary system grouping participants as being either users or non-users (Mata et al., 2008; Scholes & Martin-Iverson, 2010; Sevy et al., 2007; Stirling et al., 2005) and cannabis use parameters such as severity/quantity, frequency, and duration were not accounted for in the researchers’ classification of what characterised a user. In most of these studies, either no significant differences were reported or worse cognitive performance was associated with cannabis. However, Stirling and colleagues (2005) reported better performance. Contrastingly, those studies which classified participants as having a cannabis use disorder diagnosis or being defined by a minimum amount or duration of use showed only better cognitive performance associated with cannabis (Coulston et al., 2007; DeRosse et al., 2010; Jockers-Scherübl et al., 2007; Leeson et al., 2011; Rabin et al., 2013; Rodríguez-Sánchez et al., 2010; Schnell et al., 2009). In addition, two studies reported a relationship between higher frequency of cannabis use and superior cognitive functioning (Coulston et al., 2007; Schnell et al., 2009). Therefore, considering the differences in findings it seems that assessing the different parameters of cannabis use is of particular importance when examining the effect of cannabis on cognition in schizophrenia.

Studies also differed in the range of tests used to assess cognitive functioning or the types of measures used to tap into specific cognitive functions. Further, it is acknowledged that the selection of measures used in previous studies appears to be relatively atheoretically driven and instead based upon face validity (i.e., they appear to
assess these functions) in measuring their proposed cognitive constructs. In addition, the cognitive assessment conducted in some studies were restricted to only a few cognitive domains (DeRosse et al., 2010; Schnell et al., 2009; Scholes & Martin-Iverson, 2009). The means in which these domains were assessed were also limited by the diminutive number of measures used to do so. Performance on the measures utilised in previous research may not precisely enough reflect the range of deficits implicated in schizophrenia, as well as in cannabis users, particularly when considering the multi-faceted neurocognitive processes involved in the executive function system. Therefore, it is possible that these studies could fall short of being able to adequately assess the full range of abilities or components that are theoretically conceptualised to be involved in the executive functioning system. Considering the relationship between executive function and functional outcome in schizophrenia, consequently it may be more difficult to fully evaluate the clinical relevance of previous findings regarding overall cognitive performances. A methodological problem commonly involved in neuropsychological research, involves the issue of how the multi-faceted and complex construct that is termed ‘executive function’ has been mainly assessed by relatively few psychometric measures (e.g., the WCST, the Stroop test, verbal fluency or TMT). This potential inadequacy in assessment approach has been considered an important issue (Green, 1996; Green et al., 2000; Thoma, Wiebel, & Daum, 2007). Therefore, previous neuropsychological evidence may not be reflective of the true nature of, or sufficiently narrow down, the various subcomponents which could be specific to the executive deficits deemed to be crucial to the illness of schizophrenia. It is possible that the inconsistencies in previous findings may be related to the methodological difficulties that are involved in precisely defining and measuring the construct of executive function, as well as assessing the range of sub-processes which fall under the executive
function domain. Neurocognitive test batteries should aim to target and delineate the construct(s) of interest (e.g., executive function) more precisely. In addition, a lack of examination of whether performance on such measures is related to day-to-day functioning abilities (i.e., functional outcome) questions the ecological validity of the employed measures used in previous studies (i.e., are they are adequately reflective, and predictive, of the abilities required to function in the ‘real-world’?). It is possible that outside of the testing context, there are more complex demands and distractions that an individual may encounter in more naturalistic settings. Therefore, any absence of deficits demonstrated in a psychometric assessment situation may not necessarily reflect intact neurocognitive function. It is possible that utilising more ecologically valid measures could potentially allow for the detection of more subtle deficits by creating conditions that could serve to place greater ‘real-world’ demands on an individual.

The inconsistency in past findings suggests that the evaluation of neurocognitive function in schizophrenia patients with cannabis use requires further examination. Considering the results in previous studies indicating superior cognitive performances in cannabis-using schizophrenia patients, in comparison to patients without a cannabis-use history, it is possible that the use of a matched-pairs control group with cannabis use could potentially help to further tease apart or further explain these observations. An otherwise healthy control group with a similar cannabis use history could possibly allow for more information in addition to the previous findings, by assisting to determine whether cannabis acts correspondingly in otherwise healthy users in comparison to patient users, or whether there is something truly unique to the schizophrenia patient with cannabis use population. Considering the prevalence rates of cannabis use in this particular clinical population, cannabis use in schizophrenia is an often unavoidable confounding variable that needs to be carefully accounted for. Indices of cannabis use
are also often highly variable across individuals and consequently cannabis use per se can be difficult to define. Therefore, in order to address this issue it is imperative that a detailed assessment of the different parameters of cannabis use is conducted (e.g., severity/quantity, frequency, duration, time since last use). The use of a control group with a similar cannabis use history would also help to control for any confounding influence contributed to by such variations in crucial cannabis-use indices which have been considered to have an impact on cognitive performance. In addition, as executive impairments have been found to be associated with age-related cognitive decline, age is also deemed an important variable to control for.

The previously mentioned methodological issues also provide scope for the further development of neuropsychological battery measures in not only being able to more effectively examine complex cognitive constructs such as executive function, but in addition sufficiently validate individual neurocognitive sub-components against various aspects of functional outcome. In order to critically examine the validity of various tests of executive function, further exploration into the concept of executive function and its specific components, will be discussed in the following section.

Part B

The Assessment of Executive Function

Over the years, establishing a precise definition, as well as developing the effective measurement, of executive function has had its challenges. This can be explained in part by there being much debate about the validity of specific measures in being able to capture the full range of abilities which fall under this domain (i.e., being able to successfully ‘fractionate’ the executive system). While various studies have aimed to assess executive functioning in patients with schizophrenia, many of these studies have appeared to examine only a unitary concept of the construct using a limited
number of assessment measures (for review, see Green, 1996; Green et al., 2000). Therefore, many studies have failed to directly address the fractionation of the executive function system in schizophrenia and hence, it is possible that performance on selected measures may not adequately reflect the range of processes that fall within the construct that is termed ‘executive function’. It is thought that the more successful fractionation of the executive functions is largely dependent on the ability to develop specific theoretical models of this neurocognitive system (Baddeley, 1998; Burgess et al., 1998; Shallice & Burgess, 1991). While there is a long history of various models conceptualising the construct of executive function in the neurocognitive literature, for the purposes of this study one specific model (chosen on the basis of its comprehensive features), will be discussed in detail.

Models of executive function. Developing a good understanding of the specific mechanisms and components of executive functioning has unfolded over various approaches. The conceptualisations, definitions and models of executive functioning subscribe to various research findings arising from neuroanatomical, neurophysiological and neural circuitry evidence from animal brain-behavioural relationship observations (for overview, see Goldman-Rakic, 1987), the examination of the relationship between cognitive and behavioural deficits and frontal lobe damage (e.g., Fuster, 1989; Goldman-Rakic, 1996; Luria, 1973; Royall, Lauterbach, Cummings, Reeve, Rummans, Kaufer et al., 2002), as well as theoretical model fit from statistical approaches such as confirmatory factor analysis methods (e.g., Daigneault, Braun, & Whitaker, 1992).

More recently, there has been various theoretical and psychometric approaches that have been developed in an attempt to determine whether executive functioning should be conceptualised as a unitary system or whether it is more adequately described by a model involving multi-processes (Baddeley, 1998; Miyeake, Friedman,
Emerson, Witzky, & Howerton, 2000; Parkin, 1998; Stuss & Alexander, 2000). Increasingly it has become more apparent that executive functioning cannot be considered as a unitary construct as various executive function components have been able to be individualised and while found to be related, are shown to be independent to each other (Chevignard et al., 2008; Duncan, Johnson, Swales, & Freer, 1997; Miyake et al., 2000; Robbins, James, Owen, Sahakian, Lawrence, McInnes, & Rabbit, 1998). Models of executive function which have emerged over the years view the overall system as comprising of individual and distinct subcomponents (Andres, 2003; Baddeley, Della Sala, Robbins, & Baddeley, 1996; Goethals, Audenaert, Van de Wiele, & Dierckx, 2004) which are then conceptualised as being structured either in a hierarchical manner (e.g., Fuster, 1989; West, 1996) or as a distinction between 'hot/cold’ processes (e.g., Damasio, 1995).

**West’s model of executive function.** West’s (1996) model of executive function builds upon a previous hierarchical model originally proposed by Fuster (1989), which incorporates the conceptualisation of superordinate and subordinate functions. According to Fuster’s model, it is postulated that executive functioning involves an overarching or ‘superordinate’ function called the ‘temporal organisation of behaviour’ which is considered to be responsible for the initiation and maintenance of behaviours that have a common goal. This function is conceptualised to be subserved by three subordinate functions. These include provisional memory which involves the recollection of previous experience; prospective memory which is thought to be responsible for the storage and cueing of information that is required to perform a future goal; and interference control which serves to suppress interference or conflicts irrelevant to the task at hand. This model emphasizes the concept of ‘temporal gestalt’, meaning that such functions support the organisation of behaviour over time in
sequence, connecting past actions and future events or goals in conjunction with the integration of information that is task-relevant and the disregard of task-irrelevant information (Fuster, 1989). It is acknowledged that Fuster’s model affords, at least in part, a way of theoretically explaining the executive function system as a hierarchy of cognitive processes. However, considering that many previous studies investigating executive function have also examined the cognitive process of inhibition, Fuster’s model appears to be somewhat lacking. Therefore, additional models of executive function will also be discussed in order to incorporate other executive function domains which appear to not be accounted for in this model alone.

In addition to Fuster’s (1989) conceptualised executive processes, West included a fourth subordinate function to his own model which is termed the inhibition of prepotent responses. West also used the term ‘retrospective memory’ instead of provisional memory. According to West, retrospective memory involves the retrieval and maintenance of information that is task-relevant from its storage in memory. This function has also been conceptualised to be similar to the construct of working memory (Baddeley, Della Sala, Papagno, & Spinnler, 1997). In West’s model, prospective memory is thought to aid in the preparation of an individual for an upcoming action or behavioural response. Interference control serves to manage the intrusion of task-irrelevant information incoming from external sources. Such task-irrelevant information can be incorporated into retrospective memory and, therefore, subsequently interfere with correct task execution if it is not adequately controlled. Finally, the inhibition of prepotent responses is thought to inhibit more dominant, habitual behavioural responses particularly when such responses are not considered to be optimal or appropriate for the present task. It is acknowledged that West’s (1996) model encompasses a much broader range of cognitive functions than other models of ‘executive functions’. However, as
previously mentioned Lezak et al. (2004) describes the structure of the frontal lobe as being associated with not only higher-order cognitive functions, but also the facilitation of memory functions and retrieval strategies. In addition, Fuster (2000) considers that it would be erroneous to localise various executive functions to the prefrontal cortex alone and that only part of the networks involved in memory abilities can be localised to this region. Both retrospective memory and prospective memory abilities are described to complement each other at the service of frontal executive function playing the critical role in the mediation of contingencies of action across time.

There have been a number of different measures designed and utilized to capture the different components highlighted in this model. The following section discusses an approach in the measurement of each of these domains guided by West’s (1996) theoretical model of executive function, as well as a comprehensive investigation in evaluating the validity of the theoretical constructs involved.

Num (2006) evaluated the construct validity of a hierarchical model of the executive functions proposed by West (1996). In the study, participants were administered a battery of neurocognitive tests individually selected based on the theoretical concepts of the individual processes outlined in West’s model. The study utilised the Zoo Map task from the Behavioural Assessment of the Dysexecutive Syndrome test battery (BADS; Wilson, Alderman, Burgess, Emslie, & Evans, 1996), a modified version of the Self-Ordered Pointing Task (Bryan & Luszcz, 2001), and the Modified Six Elements task also from the BADS, in order to assess the construct of the temporal organisation of behaviour. Retrospective memory was assessed using memory for items from the Zoo Map task, recall of items from the Self-Ordered Pointing Task, and a measure of working memory called the Reading Span test (Daneman & Carpenter, 1980). Prospective memory was assessed using both event-based and time-based tasks.
which have been used in previous research aimed to measure this particular cognitive construct (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997; Smith & Bayen, 2005). Interference control was assessed using the Symbol Search subtest of the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997), and the Letter Cancellation test (Diller, Ben-Yishay, Gerstman, Goodkin, Gordon, & Weinberg, 1974). The inhibition of prepotent responses was measured using the Stroop test (Dodrill, 1978), a modified version of the Rule Shift card test from the BADS, and the Trail Making Test from the Delis-Kaplan Executive Function System test battery (D-KEFS; Delis, Kaplan, & Kramer, 2001).

Results of the study demonstrated that measures of the temporal organisation of behaviour, retrospective memory, prospective memory, interference control and the inhibition of prepotent responses significantly correlated within each of the constructs tested. However, it was also found that only retrospective memory performance predicted temporal organisation of behaviour performance after controlling for the effects of fluid intelligence. Through factor analysis these measures were compared in order to determine whether the pattern of results served to support West’s hierarchical model of executive function. Overall, results of the study suggested that ‘executive functions’ operate as a group of individual, though related, functions. It was also found that performance on these functions were found to be independent of performance on a measure of fluid intelligence, suggesting that such functions were distinct from general intellectual ability. Findings of the study were in support of West’s (1996) theoretical hierarchical model of executive function. These findings are particularly relevant to the current study as previous research investigating the executive functioning of schizophrenia patients with cannabis use appear to fall short of examining the range of abilities that have been considered to be reflective of the executive function construct as
a whole. It should be noted that this particular testing protocol has also yet to be utilised among clinical samples.

*Damasio’s somatic marker hypothesis.* Taking a different perspective, Damasio’s ‘somatic marker hypothesis’ model (Damasio, 1995; Damasio, Everitt, & Bishop, 1996; Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994) conceptualises the role of frontal lobe functions in emotion and interpersonal behaviour, specifically in relation to reasoning and decision-making. It was considered by Damasio that emotion is mediated by the prefrontal regions, via the complex links found between the cortical (which involve the ventromedial cortex) and subcortical (which involve the mediodorsal nucleus of the thalamus, the amygdala, and the hypothalamus) linkages. This model considers and emphasizes the ‘hot’ or emotional-related component of executive function and its associated relationship with ‘cold’ or more mechanistic cognitive components of executive function with regard to decision-making processes and the development and/or maintenance of social relationships. Damasio (1995) developed the model to help explain impairments such as dramatic personality change, emotional and interpersonal problems which are commonly seen after VPFC damage in patients. It is thought that individuals with damage to the VPFC experience difficulties in behaviour regulation due a reduced ability to utilise emotion-related somatic signals which are used to ‘mark’ inappropriate behaviours. Therefore, considering the conceptualised relationship between the prefrontal cortex and executive function, Damasio’s model provides further insight into the construct of executive function and its potential subcomponents.

The Iowa Gambling Task (IGT) was developed by Damasio and his colleagues in order to test the somatic marker hypothesis (Bechara et al., 1994; Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Tranel, & Damasio, 2000; Bechara, Tranel,
Studies have shown the IGT to demonstrate sound sensitivity in individuals with VPFC lesions. Previous research has also utilised the IGT in the examination of cognitive function related to the frontal regions in cannabis users, schizophrenia patients, as well as schizophrenia patients who also abuse cannabis (Mata et al., 2008; Sevy et al., 2007; Shurman et al., 2005; Whitlow et al., 2004). However, studies have reported that performance on ‘traditional’ measures of executive function, such as the WCST, is poorly correlated with performance on the IGT (Ritter, Meador-Woodruff, & Dalack, 2004; Wilder, Weinberger, & Goldberg, 1998). These findings therefore suggest that the IGT is more sensitive in tapping into other components of executive function which have yet to be adequately measured by more traditional tests of executive function, and fails to be addressed through West’s (1996) model alone.

The Validity of Tests of Executive Function

One of the difficulties in the neuropsychological examination of executive functioning (and its potential in determining corresponding rehabilitation regimes) lies in the ability of traditional psychometric tests in providing a true and accurate assessment of the executive functions per se (i.e., whether such tests are really measuring what they claim to measure), as well as whether performance on such measures relates to performance in the real world. In other words, the question is whether commonly used psychometric measures of executive function are ‘ecologically valid’. Although meta-analytic results have shown that performance on neurocognitive tests have the ability to predict everyday functioning on a relatively global scale, more often than not, the typical standardised neuropsychological tests used to conduct such assessments are selected on the basis of their ability to detect pathology (Green et al., 2000). Therefore, it is plausible that such measures may not truly capture the essence of the demands and routines involved in everyday life. Wilson and colleagues (1997)
emphasised that some clinical patients who exhibit deficits in day-to-day functioning can also demonstrate normal performance on executive functioning tests. Accordingly, it seems reasonable that the evaluation of the ecological validity of executive functioning tests as an empirical research target has specific clinical relevance to the schizophrenia population.

Many common neuropsychological test approaches involve presenting the subject with a single explicit task at any one time, relatively short task trials, prompts or instructions by the examiner regarding when to initiate behaviour, and some type of indication of the intended/expected successful outcome (Shallice & Burgess, 1991). However, through the process of administering a set of standard instructions and scoring systems in such approaches, it is reasonable to consider that these approaches may not adequately correspond to the naturalistic demands involved in everyday life. The use of quantitative approaches in research is mainly thought to capture an individual’s performance at either the pathological or impairment level, but fails to tap into more clinical concerns such as functional everyday life deficits (Whyte, Polanski, Cavallucci, Fleming, Lhulier, & Coslet, 1996). It is considered that much of the discrepancy between cognitive performances demonstrated in formal testing and real-world situations could possibly be explained by the notion that such testing contexts provide a structured and often well-controlled environmental setting for the examinee (Chaytor & Schmitter-Edgecombe, 2003; Lezak et al., 2004; Manchester, Priestley, & Jackson, 2004, Shallice & Burgess, 1991; Whyte et al., 1996). Due to these characteristics, many traditional tests of executive function are said to lack ecological validity (Acker, 1990; Cripe, 1996), and consequently may fail to sufficiently assess the complex interplay of behaviours that are involved in ‘real-world’ living.
A general limitation involved in standardised test procedures is that such experimental contexts strongly prompt the participant toward exhibiting certain behaviours. It is therefore plausible that situations that require behaviours such initiative or volition may not be able to adequately be assessed and represented by such measures. This notion is particularly relevant to the assessment of executive functioning, which can be conceptualised as reflecting not solely what an individual does, but how they do it as well as whether or not the individual exhibits the behaviour in the first place (Lezak et al., 2004). It is thought that measures sensitive to executive dysfunction should involve those contexts which are ill-structured and capture strategic planning, and retrospective memory and prospective memory abilities, particularly when considering the relationship between performance on such measures and performance in daily living (Burgess, Veitch, de Lacy Costello, & Shallice, 2000; Fortin, Godbout, & Braun, 2003; Godbout, Grenier, Braun, & Gagnon, 2005; Goel et al., 1997). Due to the structured and standardised nature of many traditional executive function tests, it is argued that such measures may not be adequate in their sensitivity to detect true executive deficits, such as the ability to deal with multi-task demands that are required for day-to-day functioning (Burgess, 2000; Shallice & Burgess, 1991).

‘Traditional’ tests of executive function. Typical measures which have been deemed to assess executive abilities are usually those which have been found to be related and sensitive to dysfunction of the frontal lobe. Examples of such measures include the WCST (Milner, 1963). Deficits have also been shown on other widely used measures of executive functioning such as the TMT (Reitan, 1958), verbal fluency (Allen, Liddle & Frith, 1993; Benton, 1968), and the Stroop test (MacLeod, 1991; Stroop, 1935). However, it is considered that the construct validity of many traditional tests of executive function, such as the WCST, verbal fluency, the Tower of Hanoi, and
the TMT, is not well established despite their extensive use in neuropsychological
assessment (Kafer & Hunter, 1997; Phillips, 1997; Rabbit, 1997). In the schizophrenia
literature, the WCST is the single most commonly applied measure in the investigation
of executive functioning (Reicheberg & Harvey, 2007). However, despite its
widespread use not all schizophrenia patients have been found to demonstrate deficits in
WCST performance (Braff et al., 1991; Goldstein, 1990; Goldstein, Beers &
Shemansky, 1996). Reports of normal performances in schizophrenia patients on the
WCST further suggests that the construct of executive function is not only complex, but
comprises a range of different components. Therefore, the ability of psychometric
measures to fractionate the executive functions seems crucial in order to be more
sensitive to individual variation in executive functioning performance. Considering the
importance of executive functions in schizophrenia, previous research has failed to
employ a range of neurocognitive measures aimed at tapping into the various
subcomponents theorized to be involved in the construct of executive function. It also
appears that the construction of many commonly used measures of executive function
has been fundamentally atheoretical in nature. The selection of such tests which are
hypothesised to assess this neurocognitive domain more often than not, rely on their
apparent face validity which is largely subjectively based (Salthouse, Atkinson, &
Berish, 2003). New research in this area should endeavour to take into account this issue
as an important methodological consideration when assessing a neurocognitive domain
that is as complex and multi-faceted as executive function.

However, there are some more theoretically-driven psychometric measures that
exist which have been specifically developed in order to attempt to tap into the
processes conceptualised be involved in executive function and validated to assess their
reliability in the detection of executive dysfunction. Such tests include the Tower of
London test (Shallice, 1982), the Cognitive Estimates Test (Shallice & Evans, 1978), and the Self-Ordered Pointing Task (Petrides & Milner, 1982; Bryan & Luszcz, 2001). However, establishing the construct validity of such tests has not been without difficulty. For example, Kafer and Hunter (1997) utilised a structural equation modelling approach in order to evaluate the relationship among four tests conceptualised to measure planning/problem-solving abilities (i.e., the Tower of London test, the Six Element Test, the Twenty Questions Test, and the Rey Complex Figure Test) and the latent construct of planning/problem-solving. Findings indicated that an adequate statistical model was not able to be estimated in their analyses. Such results therefore served to question the construct of planning/problem-solving, as well as problems were specifically identified with the psychometric structure of the Tower of London test. O’Carroll, Egan and MacKenzie (1994) conducted a study in order to provide normative data for the Cognitive Estimates Test from a representative sample of the general population. A Principal Component Analysis resulted in a five-factor solution, suggesting that the test does not measure a single factor. In addition, while the test demonstrated adequate inter-rater reliability, it was also found to have poor internal reliability. From the results obtained, the investigators concluded that the Cognitive Estimates Test is psychometrically unsatisfactory. Issues in establishing the validity of measures has also been the case where various classic tests of executive function (e.g., WCST, COWAT/phonemic verbal fluency, and the Stroop test), have shown sensitivity to frontal lobe lesions, but fail to demonstrate specificity to frontal lobe pathology alone (Alvarez & Emory, 2006).

Despite the importance of the various theoretical models of executive function, it was not until approximately the last two decades that specific constructs were incorporated into the development of clinical and experimental assessments of executive
functions. For example, the Behavioural Assessment of the Dysexecutive Syndrome (BADS) is an executive function test battery that is specifically designed to assess the everyday deficits in executive functioning among clinical groups (Wilson, Alderman, Burgess, Emslie, & Evans, 1996) and was developed as a modification of the Six Elements Test and Multiple Errands Test (Shallice & Burgess, 1991). It consists of six subtests aimed at measuring different facets of executive functioning such as initiation and task implementation, as well as planning and cognitive flexibility. However, this test battery as a whole has been limited in its use when assessing schizophrenia patients (Evans, Chua, McKenna, & Wilson, 1997; Katz et al., 2007; Krabbendam, de Vugt, Derix, & Jolles, 1999). Findings from Katz and colleagues’ (2007) study confirmed the ecological validity of the BADS test battery in its sensitivity and predictive validity in determining ‘real-world’ functioning in individuals with schizophrenia.

Another major difficulty related to the assessment of the executive functions lies in the ability for performance on one particular test of executive function in not only having predictive value in performance on another test of executive function, but also in coping and performance in the functional domains of ‘real world’ contexts (Burgess, 1997; Burgess et al., 1998). Due to this issue, reduced performance on executive function tests may be due to many different reasons and could be independent of actual executive dysfunction. It is also possible that individuals may demonstrate adequate performance on such measures and still experience significant difficulties in their ability to navigate the complex demands of day-to-day life activities (Shallice & Burgess, 1991). Therefore, incorporating more ‘real-world’ characteristics into specific assessment measures has been considered imperative when attempting to make progress in this area (Schwartz, Reed, Montgomery, Palmer, & Mayer, 1991; Shallice & Burgess, 1991). Particular assessment methods have been developed to attempt to achieve this
such as in the Modified Six Elements test from the BADS test battery (MSE; Evans et al., 1997; Wilson, Alderman, Burgess, Emslie, & Evans, 1996). The MSE aims to assess planning abilities by allowing subjects to complete several tasks and navigate their work according to their own self-driven plan, as well as a set of prescribed rules. This test has been shown to demonstrate superior ecological validity, as well as sensitivity, in comparison to other subtests in schizophrenia patients (Evans et al., 1997). There appears to be many factors to take into account when considering the more precise and effective measurement of specific cognitive domains, particularly in the case of those conceptualised to be multi-faceted and fractionable in nature, such as executive function.

**Assessing Functional Outcome**

A number of methods have also been employed to assess functional outcome status. In order to achieve a more ecological approximation in the measurement of executive functions, several approaches have been taken such as the use of questionnaires (Bennett, Ong, & Ponsford, 2005; Broadbent, Cooper, Fitzgerald, & Parkes, 1982; Burgess, Alderman, Wilson, Evans, & Emslie, 1996), or through laboratory tasks approximating real-life situations, such as those tasks used in the BADS (Evans et al., 1997; Katz et al., 2007; Krabbendam et al., 1999; Wilson et al., 1996; 1998). Other means involve observing and assessing the behaviours demonstrated by patients in daily activity simulations (Knight, Titov, & Crawford, 2006; Zalla, Plassiart, Pillon, Grafman, & Sirigu, 2001; Zhang, Abreu, Seale, Masel, Christiansen, & Ottenbacher, 2003). In a study by Rempfer, Hamera, Brown and Cromwell (2003), the relationship between performance on various cognitive tests and performance on a functional outcome measure, namely the Test of Grocery Shopping Skills (TGSS), was examined. The TGSS evaluates the performance of shopping skills within the natural
context of a grocery store, with the measure yielding three outcome scores (1) accuracy; (2) redundancy (a measure of shopping efficiency); and (3) time. Associations were found between shopping accuracy and measures from the first two trials of the Stroop test, namely word reading and colour naming. There were also correlations between accuracy and verbal recall on the Rey Auditory Verbal Learning Test (Rey, 1964) and perseverative errors on the WCST. In addition, ‘redundancy’ while shopping was found to be significantly related with poorer performance on three measures of executive functioning (WCST total correct and perseverative errors, verbal fluency/FAS, and performance on the colour-naming and colour-word trials of the Stroop test). Total time on the Letter Cancellation test was also correlated with redundancy. Verbal memory was shown to be associated with both shopping accuracy and redundancy. However, while this investigative approach provides a good demonstration of the ecological validity of certain standardised psychometric tasks, the results of this study were limited specifically to the particular skill of independent living that was simulated (e.g., grocery shopping). Therefore, addressing real-world functioning in a more precise manner by making distinctions amongst the various aspects of social and community living activities are warranted.

Keefe and colleagues (2006) examined the relationship between cognitive performance in schizophrenia with functional capacity and functional outcome. In their study, functional capacity was assessed using the UCSD Performance-based Skills Assessment (UPSA; Patterson, Goldman, McKibbin, Hughes, & Jeste, 2001) and ‘real-world’ functional outcome was measured using the Independent Living Skills Inventory (ILSI; Menditto, Wallace, Liberman, Wal, Jones, & Stuve, 1999). The UPSA requires patients to perform a number of tasks reflective of a range of skills considered important for functioning in the community. Patients are then rated on their performance on these
tasks. The ILSI is a functional assessment tool which also aims to measure an individual’s competence in a broad range of skills considered pertinent for successful autonomous community living. Ratings are made on the basis of an interview with the patient or the reports/observations of care givers. Findings from the study indicated that cognitive performance (as assessed by the Brief Assessment of Cognition in Schizophrenia (BACS); Keefe, Goldberg, Harvey, Gold, Poe, & Coughenour, 2004), was found to be significantly correlated with both functional capacity and real-world functional outcome. Results also suggested that measures of cognition and functional capacity significantly predicted variance in real-world functional outcome. However, only the measures of cognition independently accounted for significant variance in real-world functional outcome, when compared to the contribution of performance-based functional skills. The authors concluded that the latter measure appeared to fail to uniquely contribute to real-world outcomes above and beyond that which was accounted for by the cognitive performance measures. Results of the study are suggestive that performance-based skills assessment may not necessarily have better predictive capacity when considering ‘real-world’ functional outcome in schizophrenia in comparison to the cognitive measures used.

While there are a range of methods in assessing functional outcome, it is acknowledged that such an assessment can be difficult to achieve through observation of real-world performance on activities in a research setting. In addition, the observation of performance on specific daily activities is not only time consuming, but is limited to the assessment of only the activity or task in question. While skill demonstrations and task simulations have their important merits, the number and wide range of daily skills thought to be required in successful community functioning would render such an approach difficult when attempting to make a thorough assessment. Thus, a critical
advantage of the questionnaire method (e.g., the ILSI) is that it permits a more comprehensive assessment of functional outcome across a variety of independent living skill domains while at the same time allowing for a more resource efficient approach as opposed to task simulation methods.

**The Current Study**

It has been widely established that cognitive impairment is a fundamental characteristic of the illness of schizophrenia. In addition, the cognitive domain of executive function is not only considered to be particularly implicated, but is also shown to be significantly related to functional outcome. As cannabis is a commonly used substance of abuse in schizophrenia, but in addition has also been found to contribute to detrimental effects on the illness’ presentation, the examination of the relationship between cannabis use, schizophrenia and neurocognitive performance has clinical significance. There is already substantial evidence comparing schizophrenia patients with non-schizophrenia controls, demonstrating deficits across different executive tasks. Similarly, there is also extensive research demonstrating executive function impairment associated with cannabis use. However, there have been some mixed and surprising findings in relation to the associations between schizophrenia, cannabis use and neurocognition. Contrary to expectation (which has been largely based on the premise of well established cognitive deficits associated with the illness of schizophrenia, as well as cannabis use alone, thus leading to a hypothesis of additive effects), some of the findings that have emerged over the years have suggested that cannabis use in schizophrenia is associated with better neurocognitive performances. Factors related to variability in sample characteristics, neurocognitive assessment protocols, research design, and failure to adequately control for potential confounds have been considered as possible contributors to the inconsistent results.
Many previous studies have employed measures of executive function which are adopted from frontal lobe neuropsychological paradigms based on lesion studies. On the whole, it appears that the majority of schizophrenia research regarding cognition has failed to adopt comprehensive enough theoretical approaches and assessment methodologies in order to adequately tap into the range of executive abilities, and therefore fall short of achieving the successful fractionation of the executive function system. The current study employed the use of several theory-driven selected tests of executive function guided by West's (1996) hierarchical model of executive function. The current study proposes to apply a theoretical model of executive function, in particular West’s model, to examine the executive functioning of schizophrenia patients with a cannabis use history. A verbal fluency and an emotion-based decision-making measure were also included in the present study. Verbal fluency (particular letter verbal fluency) has been shown to be sensitive to frontal dysfunction (for review, see Parker & Crawford, 1992) and deficits on this measure is found to be consistently observed in patients with schizophrenia (Chen et al., 2000, Crawford, Obonsawin, Bremner, 1993, Gruzelier, Seymour, Wilson, Jolley, & Hirsch, 1988). In addition, emotions are known to play a key role in decision-making processes (Bechara et al., 1997). These additional components do not appear to be accounted for in West's model. Therefore, this assessment approach will permit us to examine executive functioning with a range of measures sampling both the conceptualised mechanistic and emotion-related components of executive function.

Considering the inconsistency in the literature regarding the assessment of executive function, it is important to evaluate and further develop the theoretical conceptualisation of this neurocognitive domain that will in turn lead to the better refinement, clarification and successful measurement of the construct. As it has been
shown in previous research that there are executive functioning deficits in individuals with schizophrenia, as well as in individuals who use cannabis, it is important to ascertain whether cannabis use in schizophrenia is associated with poorer executive functioning and hence greater impairment and poorer adjustment in everyday life. While previous studies have examined the relationship between executive function and various aspects of functional outcome in schizophrenia, there appears to be a paucity of a comprehensive examination of the link between performance on tests of executive function and functional outcome measures amongst the schizophrenia with cannabis use population.

In the first part of the present study, the aim was to identify the relative differences in executive functioning associated with cannabis use in schizophrenia compared to those which are associated with cannabis use alone. Exploring the pattern of executive functioning in schizophrenia patients with cannabis use and non-schizophrenia controls with a similar cannabis use history will help to tease out such differences. Since performance on executive function tests is rarely evaluated for its 'real-world' significance, in the second part of the study another aim was to examine the relationship between performance on the tests selected in the current research and ratings on a measure of ‘real-world’ functional outcome. This will enable not only the comprehensive evaluation of executive functioning in schizophrenia patients with a cannabis-use history, but also allow for the examination of whether performance on a range of tests of executive function serve as effective predictors of performance in specific ‘real-world’ functional outcome domains. This in turn, will permit an evaluation of whether such executive function measures are 'ecologically valid' (i.e., reflective of 'real world' abilities and adjustment). The assessment of this clinical population with ecologically valid measures may therefore help to better inform and
guide future treatment planning. This may be achieved by being able to more precisely identify the various executive functioning components thought to more closely relate to the specific functional skills that are required for successful independent living. From the results of the study, it is hoped that through the neurocognitive sub-typing of individuals with schizophrenia who use cannabis, specific cognitive rehabilitation and/or behavioural strategies can be better directed and consequently help to assist in the prediction of those who are more likely to successfully respond to such intervention.

**Hypotheses.** The aims of the current study will thus be achieved by dividing the study into two parts. Part A of the study specifically aimed to examine the relative differences in executive functioning associated with cannabis use in schizophrenia patients, in comparison to individuals with no psychiatric or mental illness diagnoses with a similar pattern of cannabis use. It was predicted that schizophrenia patients with cannabis use will demonstrate poorer performance in constructs of executive functioning, compared to healthy controls with a similar cannabis use history. Further, performances falling greater than 1.0 standard deviation below normative mean criteria will be described in schizophrenia patients with cannabis use, compared to controls. In addition, it was hypothesised that the discontinuation or abstinence from cannabis use will be associated with the recovery of executive function (i.e., ‘non-current users’ will demonstrate significantly better performance on executive function measures than ‘current’ users). It was also predicted that former users who have ceased their cannabis use for a longer period of time will have significantly better executive function performance, in comparison to those individuals who have ceased cannabis use for a shorter period of time.

Part B of the study aimed to further our understanding of the functional outcome correlates associated with the executive functioning of schizophrenia patients
with cannabis use, relative to matched-control subjects with a similar cannabis use history. The investigation into the relationship between the executive function components belonging to West’s (1996) model and functional outcome is exploratory in nature. However, due to reports of a significant association between executive function and functional outcome in the literature, it is predicted that executive function scores will have a significant relationship with functional outcome ratings. More specifically, it was hypothesised that executive function scores will have significant predictive ability in relation to functional outcome ratings.

Method

Participants

Participants included in the current study were aged between 18 and 55 years. Schizophrenia patients were recruited as outpatients from public mental health services in South Australia. Clinical participants were eligible for the study if they had a current diagnosis of schizophrenia according to the DSM-IV (American Psychiatric Association, 2004), which was verified by the patient’s clinical file information upon their consent. Control subjects were eligible for the study if they did not have any current psychotic, anxiety, or mood disorder diagnoses. While this was based on the self-report of the healthy control group, subjects were also screened for elevated and clinically significant levels of depression, anxiety and stress symptoms (see below for further detail regarding the determination of the presence of group differences in depression, anxiety and stress symptoms). An overall sample of 76 was recruited for the study. However, data from 4 participants in the schizophrenia group were excluded from the study due to these individuals not having a reported cannabis use history. Due to the total sample size of this subgroup being too low, the maintenance of these cases
in the final data set was considered insufficient for meaningful between-subject statistical analyses to be conducted. Data from an additional participant from the schizophrenia patient group who did however have a reported history of cannabis use, was also excluded due to the participant not being able to complete the full neurocognitive battery. It was observed by the researcher that the participant demonstrated significant difficulty in being able to understand the instructions of the psychometric measures and was therefore assessed to be ineligible for the continuation of testing. Data from two schizophrenia patients with cannabis use were also excluded from the study, due to these participants not being able to be adequately matched to a corresponding control subject on the matched variables. In addition, data from 13 otherwise healthy control subjects with cannabis use were also excluded from the study, due to these participants not being able to be adequately matched to a corresponding schizophrenia patient on the matched variables. The final sample included 28 individuals with schizophrenia (both former and current users) who had a regular cannabis use history and 28 matched-controls (both former and current users) with a similar cannabis use history. The process of recruiting matched controls involved finding a suitable matched pair for an already recruited patient subject. Premorbid IQ was matched with a suitable pair within +/- .05 standard deviation (SD) of the schizophrenia patient’s score. The age, years of education, severity/quantity, duration, and time since cessation variables were matched with a suitable pair in the control groups within +/- 1.0 SD of the schizophrenia patient’s score. The frequency variable was matched with a suitable pair according to frequency group category (i.e., light users ≤ 2 times per week; heavy users ≥ 3 times per week). Gender was equally matched between groups. While the +/- 1.0 SD matching criteria was acknowledged to be much less conservative than a +/- 0.5 SD matching criteria, it was considering necessary due
to the large variability found in such variables and consequently attempting to match within +/- 0.5 SD would have made the process increasingly more difficult considering the timeframes and resources available. However, independent sample t-tests indicated that no significant differences were found between groups on the cannabis use parameters (all p’s > .05), suggesting that the two groups were well matched on all of these indicators of cannabis use. Participants were considered to be regular cannabis users if they used cannabis for more than 2 years duration, with a frequency of use of one or more days per week. Further, 34 participants (17 schizophrenia patients and 17 matched-controls) who reported regular cannabis use in their history, were currently abstinent at the time of testing. In addition, 22 participants (11 schizophrenia patients and 11 matched-controls) who reported to be regular users of cannabis were current users at the time of testing. All participants were required to provide written informed consent, as well as have the physical capacity to participate in cognitive assessment.

Participants with ages falling outside the range of 18 to 55 years, who had any other mental illness diagnoses (other than schizophrenia for the patient group only), a medical history of head or brain injury, a history of neurological disorder, or an intellectual or developmental disability, were excluded from the study. Subjects who regularly used other drugs of dependence or had a history of alcohol abuse/dependence were also excluded from the study. This criteria was assessed in a structured interview (see Appendix A) via self-report. Participants were required to abstain from cannabis use for at least 24 hours prior to testing (if still a current user), as well as abstain from the consumption of caffeine and nicotine use within 1 hour of testing. Adherence to the 24-hour and 1-hour abstinence period was assessed using self-report. Participants were also required to be proficient in understanding and speaking the English language. All
participants were given a $25 Coles-Myer voucher as a token of appreciation for their participation in the study.

The sociodemographic characteristics of the two groups are detailed in Table 1. Independent sample t-tests indicated that no significant differences were found between groups on the sociodemographic variables (all p’s > .05), suggesting that the groups were well matched on all of these characteristics. No significant difference was found between groups in nicotine use (p > .05). The groups also did not significantly differ on self-reported depression, anxiety or stress symptoms (as measured by the Depression Anxiety Stress Scales (DASS); S. H. Lovibond & P. H. Lovibond, 1995) (all p’s > .05). It was noted that the between group differences in reported anxiety symptoms approached significance (p = .052). However, the mean ratings for the schizophrenia group fell in the moderate range for depressive and anxious symptomatology and in the mild range for stress symptomatology. Mean ratings for the matched-controls group fell in the mild range for depressive, anxious and stress symptomatology. A chi-square test for goodness of fit examining symptom categories (as assessed by the the Structured Clinical Interview for the Positive and Negative Syndrome Scale (SCI-PANSS); Kay, Fiszbein & Opler, 1987) indicated that there was no significant difference in the proportion of schizophrenia patients with cannabis use, falling in either the positive symptom subtype or negative symptom subtype category, $\chi^2(1, N = 27) = .333$, p = .564, $w = .111$. All but one schizophrenia patient were taking antipsychotic medications. Four patients were taking typical antipsychotics, 16 were taking atypical antipsychotics, 7 were on combined therapy (i.e., taking both typical and atypical antipsychotic medications), and 1 patient was currently not taking any medication.
Table 1. Sociodemographic characteristics of the sample

<table>
<thead>
<tr>
<th></th>
<th>Total (N=56)</th>
<th>Schizophrenia Patients (n=28)</th>
<th>Matched Controls (n=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Age</td>
<td>34.50 (7.20)</td>
<td>34.57 (7.71)</td>
<td>23-51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>34.43 (6.78)</td>
<td>25-49</td>
</tr>
<tr>
<td>Male:Female</td>
<td>38:18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years of Education</td>
<td>11.83 (1.77)</td>
<td>11.77 (2.05)</td>
<td>8.0-16.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.89 (1.47)</td>
<td>9.0-14.0</td>
</tr>
<tr>
<td>Estimated Premorbid IQ</td>
<td>99.09 (6.17)</td>
<td>98.75 (7.02)</td>
<td>82-108</td>
</tr>
<tr>
<td>Nicotine Use Frequency</td>
<td>11.21 (10.76)</td>
<td>13.50 (13.16)</td>
<td>0-40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.93 (7.19)</td>
<td>0-25</td>
</tr>
<tr>
<td></td>
<td>5.43 (2.08)</td>
<td>5.61 (2.15)</td>
<td>1.0-7.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.25 (2.03)</td>
<td>1.0-7.0</td>
</tr>
<tr>
<td>Severity (grams)</td>
<td>1.42 (1.03)</td>
<td>1.44 (1.21)</td>
<td>.25-5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.39 (.82)</td>
<td>.25-4.0</td>
</tr>
<tr>
<td>Duration (years)</td>
<td>13.14 (8.85)</td>
<td>13.57 (10.04)</td>
<td>2.0-38.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.71 (7.64)</td>
<td>3.0-33.0</td>
</tr>
<tr>
<td>Time Since Cessation (years)</td>
<td>3.63 (5.40)</td>
<td>3.71 (5.74)</td>
<td>.00-28.0</td>
</tr>
<tr>
<td>DASS</td>
<td></td>
<td>3.55 (5.14)</td>
<td>.00-25.0</td>
</tr>
<tr>
<td>Depression</td>
<td>13.18 (11.23)</td>
<td>16.00 (13.84)</td>
<td>0-42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.36 (6.99)</td>
<td>0-20</td>
</tr>
<tr>
<td>Anxiety</td>
<td>9.98 (7.80)</td>
<td>12.00 (9.36)</td>
<td>1-30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.96 (5.27)</td>
<td>0-14</td>
</tr>
<tr>
<td>Stress</td>
<td>12.88 (8.57)</td>
<td>14.21 (10.02)</td>
<td>0-34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.54 (6.74)</td>
<td>0-24</td>
</tr>
<tr>
<td>PANSS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>18.25 (6.97)</td>
<td>18.79 (5.71)</td>
<td>7-36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.33</td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>39.18 (12.07)</td>
<td>-54 (4.84)</td>
<td>16-69</td>
</tr>
<tr>
<td>General</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recruitment

Advertisements (see Appendix B: (i) and (ii)) were distributed to the Royal Adelaide Hospital, the Queen Elizabeth Hospital, Lyell McEwin Hospital Service, Flinders Medical Centre, various local public mental health service locations (Port Adelaide Mental Health Service, Beaufort Clinic, Southern Mental Health Service, Adaire Clinic), a community-based mental health organisation (The Mental Illness Fellowship of South Australia), mental health community centres and supported residential facilities, requesting for patient volunteers willing to participate in the current research study. The contact details of the researcher were provided for any prospective patient participants to contact in order to express their interest. The advertisement also informed potential participants that a form could alternatively be completed and posted at the reception desk (found in each location) in order for the
participant to leave their contact details should they wish to be contacted by the researcher instead. An information sheet about the study (see Appendix C) was then provided through reception, upon request. In addition, the researcher attended the local clinics on an arranged basis in order to be available to talk to individuals who were interested in participating in the study.

Advertisements (see Appendix D) were also posted in various locations in the local community (e.g., shopping/public community centre notice boards) requesting for otherwise healthy control volunteers willing to participate in the research study. Potential control subjects were initially screened using a telephone interview gathering demographic details and information pertaining to patterns of cannabis use. Once individuals were deemed eligible for inclusion in the study, an appointment time was scheduled to attend a testing location in order to be assessed and an information sheet (see Appendix E) was then sent out to the participant via post.

The current study employed a matched-control design to ensure that any individual differences occurring between groups (outside of the variables of interest), were controlled for. Due to the variation in indices of cannabis use (i.e., frequency, severity/quantity, duration and time since last use), the interpretation of results based on comparisons between groups is made more difficult. Therefore, the current study aimed to take these indices into account when matching control subjects. Control subjects were matched with schizophrenia subjects based on age, gender, years of education, estimated premorbid IQ, frequency of cannabis use, severity of cannabis use, duration of cannabis use and time since cannabis use cessation.

Measures

Demographics. The demographic information gathered included age, gender, years of education, medical history (e.g., head/brain injury, neurological conditions,
stroke, cardiac problems etc.), medication, frequency, severity/quantity, duration of cannabis use, time since cessation (if relevant), as well as other types of drugs used and their patterns of use. Average days of use per week, average grams consumed per using-day (where 1 joint was estimated to be .5 grams (Zeisser et al., 2011); and 1 cone was estimated to be .25 grams), years of use, and years since last use were determined as measures of frequency, severity/quantity, duration and time since cessation, respectively. This was assessed through the structured interview conducted prior to neurocognitive testing. This information was also gathered to assess the exclusion criteria.

**Clinical symptoms.** To assess the positive and negative symptom profile of the schizophrenia group, the Structured Clinical Interview for the Positive and Negative Syndrome Scale (SCI-PANSS) was administered. The SCI-PANSS was used to evaluate the presence and severity of positive, negative and general symptoms of schizophrenia. Thirty items were rated on a 7-point scale from 1 = absent to 7 = extreme and total scores were then calculated for the positive, negative and general symptom areas. High internal reliability \( r = .73 - .83 \) (Kay et al., 1987; Kay, Opler, & Lindenmayer, 1988) is reported across each scale of the instrument.

To assess whether there were any significant differences between groups in affective state the Depression Anxiety Stress Scales (DASS; S. H. Lovibond & P. F. Lovibond, 1995) was administered. The DASS is divided into 3 scales (constituting 14-items each) which correspond to the syndromes of depression, anxiety and stress. Each syndrome has been found to be correlated, but distinct from each other (P. F. Lovibond & S. H. Lovibond, 1995; S. H. Lovibond & P. F. Lovibond, 1995). Subjects were asked to indicate the presence of symptoms occurring over the past week only, with responses to the items based on a 4-point severity/frequency scale, ranging from ‘did not apply to
me at all’ (0) to ‘applied to me very much, or most of the time’ (3). The DASS has been reported to have internal reliability coefficients of $r = .87 - .95$.

**Neuropsychometric battery.** Standardised measures of estimated premorbid intelligence and executive function were chosen from the Behavioural Assessment of the Dysexecutive Syndrome (BADS; Wilson et al., 1996), the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001), the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997), and also included tests modified or developed by previous researchers (e.g., Num, 2006). Considering a number of tests used in the current study originate from well validated test batteries, the validity of the batteries themselves will be discussed first. Individual test information will then be further discussed in the sections following.

The main purpose of the BADS battery was to predict the presence and severity of everyday executive problems amongst brain injured groups. The technical manual reports correlations (using Pearson’s method), between the BADS profile score, each of the six individual subtests, age, the National Adult Reading Test - Second Edition (NART-II; Nelson & Willison, 1991), and WAIS FSIQ, with others’ and self-ratings on the Dysexecutive Questionnaire (DEX) for a brain injured patient group. The degree of insight, which is measured by the discrepancy between others’ and self-ratings is also reported. Significant moderate negative correlations between each of the six individual subtests and others’ ratings of executive problems were found. The negative correlations indicate that satisfactory performance on any subtest in the BADS is indicative of low ratings by significant others who know the patient well regarding the presence or severity of executive problems, demonstrating the construct and predictive validity of the BADS tests in detecting every day executive problems. Katz and colleagues (2007) examined the construct validity and sensitivity of the BADS in differentiating between
different types of schizophrenia patients. The predictive validity of the BADS with regard to functional outcomes within the outpatient group was also examined. Performances were compared between adult schizophrenic inpatients who were in an acute episode of the illness, adult schizophrenic outpatients who were in the more chronic stages of the illness, and healthy control subjects. Results of the study showed not only significant differences between schizophrenia patients and control subjects, but also between both of the schizophrenic patient groups such that patients in the outpatient (chronic) group demonstrated greater executive function deficits. It was also found that within the outpatient group that performance on the BADS significantly predicted Independent Activities of Daily Living (IADLs) and communication outcome areas. These results were demonstrated to be beyond that which was accounted for by a measure of basic cognitive skills. Not only do the results of the study show the BADS to be a valid measure in the assessment of executive function of individuals with schizophrenia by distinguishing between patients and healthy subjects, but in addition distinguishing between patients with differing illness phases.

The technical manual for the D-KEFS (Delis et al., 2001) reports evidence for the validity of the D-KEFS measures. The range of tests included in the current study (see below for further discussion of specific tests used) are those which were either developed by the test authors or modified versions of well-established, standardised executive function measures. The modified D-KEFS instruments (i.e., versions of the Stroop test, Trail Making Test, verbal and design fluency tests, Tower Task, the Twenty-Questions test, and proverb interpretation) have demonstrated validity evidenced across a number of neuropsychological studies spanning over 50 years. Reviews of these studies are reported in Lezak (1995, cited in Delis et al., 2001, p. 47) and Spreen and Strauss (1998, cited in Delis et al., 2001, p. 47). Validity studies have
also indicated that various D-KEFS measures have reasonable sensitivity in the assessment of executive functioning of different clinical populations which include patients with focal frontal-lobe lesions (Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001; Delis, Squire, Bihrlie, & Massman, 1992; Dimitrov, Phipps, Zahn, & Grafman, 1999), as well as schizophrenia (Beatty, Jocic, Monson, & Katzung, 1994; Savla, Twamley, Thompson, Delis, Jeste, & Palmer, 2011). The current study only selected those tests from the D-KEFS that were modifications of pre-existing, long-standing clinical tests with proven validity.

The WAIS-III is a popular and widely used scale of intellectual ability. In a study conducted by Dickinson, Iannone and Gold (2002), exploratory and confirmatory analyses revealed that a four-factor model of WAIS-III performance (which was similar to that reported by the developers of the scale), adequately fit data from a sample of schizophrenia patients. In fact, the factor structure suggested by the developers (i.e., with correlated factors for verbal comprehension, perceptual organisation, working memory, and processing speed) fit the clinical sample just as well as it did for the comparison sample of non-clinical subjects. These results suggest the construct validity of the scale and its subtests in the assessment of individuals with schizophrenia.

The test selections in the current study were guided by West’s (1996) model of executive functioning and were also similar measures to those used in Num’s (2006) study. A total of 12 tests were administered, including a measure of estimated premorbid intelligence and 11 measures of executive functioning. All of the tests were in paper-and-pencil format, with some verbal responses recorded on a tape recorder, and time recorded using a stopwatch. All scores from the standardised tests used were converted to standard scores based on norms which were reported in each test manual.
**Premorbid intelligence.** The National Adult Reading Test - Second Edition, (NART-II; Nelson & Willison, 1991), was administered to assess estimated premorbid intelligence and to determine if any differences in premorbid general cognitive ability existed between groups. The NART-II consists of a list of 50 irregularly spelt words in the English language. In this test, the reader is required to ‘know’ the word, rather than rely on phonology in order to be able to read it correctly (e.g., ‘topiary’). Scores represent the number of correct responses, with higher scores representing higher estimated premorbid intelligence. The NART test manual reports a test-retest reliability of $r = .98$.

Crawford and colleagues (1992) aimed to determine whether the National Adult Reading Test would provide a valid estimate of premorbid intelligence in a sample of schizophrenia patients. The overall sample comprised of a group of patients who resided in long-stay wards and a group of patients residing in the community. Schizophrenia subjects were individually matched with healthy control subjects on the variables of age, sex, and education. Findings from the study indicated that a significant discrepancy was found between the two IQ measures administered, where current WAIS IQ scores were significantly lower than NART-derived estimated premorbid IQ scores. Such results indicated a decline in cognitive functioning was present in the sample. These results are indicative of the NART measure providing a valid measure of estimated premorbid IQ in a schizophrenia sample. O’Carrol et al. (1992) also found NART scores estimated significantly higher IQ scores than a current measure of IQ (i.e., the Wechsler Adult Intelligence Scale - Revised (WAIS-R); Wechsler, 1981) in a schizophrenia patient sample. Results of the study were consistent with Crawford et al.’s (1992) findings.
Executive Function

The temporal organisation of behaviour. Two measures of the temporal organisation of behaviour were used: the Zoo Map task from the BADS (Wilson et al., 1996), and the Modified Six Elements test also from the BADS. In the Zoo Map task, participants were required to plan and execute a trip on a map of a zoo visiting various locations which were specified prior to commencing the test. They were also required to follow rules involving using designated paths with which some can be travelled along multiple times and others only once. Other rules in the task required the participant to begin the trip at the entrance and finish at the picnic area. Two trials of the task were administered. The first trial is of high demand (i.e., participants are required to negotiate the trip independently) and the second trial is of low demand (i.e., participants are given directions as to the route required). Scores on this measure reflected overall planning time (i.e., the time that has elapsed between the participant finishing reading the instructions and when they began the trial), the total time to complete the trial itself, the number of places correctly visited and number of rules correctly adhered to. A profile score was then calculated reflecting the extent to which participants followed the correct path sequence minus error deductions, with a low profile score reflecting poor planning and temporal organisation of behaviour. The BADS manual reports the Zoo Map test to have inter-rater reliabilities of $r = .88 – 1.0$ and a test-retest reliability correlation of $r = .39$.

The Modified Six Elements test comprised of six sub-tasks which require the solving of two sets of arithmetic problems, the identification of pictures in two sets of picture booklets, and two verbal tasks involving dictation (e.g., one task describing the best holiday the participant has ever experienced and the second task describing any memorable event in their life). Participants were required to attempt each task within an
allocated 10-minute period and attempt to spend equal amounts of time on each task. However, participants were not allowed to attempt two tasks from the same superset consecutively (e.g., not attempting two arithmetic tasks in a row). If the participant failed to attempt every task within the allocated 10 minutes, if they spent more than 271 seconds on a single task, or if the participant attempted two tasks from the same superset consecutively, then errors were incurred. A profile score was calculated based on the number of tasks completed minus error deductions. A high profile score on this measure reflected higher planning and temporal organisation of behaviour ability. For this test, inter-rater reliabilities of $r = .90 - .97$ and a test-retest reliability of $r = .33$ is reported.

*Retrospective memory.* Retrospective memory was assessed using two measures: memory for items from the Zoo Map task from the BADS (which assessed task-specific retrospective memory), and the Digit Span subtest from the WAIS-III. Measures of task-specific retrospective memory were derived from Num’s (2006) study. For memory for items from the Zoo Map task, participants were required to remember the places they were asked to visit in the original Zoo Map task. Scores ranged from 0 to 7, with higher scores representing higher retrospective memory performance.

In the Digit Span subtest of the WAIS-III, participants were read a series of numbers and were required to repeat them back to the examiner in sequence. The length of the series of numbers was increased until the participant was no longer able to repeat them back to the examiner in correct sequence across two trials. Two forms of digit-spans were presented, one in which the participant was required to repeat the series of numbers forwards and the other in which the participant was required to repeat the series of numbers in reverse order to how they were verbally presented. Each length of number series has two trials, with participants obtaining 1 point if they passed only one.
trial and 2 points if they passed both trials. The maximum score on digits forwards is 16 points and maximum score on digits backwards is 14 points. The sum of digits forwards and backwards gave a total Digit Span score. Higher scores on this measure represented higher retrospective memory performance. The Digit Span subtest has a test-retest reliability correlation of $r = .90$.

**Prospective memory.** For the current study, an event-based prospective memory task was used. This measure was also derived from Num’s (2006) study. In the event-based prospective memory task, participants were informed at the beginning of neurocognitive testing to place a paperclip into a plastic cup at the completion of every second task administered throughout the testing session. Paperclips and the plastic cup were positioned in front of the participant on the table used for test administration. Scores ranged from 0 to 6, with higher scores reflecting higher performance on prospective memory.

**Interference control.** Interference control was assessed using two measures: the Symbol Search subtest from the WAIS-III, and the Trail Making Test from the D-KEFS. In the Symbol Search test, participants were required to indicate whether either of two symbols which were printed on the left of the page, were present in a row of a five symbols printed on the right of the page. They were given a time limit of 120 seconds to complete as many rows (trials) as possible. Scores represented the number of trials completed correctly minus the number of incorrect trials, with higher scores indicating an increased ability to control for interference. The Symbol Search test has a test-retest reliability correlation of $r = .77$.

Trial 4 of the Trail Making Test from the D-KEFS was also used to assess interference control. In this trial of the Trail Making Test, the participant was presented with an array of 16 circles with consecutive numbers in them and 16 circles with
consecutive letters in them. Participants were required to join the numbers and letters
with a continuous line, by alternating between them (e.g., 1-A-2-B-3-C and so forth) in
the quickest time possible, without sacrificing accuracy. Scores represented the number
of errors and the time taken to complete the task. If the participant took longer than 240
seconds then they were required to stop completion of the task. Higher scores reflected
a lower ability to control interference. A Trial 4 Contrast score was also calculated to
provide a measure of the time taken to complete Trial 4 divided by the time taken to
complete both Trial 2 and Trial 3 (which provide an index of visuo-motor speed). Trial
2 of the TMT involved joining an array of circles with consecutive numbers in them
with a continuous line, in sequence and in the quickest time possible. Trial 3 of the
TMT involved joining an array of circles with consecutive letters in them with a
continuous line, in sequence and in the quickest time possible. Both Trial 2 and Trial 3
were administered prior to the participant commencing Trial 4 as part of an overall
TMT subtest administration procedure. The D-KEFS manual reports a test-retest
reliability correlation of $r = .36$ for this trial.

*Inhibition of prepotent responses.* The inhibition of prepotent responses was
assessed using two measures: the Color-Word Interference subtest (D-KEFS) and a
modified version of the Rule Shift card test from the BADS. Trial 3 of the Color-Word
Interference subtest was used in the current study, which is a variant of the Stroop test.
In this trial, participants were presented with a page of names of colours which were
printed in incongruent coloured ink. The participant is asked to name the colour of the
ink that each word is printed in, as quickly as possible but not naming the actual word
printed. The time taken to complete the trial, as well as the number of errors, was
recorded. A higher score reflected a lower ability to inhibit a prepotent response. In
addition, a Color-Word Trial 3 Contrast score was calculated to provide a measure of
the time taken to complete Trial 3 divided by the time taken to complete Trial 1 (which is an index of processing speed). Trial 1 of the Color-Word subtest required the participant to name colours (presented as colour patches on the page) in the quickest time possible. Trial 1 was administered prior to the participant commencing Trial 3 as part of the overall Color-Word Interference subtest administration procedure. Test-retest reliabilities are reported to be in the moderate to high range \((r = .60 - .90)\).

A modified version of the Rule Shift card test from the BADS was derived from Num’s (2006) study. In this task, participants were provided with a booklet of 20 playing cards which were presented in random order throughout the booklet. In the first trial, the participant was required to say ‘yes’ if the colour of the card suit was red and ‘no’ if the colour of the card suit was black, until the participant went through all of the cards in the booklet. Using the same 20-card booklet, on the second trial participants were required to say ‘yes’ if the colour of the card suit was black and ‘no’ if the colour of the card suit was red. In the third trial (which was a modified addition to the original test), participants were required to once again go through the booklet and say ‘yes’ if the card colour was the same colour as the previous card and ‘no’ if the card colour was different to the colour of the card previously presented. In the fourth trial (also a modified addition to the original test), participants were required to say ‘no’ if the card colour was the same colour to the previous card and ‘yes’ if the card colour was different to the colour of the card previously presented. The participant was required to go through each trial as quickly as they could, without sacrificing accuracy. The overall time taken to complete each trial, as well as the number of errors, was recorded. Profile scores were calculated for performance on trial 2 and trial 4 of the test by the summing the number of errors incurred minus an error deduction if the completion time on either of these two trials was over 67 seconds. A Rule Shift Trial 2 and 4 combined score was
calculated to represent the average score across both trials. A lower profile score reflected a lower ability to inhibit a response. A test-retest reliability coefficient of $r = .76$ is reported for the original version of this test.

**Verbal fluency.** The Letter Fluency subtest of the D-KEFS was used to assess verbal fluency. Participants were asked to generate as many words as they could, beginning with a specified letter (e.g., F, A, S), within a timeframe of 60 seconds for each letter. Participants were asked to exclude proper nouns, numbers, and multiple forms of the same word. The total score was the number of correct responses summed across the three letters. Sound internal consistency is reported for this subtest ranging from .60 to .90, as well as adequate test-retest reliability ($r = .60$ - .90).

**Emotion-based decision-making.** The Iowa Gambling Task (IGT; Bechara et al., 1994) was used to measure emotion-related decision-making. A computerized version of the IGT was administered where participants were required to choose between decks of cards which yielded high immediate gains but large future loss, and decks which yielded lower immediate gains but a smaller future loss. The goal of the task was to optimise profit on a loan of play money. Participants were presented with four decks of cards (1, 2, 3 & 4), and were given a $2000 loan of play money. Participants were informed that the game requires a series of card selections, one card at a time, from any of the four decks, until they were told to stop (which was after 100 trials). Decks 1 and 2 were ‘disadvantageous’ because they resulted in larger overall loss, whereas decks 3 and 4 were ‘advantageous’ because they resulted in larger overall gain. A total score was calculated by subtracting the total number of cards selected from the two disadvantageous decks from the total number of cards selected from the two advantageous decks. Lower total scores reflected poorer decision-making abilities.
The ability of the IGT to detect decision-making impairments has been demonstrated across a variety of clinical samples which have included populations with VPFC lesions (Bechara et al., 1994; Bechara et al., 1997; Bechara et al., 2001; Ernst, Grant, London, Contoreggi, Kimes, & Spurgeon, 2003). These findings are suggestive of the construct validity of this test. More specifically to the current study, individuals with schizophrenia have been found to demonstrate a distinct pattern of impaired decision-making (as assessed by the Iowa Gambling Task), that is somewhat different to that found in patients with OFC lesions, as well as healthy participants (Ritter et al., 2004; Shurman et al., 2005). Published reliability information on the computerised version of the test is not available and internal consistency on this measure is difficult to calculate due to the IGT not consisting of test items that usually make up conventional neuropsychological tests (Dunn, Dalgleish, & Lawrence, 2006). There are also difficulties examining the reliability of the measure as the ability to assess the temporal stability of the test could be potentially impacted by practice effects on retesting (Beulow & Shur, 2009).

**Functional outcome.** The Independent Living Skills Inventory (ILSI; Menditto et. al., 1999), was used to measure functional outcome. This inventory measures the extent to which individuals are able to perform competently on a broad range of skills which have been found to be important for successful community living. The inventory was completed on the basis of obtaining ratings from the patient’s key worker or community support worker. The original version of the ILSI included 89 items divided into 11 subscales. Items assessed a range of skills including personal management, hygiene and grooming, clothing, basic skills, interpersonal skills, home maintenance, money management, cooking, resource utilisation, general occupation skills and medication management. Each item was rated in relation to the extent in which the
individual was considered to be able to perform particular skills in conjunction to the extent in which assistance or support is required. Ratings ranged from ‘No Competence’ (0) to ‘Independent Competence’ (3). A total ILSI score was calculated as the average score across all of the ILSI subscales. The present study used the current version of the inventory which contained 55 items. The shorter version was based on the psychometric properties of items from the original scale, as well as on the feedback from raters about their usefulness. The internal consistency among the items of the original version of this scale is 0.82 (Cronbach’s coefficient alpha). This measure has been used in previous research investigating the relationship between cognitive impairments in individuals with schizophrenia and 'real-world' functional outcome (Keefe et al., 2006). As the matched-control participants were not clinical patients, the measure was completed as a self-report questionnaire by these subjects.

**Procedure**

After patient participant recruitment, an information sheet about the study was provided and a mutually convenient time for testing was scheduled. Testing took place at various local public mental health service suburban clinics. At the beginning of each testing session, participants were informed that participation was voluntary and they had the right to withdraw at any given time. Informed consent was then obtained (see Appendix F). The structured interview gathering demographic information was conducted after informed consent was obtained and this took approximately 10 minutes to complete. The DASS and the SCI-PANSS were administered afterwards, taking approximately 30 minutes to complete. Neurocognitive testing followed taking approximately 60 to 90 minutes to complete. Tests were administered in a standardised order so as to minimize measurement error due to test order interaction. A break was also provided to participants depending on the level of participant motivation and
fatigue demonstrated/reported. All testing was completed by the researcher who is a registered psychologist and has professional training in the administration and scoring of neuropsychometric assessments, as well as additional professional training in the administration and scoring of the SCI-PANSS. The Independent Living Skills Inventory was given to the rater which was nominated by the patient participant as being able to give the most accurate evaluation of their independent living skills. This questionnaire was then returned to the researcher via post by a self-addressed stamped envelope which was either provided to the participant at the time of testing or posted directly to the nominated rater.

The matched-control subjects underwent a similar procedure. Testing took place at one of the available testing locations selected by the participant. Informed consent was obtained prior to the testing session (see Appendix G) and overall testing time for this group of participants was approximately 60 to 90 minutes. The SCI-PANSS was not administered to this group. For matched-control subjects, the Independent Living Skills Inventory was self-completed in their own time and then sent back to the researcher via post.

Debriefing information (see Appendix H) was given at the conclusion of testing detailing the use of the obtained data from the research.

Results

Data Screening

Prior to testing hypotheses, data was entered into a statistical analysis program, SPSS Version 22.0 (2013), and checked for missing values, outliers and departures from normality. There were no missing values in the final data set. Outliers were detected on two variables, Color-Word Trial 3 and the Iowa Gambling Task. The distributions of
these variables were Winsorised whereby the ranks of extreme scores (i.e., values falling outside of 3.29 standard deviations from the mean) were maintained by assigning them a value of the closest score that was not greater than 3.29 standard deviations from the mean (for discussion, see Erceg-Hurn & Mirosevich, 2008; Field, 2009). Two scores on the Color-Word Trial 3 variable and one score on the Iowa Gambling Task variable were dealt with using this protocol in order to maintain the integrity of the data and protect against any departures from normality. Following winsorisation of these variables, normality was achieved. Further data screening demonstrated that there were no departures from normality on any of the other variables.

**Part A**

**Group Differences in Executive Function**

As the first aim of the current study was to determine if schizophrenia patients with cannabis use demonstrate poorer performance in constructs of executive functioning compared to a matched-control group with a similar cannabis use history, the focus of the initial statistical analyses was to compare the executive function performance of these two groups. For further exploration, the proportion of schizophrenia patients with cannabis use which demonstrated executive function performance falling in the ‘impaired’ range (compared to normative criteria), was described. Prior to analyses, standardised scores (z) were calculated using normative means and standard deviations. However, as Zoo Map recall, Rule Shift Trial 4, the Rule Shift Trial 2 and 4 combined score, and the event-based prospective memory task did not have normative mean criteria available, scores relating to these measures were left in their original form. In order to examine the executive function performances of schizophrenia patients with cannabis use, relative to matched-controls with a similar cannabis use history, a series of Analysis of Covariance (ANCOVA) analyses were conducted to determine the effect
of Group on executive function performance when accounting for the effects of premorbid IQ. Examination of Shapiro-Wilk statistics and histograms for each group indicated that the ANCOVA assumption of normality was supported. Scatterplots indicated that the relationship between the covariate (premorbid IQ) and the dependent variables (performance on the individual executive function measures) was linear. Finally the assumptions of homogeneity of regression slopes and homogeneity of variances were supported by the absence of a significant interaction between the independent variable and the covariate. The ANCOVA results will be categorised according to the executive function components defined by West’s (1996) hierarchical model of executive function specifically: (i) the Temporal Organisation of Behaviour, (ii) Retrospective Memory, (iii) Interference Control, (iv) the Inhibition of Prepotent Responses and (v) Prospective Memory. Performance in the additional executive function domains included in the current study that were not outlined in West’s model, specifically verbal fluency and emotion-based decision making, will also be discussed. Table 2 displays the results of the covariate analyses of executive function performance for the schizophrenia group with cannabis use and matched-control group with a similar cannabis use history, with premorbid IQ as a covariate. Premorbid IQ was found to have an impact on Modified Six Elements, Digit Span and Letter Fluency task performance. However, the main effects of Group remained significant for Digit Span after accounting for the effects of premorbid IQ. An examination of the adjusted means indicated that schizophrenia patients with cannabis use demonstrated significantly lower scores on the Temporal Organisation of Behaviour (except for on the Modified Six Elements measure), Retrospective Memory, Interference Control (except for the Trail Making Test Trial 4 Contrast score), and the Inhibition of Prepotent Responses (except for the Color-Word Trial 3 Contrast score), relative to controls. Adjusted means
Table 2. Results of ANCOVAs of executive function performance for Group with covariate of premorbid IQ

<table>
<thead>
<tr>
<th>Executive Function Performance</th>
<th>Adjusted Mean</th>
<th>Effects</th>
<th>Group</th>
<th>Premorbid IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SCH/C n=28</td>
<td>MC n=28</td>
<td>F</td>
<td>p</td>
</tr>
<tr>
<td>TOB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoo Map</td>
<td>.055</td>
<td>.936</td>
<td>11.46</td>
<td>.001 **</td>
</tr>
<tr>
<td>Modified Six Elements</td>
<td>-.008</td>
<td>.315</td>
<td>3.03</td>
<td>.088</td>
</tr>
<tr>
<td>RM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoo Map Recall</td>
<td>4.79</td>
<td>6.39</td>
<td>21.42</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>Digit Span</td>
<td>-.511</td>
<td>.392</td>
<td>26.93</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>IC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symbol Search</td>
<td>-.662</td>
<td>.377</td>
<td>20.05</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>TMT Trial 4</td>
<td>-.729</td>
<td>.420</td>
<td>34.05</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>TMT Trial 4 Contrast</td>
<td>.043</td>
<td>-.019</td>
<td>.081</td>
<td>.777</td>
</tr>
<tr>
<td>IPR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule Shift Trial 2</td>
<td>-.260</td>
<td>.518</td>
<td>7.60</td>
<td>.008 **†</td>
</tr>
<tr>
<td>Rule Shift Trial 4</td>
<td>2.01</td>
<td>3.31</td>
<td>25.32</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>RS Trial 2 and 4</td>
<td>5.37</td>
<td>7.27</td>
<td>27.84</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>Color-Word Trial 3</td>
<td>-.817</td>
<td>.531</td>
<td>26.23</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>Color-Word Trial 3 Contrast</td>
<td>.484</td>
<td>.778</td>
<td>1.85</td>
<td>.179</td>
</tr>
<tr>
<td>PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event-based task</td>
<td>3.05</td>
<td>3.52</td>
<td>1.52</td>
<td>.224</td>
</tr>
<tr>
<td>Verbal Fluency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter Fluency</td>
<td>-.552</td>
<td>-.210</td>
<td>2.28</td>
<td>.137</td>
</tr>
<tr>
<td>Emotion-based decision making</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iowa Gambling Task</td>
<td>15.23</td>
<td>13.57</td>
<td>.062</td>
<td>.804</td>
</tr>
</tbody>
</table>

df = 2

SCH/C schizophrenia patients with cannabis use, MC matched-controls with a similar cannabis-use history, TOB Temporal Organisation of Behaviour, RM Retrospective Memory, IC Interference Control, IPP Inhibition of Prepotent Responses, RS Rule Shift, PM Prospective Memory, TMT Trail Making Test

Note. *p< .05, **p< .01, †non sig. following post hoc analyses

comparisons also revealed no significant differences between schizophrenia patients with cannabis use and matched-control subjects with a similar cannabis use history on the event-based prospective memory, verbal fluency and emotion-based decision making tasks. Post hoc analyses using a Holm-Bonferroni correction method revealed that no significant differences were detected between groups on Rule Shift Trial 2 performance while controlling for family-wise Type I error rate at level α = .05.
Level of executive function impairment between groups. To gain further insight into the extent and level of executive function impairment in the sample groups, a number of calculations using normative data and impairment criteria or impairment cut-off scores were conducted prior to analysis. The z-scores calculated prior to analyses were used for this examination. Used as a guide in Coulston et al.’s (2007) study, ‘impairment’ status was defined if neurocognitive performance fell 1.5 – 2.0 SD’s or more below the mean of the control group. Lezak et al. (2004) also suggests that a neurocognitive test performance change of 1.0, 1.5 and 2.0 SD’s may be used for determining impairment. Lezak considers that while a test performance reflective of a 1.0 SD change may not be sufficient enough to indicate a difference of statistical significance, some examiners may still classify this performance as ‘probably impaired’. However, as approximately 15% of individuals who are considered ‘intact’ are expected to obtain scores greater than 1.0 SD below normative means and therefore, potentially resulting in too many false positives, a change in performance of 2.0 SD’s is considered to be a clear indication of impairment (Lezak, 2004). Therefore, the current study aimed to examine performances between groups across the different impairment criteria of 1.0, 1.5 and 2.0 SD’s below the normative mean in order to better our understanding of the nature of any impairment that may be shown. Table 3 displays the chi-square results for proportional differences in each group that demonstrated neurocognitive performance across the different impairment ranges (i.e., greater than 1.0, 1.5 and 2.0 standard deviations below normative mean criteria) for each of the six executive function measures where significant differences were demonstrated in the previous analyses. It should be noted that as Zoo Map recall, Rule Shift Trial 4, the Rule Shift Trial 2 and 4 combined score, and the event-based prospective memory task, did not have normative mean criteria available they were therefore not included in the table. The Iowa
Table 3. The proportion (n) of each sample group and effect size of proportional differences in executive function performance across each of the impairment level categories.

<table>
<thead>
<tr>
<th>Executive Function Performance</th>
<th>Mean (SD)</th>
<th>Proportion of sample &gt; -1.0 SD’s below normative mean</th>
<th>Proportion of sample between -1.0 to -1.49 SD’s below normative mean</th>
<th>Proportion of sample between -1.5 to -1.99 SD’s below normative mean</th>
<th>Proportion of sample &lt; -2.0 SD’s below normative mean</th>
<th>Effect Size of difference between frequencies within each group</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCH/C (n= 28)</td>
<td>MC (n= 28)</td>
<td>SCH/C (n= 28)</td>
<td>MC (n= 28)</td>
<td>SCH/C (n= 28)</td>
<td>MC (n= 28)</td>
<td>SCH/C (n= 28)</td>
</tr>
<tr>
<td><strong>TOB</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoo Map</td>
<td>.05 (.14)</td>
<td>.94 (.74)</td>
<td>23</td>
<td>27</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>RM</strong></td>
<td>Digit Span</td>
<td>-.52 (.64)</td>
<td>.40 (.73)</td>
<td>19</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td><strong>IC</strong></td>
<td>Symbol Search</td>
<td>-.67 (-.87)</td>
<td>.38 (.85)</td>
<td>16</td>
<td>26</td>
<td>8</td>
</tr>
<tr>
<td>TMT Trial 4</td>
<td>-.74 (.91)</td>
<td>.43 (.53)</td>
<td>14</td>
<td>27</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td><strong>IPP</strong></td>
<td>Rule Shift Trial 2</td>
<td>-.26 (.56)</td>
<td>.52 (.24)</td>
<td>21</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>CW Trial 3</td>
<td>-.81 (1.29)</td>
<td>.52 (.52)</td>
<td>16</td>
<td>28</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. **p< .01
Gambling Task will then be discussed due to impairment criteria for this measure involving a cut-off score instead of normative means and standard deviations.

Symbol Search and Trail Making Test Trial 4 had the highest proportion of participants that performed at greater than 1.0 below the normative mean. A chi-square test for goodness of fit (with $\alpha = .01$) was used to assess whether certain levels of performance (according to the impairment level criteria of 1.0, 1.5 and 2.0 SD’s below the normative mean) were more common than others in each sample group. The chi-square test was statistically significant on all measures for the schizophrenia group with cannabis use ($p < .001$), indicating that some impairment criteria levels were achieved with significantly greater frequencies than others. Results indicate that a significantly larger proportion of schizophrenia patients with cannabis use demonstrated performance on all of the 6 measures above the impairment level criteria of greater than 1.0, 1.5 and 2.0 standard deviations below normative mean than patients with cannabis use falling below these criteria. In other words, a larger proportion of schizophrenia patients with cannabis use demonstrated performances which were classified in the normal range on these executive function measures than those which were deemed to be at the probably impaired or clinically impaired range. These findings suggest that a statistically significant larger proportion of patients with schizophrenia with cannabis use did not perform at a level that was considered to be even ‘probably impaired’, let alone fall into the clinically impaired category and this was significantly different than chance ($p < .001$). Similar results were found for matched-controls ($p < .001$) indicating a significantly larger proportion of the group demonstrating performances in the normal range. An examination of the index of effect size Cohen’s $w$ ranged from 0.50 to 1.05, which can be considered large. These results suggest that the previously reported significant results showing significant differences between groups is more reflective of
‘poorer’ performance by the schizophrenia group, but does not reflect ‘impaired’ performance relative to normative criteria.

Adjusted mean comparisons also reveal that neither group performed below the cut-off score for impaired performance on the Iowa Gambling Task (i.e., net score <10) (Bechara et al., 2001). This result also suggests that neither the schizophrenia group with cannabis use ($M = 15.23$), nor the matched-controls group ($M = 13.57$), in the current study demonstrated impairment on this measure according to this criterion.

**The Effect of Cannabis-Use Status on the Recovery of Executive Function**

As another aim was to investigate whether continued/current cannabis use is associated with the non-recovery of executive function, the groups were partitioned into current cannabis users and abstinent cannabis users based on self-reported current use at the time of testing. In order to examine this relationship, a series of two-way ANCOVA’s were conducted to determine the effect of Group and cannabis-use status on executive function, when controlling for the effects of duration of use. Once again, the results will be grouped according to the executive function domains outlined in West’s (1996) model and the additionally included measures of executive function will then be reported.

The ANCOVA assumption of normality was supported via the examination of Shapiro-Wilk statistics and histograms for each group and cannabis-use status categories. Scatterplots indicated that the relationship between the covariate (duration of use) and the dependent variables (executive function performance) was linear. Finally the assumptions of homogeneity of regression slopes and homogeneity of variances were supported by the independence of the covariate and both of the independent variables. Table 4 outlines the ANCOVA results of executive function performance for each group, with duration of use as a covariate. No statistically significant interactions
Table 4. Results of ANCOVAs of executive function performance for Group and cannabis-use status with covariate of duration of use

<table>
<thead>
<tr>
<th>Cognitive performance</th>
<th>Adjusted Mean</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td>Cannabis-Use Status</td>
</tr>
<tr>
<td></td>
<td>SC/C</td>
<td>MC</td>
</tr>
<tr>
<td>TOB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoo Map</td>
<td>.021</td>
<td>.958</td>
</tr>
<tr>
<td>Modified Six Elements</td>
<td>-.038</td>
<td>.339</td>
</tr>
<tr>
<td>RM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoo Map Recall</td>
<td>4.72</td>
<td>6.40</td>
</tr>
<tr>
<td>Digit Span</td>
<td>-.508</td>
<td>.429</td>
</tr>
<tr>
<td>IC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symbol Search</td>
<td>-.674</td>
<td>.378</td>
</tr>
<tr>
<td>TMT Trial 4</td>
<td>-.747</td>
<td>.449</td>
</tr>
<tr>
<td>TMT Trial 4 Contrast</td>
<td>.024</td>
<td>-.024</td>
</tr>
<tr>
<td>IPP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RS Trial 2</td>
<td>-.298</td>
<td>.527</td>
</tr>
<tr>
<td>RS Trial 4</td>
<td>2.06</td>
<td>3.36</td>
</tr>
<tr>
<td>RS Trial 2 and 4</td>
<td>5.39</td>
<td>7.33</td>
</tr>
<tr>
<td>CW Trial 3 Contrast</td>
<td>.430</td>
<td>.778</td>
</tr>
<tr>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event-based task</td>
<td>3.03</td>
<td>3.57</td>
</tr>
<tr>
<td>Verbal Fluency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter Fluency</td>
<td>-.495</td>
<td>-.146</td>
</tr>
<tr>
<td>Emotion-based decision making</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iowa Gambling Task</td>
<td>15.54</td>
<td>13.46</td>
</tr>
</tbody>
</table>

*Note.*p < .05, **p < .01
between the independent variables and executive function performance were found after adjustment for duration of use. Duration of use was not found to have an impact on performance for the majority of the executive function measures. However, a significant interaction between the covariate of duration of use and the independent variables of Group and cannabis-use status on Color-Word Trial 3 was found, $F(6, 49) = 3.01, p = .039, \eta_p^2 = .156$. Therefore, the assumption of the homogeneity of regression slopes was violated in this instance and an ANCOVA was not conducted. Inspection of the regression slopes revealed a poor association between duration of use and Color-Word Trial 3 scores across the test groups (i.e., schizophrenia patients with cannabis use and matched-control subjects with a similar cannabis use history). However, for the cannabis-use status groups, an association between duration of use and Color-Word Trial 3 scores was found. As a general pattern, the regression slopes indicated that in the current-user group, a longer duration of use was associated with higher Color-Word Trial 3 scores indicating better performance on this measure due to the conversion to z-scores using normative criteria. Contrastingly, in the non-current user group, longer duration of use was found to be associated with lower Color-Word Trial 3 scores indicating poorer performance.

A two-way ANOVA revealed a significant main effect of Group on Color-Word Trial 3, $F(3, 52) = 26.86, p < .001, \eta_p^2 = .341$. Main effects of cannabis-use status, $F(3, 52) = 3.41, p = .071, \eta_p^2 = .062$ and the interaction, $F(3, 52) = .446, p = .512, \eta_p^2 = .008$ were not significant. Comparison of means indicated that the schizophrenia group with cannabis use ($M = -.81$) had significantly lower scores on Color-Word Trial 3, than matched-controls ($M = .53$). Although, current users ($M = -.44$) and non-current users ($M = .05$) showed similar performance on this measure.
An examination of the adjusted means for the other executive function domains indicated that schizophrenia patients with cannabis use had significantly lower scores on the Temporal Organisation of Behaviour (except on the Modified Six Elements measure), Retrospective Memory, Interference Control (except for the Trail Making Test Trial 4 Contrast score), and the Inhibition of Prepotent Responses (except for the Color-Word Trial 3 Contrast score), relative to controls. Adjusted means comparisons also revealed no significant differences between schizophrenia patients with cannabis use and matched-control subjects with a similar cannabis use history on the event-based Prospective Memory, Verbal Fluency and Emotion-based Decision-making tasks. Further, results showed no significant differences in performance on all of the executive function domains between current users and non-current users, except for in the domain of verbal fluency. Findings revealed that current users (M = -.04) had higher scores on Letter Fluency than former users (M = -.60), suggesting that continued cannabis use is associated with better performance on Letter Fluency. The effect size of this result is considered moderate. Holm-Bonferroni correction was applied to adjust for multiple comparisons, with all results remaining statistically significant following correction.

The Effect of Length of Abstinence on the Recovery of Executive Function

An additional aim of the study was to investigate if a longer period of abstinence is associated with the recovery of executive function. In order to examine this relationship, a series of two-way ANCOVA’s were conducted to determine the effect of Group and time since cessation (i.e., abstinence for less than 5 years and abstinence for equal to, or greater than, 5 years) on executive function, when controlling for duration of use. For this analysis, non-current users were divided into two groups using a median split. Following this, 16 subjects were in the less than 5 years abstinence group and 18
subjects were in the equal to, or greater than, 5 years abstinence group. The following analyses were only conducted on the sample of non-current cannabis users ($n = 34$). Examination of Shapiro-Wilk statistics and histograms for each group and time since cessation categories indicated the ANCOVA assumption of normality was supported. Scatterplots indicated that the relationship between the covariate (duration of use) and the dependent variables (performance on the individual executive function measures) was linear. Finally the assumptions of homogeneity of regression slopes and homogeneity of variances were supported by the absence of a significant IV-by-covariate interaction. Table 5 outlines the ANCOVA results of executive function performance for Group and time since cessation categories amongst the non-current user sample, with duration of use as a covariate. There were no statistically significant interactions found between either group, or time since cessation categories, and executive function performance after adjustment for duration of use. Duration of use was not found to have an impact on performance for the majority of the executive function measures, except for Color-Word Trial 3. However, the main effect of group on Color-Word Trial 3 remained significant after accounting for the effects of duration of use. Comparison of adjusted means show that schizophrenia patients with cannabis use had significantly lower scores on Retrospective Memory, Interference Control (except for the Trail Making Test Trial 4 Contrast score), and the Inhibition of Prepotent Responses domains, relative to controls (except for Rule Shift Trial 2 and the Color-Word Trial 3 Contrast score). Adjusted means comparisons also revealed no significant differences between schizophrenia patients with cannabis use and matched-control subjects with a similar cannabis use history on the Temporal Organisation of Behaviour (on the Modified Six Elements measure only), Prospective Memory, Verbal Fluency and Emotion-based Decision-making domains. Post hoc analyses using the Holm-
## Table 5. Results of ANCOVAs of executive function performance for Group and time since cessation categories with covariate of duration of use

<table>
<thead>
<tr>
<th>Cognitive performance</th>
<th>Adjusted Mean</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td>Time Since Cessation</td>
</tr>
<tr>
<td></td>
<td>SCH+C</td>
<td>C CTRL</td>
</tr>
<tr>
<td><strong>TOB</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified Six Elements</td>
<td>.014</td>
<td>.311</td>
</tr>
<tr>
<td><strong>RM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zoo Map Recall</td>
<td>5.08</td>
<td>6.30</td>
</tr>
<tr>
<td>Digit Span</td>
<td>-.664</td>
<td>.345</td>
</tr>
<tr>
<td><strong>IC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symbol Search</td>
<td>-.584</td>
<td>.373</td>
</tr>
<tr>
<td>TMT Trial 4</td>
<td>-.677</td>
<td>.338</td>
</tr>
<tr>
<td>TMT Trial 4 Contrast</td>
<td>.111</td>
<td>.024</td>
</tr>
<tr>
<td><strong>IPP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RS Trial 2</td>
<td>-.085</td>
<td>.480</td>
</tr>
<tr>
<td>RS Trial 4</td>
<td>1.76</td>
<td>3.17</td>
</tr>
<tr>
<td>RS Trial 2 and 4</td>
<td>5.26</td>
<td>7.11</td>
</tr>
<tr>
<td>CW Trial 3</td>
<td>-.484</td>
<td>.606</td>
</tr>
<tr>
<td>CW Trial 3 Contrast</td>
<td>.722</td>
<td>.728</td>
</tr>
<tr>
<td><strong>PM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event-based task</td>
<td>3.12</td>
<td>3.43</td>
</tr>
<tr>
<td><strong>Verbal Fluency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter Fluency</td>
<td>-.821</td>
<td>-.367</td>
</tr>
<tr>
<td><strong>Emotion-based decision making</strong></td>
<td>14.00</td>
<td>14.96</td>
</tr>
</tbody>
</table>

*Note.* *p* < .05, **p** < .01, †non sig. following post hoc analyses
Bonferroni correction method revealed that significant differences no longer remained between groups on Zoo Map recall performance after adjusting the alpha level for multiple comparisons. Further, results showed no significant differences in performance on all of the executive function domains between non-current users who were abstinent for less than 5 years and non-current users who were abstinent for equal to, or greater than, 5 years, except for in the Temporal Organization of Behaviour domain (on the Zoo Map measure only). Findings revealed that non-current users who were abstinent for less than 5 years ($M = .92$) had higher scores on Zoo Map than non-current users who were abstinent for equal to, or greater than, 5 years ($M = .11$), suggesting that shorter abstinence periods (i.e., less than 5 years) was associated with better performance on this measure. The effect size of this result is considered moderate.

**The Validity of West’s Theoretical Model of Executive Function**

**Principal Components Analysis.** Principal Components Analysis (PCA) was conducted to determine what, if any, factor structures underlie the following executive function measures: Zoo Map, Zoo Map recall, Digit Span, Symbol Search, Trail Making Test Trial 4, Rule Shift Trial 2, Color-Word Trial 3, the event-based prospective memory task, Letter Fluency, and the Iowa Gambling Task. Rule Shift Trial 4 and the Rule Shift Trial 2 and 4 combined score were not included in the analyses as they involved modified versions of the original measures. The Trail Making Test Trial 4 Contrast score and Color-Word Trial 3 Contrast score were also not included in PCA as the Trail Making Test Trial 4 and Color-Word Trial 3 appeared to be more successful in detecting differences between groups. This was considered an important concern when attempting to determine any underlying factors amongst the executive function measures administered which may serve to be more sensitive and thus, reflective of the fundamental construct in question. The purpose of the PCA was exploratory in nature.
This type of analysis was conducted in order to determine which executive function measures were related to each other in a theoretically consistent way.

Criteria to determine the best factor model included: (a) exclusion of measures or items exhibiting Kaiser’s measurement of sampling adequacy (MSA), Kaiser-Meyer-Olkin (KMO) or communality values < .5; (b) Bartlett’s test of sphericity exhibiting significance ($p < .0001$); (c) retention of factors with eigenvalues > 1 that were supported by scree plot analysis and clinical/theoretical plausibility of factors; (d) factor loadings ≥ .4 for interpretation of factors (explaining ≥ 16% of total variance); and (e) stability of factor solutions across analyses employing oblique and orthogonal rotations (Field, 2009; Tabachnick & Fidell, 2007).

PCA was conducted utilising both orthogonal (varimax) and oblique (oblimin) rotations. During initial analysis, one item (the Iowa Gambling Task) failed to meet the minimum criterion of .5 for Kaiser’s MSA and was excluded in further analyses. Subsequently, PCA of the remaining 10 executive function measures yielded near-identical factor solutions across orthogonal (varimax) and oblique (oblimin) rotations. However, results of the former are reported only as varimax rotation provided the best defined factor structure (see Table 6). A three-factor solution explaining 61.57% of the total variance in executive function was extracted. Of this variance, 40.26% was accounted for by factor 1 (‘Mental Control and Self-Regulation’; 8 variables), 11.22% by factor 2 (‘Voluntary Response Generation and Disinhibition’; 2 variables), and 10.09% by factor 3 (‘Maintenance of Intention for Future Action’; 2 variables).

The outcomes of the PCA indicate that the executive function measures which loaded onto factor 1 include mostly those tests which were guided by West’s (1996) theoretical model of executive function. However, verbal fluency (which was included as an additional executive function component for exploration and did not appear to be
Table 6. Factor loadings based on a Principal Components Analysis utilising orthogonal (varimax) rotation of 10 executive function measures (N=56)

<table>
<thead>
<tr>
<th>Theoretical Construct</th>
<th>Item Measure</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal Organisation of Behaviour</td>
<td>Zoo Map</td>
<td>.576</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Modified Six Elements</td>
<td>.513</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrospective Memory</td>
<td>Zoo Map Recall</td>
<td>.646</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Digit Span</td>
<td>.692</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interference Control</td>
<td>Symbol Search</td>
<td>.703</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trail Making Test</td>
<td>.798</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trial 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhibition of Prepotent Responses</td>
<td>Rule Shift Trial 2</td>
<td>.707</td>
<td>-.473</td>
<td>.405</td>
</tr>
<tr>
<td></td>
<td>Color-Word Trial 3</td>
<td>.637</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prospective Memory</td>
<td>Event-based task</td>
<td></td>
<td></td>
<td>.903</td>
</tr>
<tr>
<td>Verbal Fluency</td>
<td>Letter Fluency</td>
<td></td>
<td></td>
<td>.847</td>
</tr>
</tbody>
</table>

Note. Factor loadings less than the absolute value of ± .4 are omitted.

included in West’s model), appeared to load onto a separate factor relative to the remaining measures (i.e., factor 2). Taken together with the negative loading of Rule Shift Trial 2 onto factor 2, this may indicate that the underlying structure of this component involves response generation/fluency abilities or cognitive responses that require disinhibition. Moreover, the positive loadings of both Color-Word Trial 3 and the event-based prospective memory onto factor 3 potentially reflect an underlying structure involving cognitive responses that require the ability to remember an intention for future action. Finally, the Iowa Gambling Task (which did not meet criterion for PCA and was excluded in the subsequent analysis) may not have been sensitive enough to sufficiently tap into the executive function constructs of interest, albeit in this particular sample.
While the sample size in the current study is notably low, it has been suggested by Stevens (1986; 2002) that as low as 5 subjects per variable is the minimum needed in Principle Components Analysis based on Gorsuch’s (1983) guidelines. The current study’s sample size is just over 50 with the combined sample and is therefore just above the minimum requirements in the recommended guidelines. In addition, recommendations arising from a study by Guadagnoli and Velicer (1988) outline that ‘components with four or more loadings above .60 in absolute value are reliable, regardless of sample size’ (cited in Stevens, 2002, p. 395). As the results indicate 6 loadings above .60, it can be considered that at least factor 1 is a reliable component. Another recommendation arising from Guadagnoli and Velicer’s (1988) study is that ‘components with only a few low loadings should not be interpreted unless sample size is at least 300’ (Stevens, 2002, p. 395). It is outlined that a low loading would include those .40 and below. However, Stevens (2002) suggested that a factor which was defined by only a few loadings was not considered as much of a factor and instead, the factor could be considered as variable specific. Therefore, as factor 2 included loadings of only two variables (Rule Shift Trial 2 at -.473 and Letter Fluency at .847), and factor 3 including loadings of only two variables (Color-Word Trial 3 at .405 and Prospective Memory at .903) this could indeed represent some of those cases.

Overall, these results are in partial support of the construct validity of the selected executive function measures (which were those guided by West’s model). That is, the measures which loaded on factor 1 seemed to adequately tap into a single theoretical neurocognitive construct, namely executive function. However, the results also suggest that while the measure of Letter Fluency may assess executive function abilities, it may also rely upon other cognitive abilities that are separate, or independent, to executive function alone. In addition, the event-based prospective memory measure
utilised may not have been sensitive enough to detect the true construct of prospective memory abilities. In alternative, the prospective memory measure used may have tapped into other cognitive processes that fall outside of the executive function domain.

Part B

The Relationship Between Executive Function and Functional Outcome

The predictive ability of executive function measures in predicting functional outcome ratings. The investigation into the relationship between the executive function domains belonging to West’s (1996) model and functional outcome is exploratory in nature. However, due to reports of an association between executive function and functional outcome in the literature, it was hypothesized that executive function performance would be significantly related to functional outcome. More specifically, scores on executive function measures would have significant predictive ability in relation to functional outcome ratings (as measured by the Independent Living Skills Inventory (ILSI)). The purpose of the following analyses is to assist in identifying a measure (or measures) of executive functioning that significantly predicts a specific domain of functional outcome in schizophrenia patients (e.g., if measures of prospective memory are shown to predict a given functional outcome domain then cognitive remediation specific to enhancing prospective memory abilities could be utilised to ultimately target improvements in that functional outcome domain). From this perspective, the goal of the analyses (and in turn the consequent results) is to assist in identifying whether there is potential for improvements to specific cognitive abilities which may in turn affect associated functional outcomes.

In order to identify the predictors that would be considered important to enter into regression analyses, Pearson correlation analyses between each of the individual executive function measures and each of the ILSI sub-scale ratings, as well as the Total
ILSI score, were first computed. Correlations were calculated for the schizophrenia group with cannabis use, the matched-control group with a similar cannabis use history, and the overall combined sample. Table 7, 8 and 9 display the correlation matrices.

A series of multiple regression and hierarchical multiple regression analyses (divided into three stages) were conducted for each functional outcome sub-domain, as well as for overall functional outcome. Only the schizophrenia group with cannabis use were used the analyses ($n = 28$). In the first stage of regression analysis, the measure(s) showing significant correlations in the schizophrenia group with cannabis use were entered as predictors into a multiple regression analysis. For stage 2, at step 1 these same predictors are entered simultaneously. At step 2, only the predictor from Stage 1 showing a significant slope was then entered. At step 3, this same predictor as well as those executive function measures showing significant correlations in the matched control group (not including those already entered), were then entered as predictors. At stage 3, all of the previous steps were used again. However, in step 4 only the predictor(s) from previous steps showing a significant slope were entered. In the final step, these same significant predictors in addition to those measures showing significant correlations in the combined sample (not including those already entered previously), were entered as predictors. Before interpreting the results of the regression analyses, a number of assumptions were tested and checks were performed. Firstly, an inspection of the normal probability plot of standardised residuals and the scatterplot of standardised residuals against standardised predicted values indicated that the assumptions of normality, linearity and homoscedasticity of residuals were met. In addition, Mahalanobis distance did not exceed the critical $\chi^2$ for degrees of freedom for any cases in the data, indicating that multivariate outliers were not of concern. Finally, relatively
Table 7. Correlations between executive function measures and ILSI sub-scales and total ILSI score for the schizophrenia group

<table>
<thead>
<tr>
<th>Independent Living Skills</th>
<th>Executive Function Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zoo Map</td>
</tr>
<tr>
<td>Personal Management</td>
<td>.223</td>
</tr>
<tr>
<td>Hygiene &amp; Grooming</td>
<td>.185</td>
</tr>
<tr>
<td>Clothing</td>
<td>-.051</td>
</tr>
<tr>
<td>Basic Skills</td>
<td>-.083</td>
</tr>
<tr>
<td>Interpersonal skills</td>
<td>.178</td>
</tr>
<tr>
<td>Home Maintenance</td>
<td>.160</td>
</tr>
<tr>
<td>Money Management</td>
<td>-.087</td>
</tr>
<tr>
<td>Cooking</td>
<td>.145</td>
</tr>
<tr>
<td>Resource Utilization</td>
<td>.097</td>
</tr>
<tr>
<td>General Occupational Skills</td>
<td>.225</td>
</tr>
<tr>
<td>Medication Management</td>
<td>.197</td>
</tr>
<tr>
<td>Total</td>
<td>141</td>
</tr>
</tbody>
</table>

Note. *p<.05, **p<.01

High tolerances indicated that multicollinearity would not interfere with the ability to interpret the outcome of the regression analyses.

**Personal Management (Independent Living Skills Inventory).** There were no significant correlations found in each of the separate groups (i.e., schizophrenia group with cannabis use and matched-controls group with a similar cannabis use history), therefore stage 1 and 2 of the regression analyses were not conducted. For stage 3, results indicate that the overall model which included Zoo Map, Zoo Map recall, Digit Span, Symbol Search, Trail Making Test Trial 4, Rule Shift Trial 4, the Rule Shift Trial 2 and 4 combined score, and Color-Word Trial 3 as predictors, did not significantly predict ratings in Personal Management on the Independent Living Skills Inventory in
Table 8. Correlations between executive function measures and ILSI sub-scales and total ILSI score for the matched-control group

<table>
<thead>
<tr>
<th>Independent Living Skills</th>
<th>Executive Function Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zoo Map</td>
</tr>
<tr>
<td>Personal Management</td>
<td>-.055</td>
</tr>
<tr>
<td>Hygiene &amp; Grooming</td>
<td>.070</td>
</tr>
<tr>
<td>Clothing</td>
<td>.337</td>
</tr>
<tr>
<td>Basic Skills</td>
<td>-</td>
</tr>
<tr>
<td>Interpersonal skills</td>
<td>.290</td>
</tr>
<tr>
<td>Home Maintenance</td>
<td>.213</td>
</tr>
<tr>
<td>Money Management</td>
<td>.051</td>
</tr>
<tr>
<td>Cooking</td>
<td>.284</td>
</tr>
<tr>
<td>Resource Utilization</td>
<td>.314</td>
</tr>
<tr>
<td>General Occupational Skills</td>
<td>-.117</td>
</tr>
<tr>
<td>Medication Management</td>
<td>.282</td>
</tr>
<tr>
<td>Total</td>
<td>.240</td>
</tr>
</tbody>
</table>

Note. *p<.05, **p<.01

schizophrenia patients with cannabis use, $R^2 = .247$, $R^2_{adj} = .070$, $F(8, 19) = .780$, $p = .625$.

**Hygiene and Grooming (Independent Living Skills Inventory).** At stage 1, Digit Span significantly accounted for 15.3% of the variance in Hygiene and Grooming ratings on the Independent Living Skills Inventory in schizophrenia patients with cannabis use, $R^2 = .184$, $R^2_{adj} = 153$, $F(1, 26) = 5.87$, $p = .023$. By Cohen’s (1988) conventions, an effect of this magnitude can be considered ‘medium’ ($f^2 = .23$). At stage 2, Rule Shift Trial 2 was added as a predictor to the regression equation and accounted for an additional 4.2% of the variance in Hygiene and Grooming ratings. However, this change was not statistically significant, $\Delta R^2 = .042$, $\Delta F(1, 25) = 1.345$, $p$
Table 9. Correlations between executive function measures and ILSI sub-scales and total ILSI score for the overall sample

<table>
<thead>
<tr>
<th>Executive Function Measures</th>
<th>Zoo Map</th>
<th>Zoo Map Recall</th>
<th>Digit Span</th>
<th>Symbol Search</th>
<th>Trail Making Test Trial 4</th>
<th>Rule Shift Trial 2</th>
<th>Rule Shift Trial 4</th>
<th>Rule Shift Trial 2 and 4 Combined</th>
<th>Color-Word Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Management</td>
<td>.392**</td>
<td>.441**</td>
<td>.358**</td>
<td>.459**</td>
<td>.399**</td>
<td>.188</td>
<td>.345**</td>
<td>.342**</td>
<td>.520**</td>
</tr>
<tr>
<td>Hygiene &amp; Grooming</td>
<td>.334*</td>
<td>.350**</td>
<td>.488**</td>
<td>.418**</td>
<td>.347**</td>
<td>.071</td>
<td>.297*</td>
<td>.247</td>
<td>.508**</td>
</tr>
<tr>
<td>Clothing</td>
<td>.205</td>
<td>.342**</td>
<td>.451**</td>
<td>.324*</td>
<td>.264*</td>
<td>.034</td>
<td>.235</td>
<td>.184</td>
<td>.451**</td>
</tr>
<tr>
<td>Basic Skills</td>
<td>.108</td>
<td>.176</td>
<td>.331*</td>
<td>.301*</td>
<td>.271*</td>
<td>-.086</td>
<td>.122</td>
<td>.042</td>
<td>.325*</td>
</tr>
<tr>
<td>Interpersonal skills</td>
<td>.393**</td>
<td>.489**</td>
<td>.455**</td>
<td>.544**</td>
<td>.519**</td>
<td>.142</td>
<td>.444**</td>
<td>.388**</td>
<td>.562**</td>
</tr>
<tr>
<td>Home Maintenance</td>
<td>.355**</td>
<td>.464**</td>
<td>.370**</td>
<td>.439**</td>
<td>.350**</td>
<td>.090</td>
<td>.260</td>
<td>.231</td>
<td>.514**</td>
</tr>
<tr>
<td>Money Management</td>
<td>.193</td>
<td>.446**</td>
<td>.453**</td>
<td>.369**</td>
<td>.271*</td>
<td>.061</td>
<td>.269*</td>
<td>.222</td>
<td>.396**</td>
</tr>
<tr>
<td>Cooking</td>
<td>.354**</td>
<td>.490**</td>
<td>.380**</td>
<td>.476**</td>
<td>.398**</td>
<td>.084</td>
<td>.409**</td>
<td>.344*</td>
<td>.526**</td>
</tr>
<tr>
<td>Resource Utilization</td>
<td>.355**</td>
<td>.497**</td>
<td>.458**</td>
<td>.517**</td>
<td>.504**</td>
<td>.250</td>
<td>.364**</td>
<td>.388**</td>
<td>.519**</td>
</tr>
<tr>
<td>General Occupational Skills</td>
<td>.405**</td>
<td>.379**</td>
<td>.391**</td>
<td>.471**</td>
<td>.473**</td>
<td>.119</td>
<td>.425**</td>
<td>.363**</td>
<td>.571**</td>
</tr>
<tr>
<td>Medication Management</td>
<td>.385**</td>
<td>.506**</td>
<td>.384**</td>
<td>.505**</td>
<td>.490**</td>
<td>.203</td>
<td>.370**</td>
<td>.367**</td>
<td>.509**</td>
</tr>
<tr>
<td>Total</td>
<td>.369**</td>
<td>.487**</td>
<td>.467**</td>
<td>.508**</td>
<td>.448**</td>
<td>.138</td>
<td>.394**</td>
<td>.350**</td>
<td>.547**</td>
</tr>
</tbody>
</table>

Note. *p<.05, **p<.01

= .257. At stage 3, results indicate that the overall model which included Zoo Map, Zoo Map recall, Symbol Search, Trail Making Test Trial 4, Rule Shift Trial 4, and Color-Word Trial 3 as additional predictors, accounted for an additional 15.1% of the variance in Hygiene and Grooming ratings. However, again this change was not statistically significant, \( \Delta R^2 = .151, \Delta F(6, 19) = .766, p = .605. \)

**Clothing (Independent Living Skills Inventory).** There were no significant correlations found in the schizophrenia group with cannabis use for Clothing ratings. Therefore, stage 1 of the regression analyses was not conducted. At stage 2, Digit Span, Rule Shift Trial 2 and the Rule Shift Trial 2 and 4 combined score were entered as
predictors to the regression equation. This model was not found to be statistically significant, $R^2 = .198$, $R^2_{adj} = .098$, $F(3, 24) = 1.975$, $p = .145$. Due to the non-significant results in the previous stage, at stage 3 only Zoo Map recall, Symbol Search, Trail Making Test Trial 4, and Color-Word Trial 3 were entered as predictors in the model. Results indicate that the overall model did not significantly predict the variance in Clothing ratings, $R^2 = .125$, $R^2_{adj} = -.027$, $F(4, 23) = .819$, $p = .526$.

**Basic Skills (Independent Living Skills Inventory).** As there were no significant correlations found in each of the separate groups for Basic Skills ratings, stage 1 and 2 of the regression analyses were not conducted. At stage 3, Digit Span, Symbol Search, Trail Making Test Trial 4, and Color-Word Trial 3 were entered as predictors. Results indicate that the overall model did not significantly predict ratings in Basic Skills, $R^2 = .068$, $R^2_{adj} = -.094$, $F(4, 23) = .418$, $p = .794$.

**Interpersonal skills (Independent Living Skills Inventory).** At stage 1, Symbol Search significantly accounted for 17.9% of the variance in Interpersonal Skills ratings in schizophrenia patients with cannabis use, $R^2 = .209$, $R^2_{adj} = .179$, $F(1, 26) = 6.881$, $p = .014$. The effect size is considered to be ‘medium’ ($f^2 = .26$) (Cohen, 1988). At stage 2, Color-Word Trial 3 was added as a predictor to the regression equation and accounted for an additional 0.9% of the variance in Interpersonal Skills ratings, with this change being non-significant, $\Delta R^2 = .009$, $\Delta F(1, 25) = 2.83$, $p = .599$. At stage 3, the overall model which included Zoo Map, Zoo Map recall, Digit Span, Trail Making Test Trial 4, Rule Shift Trial 4, and the Rule Shift Trial 2 and 4 combined score as additional predictors, accounted for an additional 0.7% of the variance in Interpersonal Skills ratings. Once again, this change was not statistically significant, $\Delta R^2 = .074$, $\Delta F(6, 19) = .328$, $p = .914$. 
**Home Maintenance (Independent Living Skills Inventory).** There were no significant correlations found in the schizophrenia group with cannabis use, hence stage 1 of the regression analyses was not conducted. At stage 2, Rule Shift Trial 2 was entered as a predictor into the regression equation. This model was not found to be statistically significant, \( R^2 = .029, R^2_{\text{adj}} = -.008, F(1, 26) = .783, p = .384 \). Due to this non-significant result, at stage 3 only Zoo Map, Zoo Map recall, Digit Span, Symbol Search, Trail Making Test Trial 4, and Color-Word Trial 3 were entered as predictors, with again no significant results, \( R^2 = .193, R^2_{\text{adj}} = -.038, F(6, 21) = .835, p = .557 \).

**Money Management (Independent Living Skills Inventory).** No significant correlations were found in the schizophrenia group with cannabis use. Therefore, stage 1 of the regression analyses was not conducted. At stage 2, Digit Span was entered as a predictor into the regression equation with the model not being statistically significant, \( R^2 = .037, R^2_{\text{adj}} = .000, F(1, 26) = 1.013, p = .324 \). Due to this result, at stage 3 only Zoo Map recall, Symbol Search, Trail Making Test Trial 4, Rule Shift Trial 4, and Color-Word Trial 3 were entered as predictors. No significant results were found, \( R^2 = .211, R^2_{\text{adj}} = .032, F(5, 22) = 1.179, p = .351 \).

**Cooking (Independent Living Skills Inventory).** At stage 1, Symbol Search significantly accounted for 17.7% of the variance in Cooking ratings in schizophrenia patients with cannabis use, \( R^2 = .207, R^2_{\text{adj}} = .177, F(1, 26) = 6.807, p = .015 \). The effect size is ‘medium’ \( (f^2 = .26) \) (Cohen, 1988). At stage 2, Rule Shift Trial 2 was added as a predictor to the regression equation and accounted for an additional 7.3% of the variance in Cooking ratings with this change not being statistically significant, \( \Delta R^2 = .073, \Delta F(1, 25) = 2.502, p = .126 \). For stage 3, the overall model which included Zoo Map, Zoo Map recall, Digit Span, Trail Making Test Trial 4, Rule Shift Trial 4, Rule Shift Trial 2 and 4 combined score, and Color-Word Trial 3 as additional predictors,
accounted for an additional 13.5% of the variance in Cooking ratings, with no further significant results found, $\Delta R^2 = .135, \Delta F(7, 19) = .557, p = .781$.

**Resource Utilization (Independent Living Skills Inventory).** At stage 1, Symbol Search significantly accounted for 11.9% of the variance in Resource Utilization ratings in schizophrenia patients with cannabis use, $R^2 = .152, R^2_{adj} = .119, F(1, 26) = 4.663, p = .040$, with a ‘medium’ effect size ($f^2 = .18$) (Cohen, 1988). At stage 2, Digit Span, Rule Shift Trial 2 and the Rule Shift Trial 2 and 4 combined score were added as additional predictors to the model and accounted for an additional 10.9% of the variance in Resource Utilization ratings. However, this change was not significant, $\Delta R^2 = .109, \Delta F(3, 23) = 1.133, p = .357$. At stage 3, the overall model which included Zoo Map, Zoo Map recall, Trail Making Test Trial 4, Rule Shift Trial 4, and Color-Word Trial 3 as additional predictors, accounted for an additional 13.2% of the variance in Resource Utilization ratings with this change being non-significant, $\Delta R^2 = .132, \Delta F(5, 21) = .775, p = .579$.

**General Occupational Skills (Independent Living Skills Inventory).** No significant correlations were found in each of the separate groups, therefore stage 1 and 2 of the regression analyses were not conducted. At stage 3, Zoo Map, Zoo Map recall, Digit Span, Symbol Search, Trail Making Test Trial 4, Rule Shift Trial 4, the Rule Shift Trial 2 and 4 combined score, and Color-Word Trial 3 were entered as predictors. Results indicate that the overall model did not significantly predict ratings in General Occupational Skills in schizophrenia patients with cannabis use, $R^2 = .200, R^2_{adj} = -.136, F(8, 19) = .595, p = .771$.

**Medication Management (Independent Living Skills Inventory).** At stage 1, Symbol Search significantly accounted for 15.5% of the variance in Medication Management ratings in schizophrenia patients with cannabis use, $R^2 = .186, R^2_{adj} = .155$,.
$F(1, 26) = 5.945, p = .022$, with a ‘medium’ effect size ($f^2 = .23$) (Cohen, 1988). At stage 2, Color-Word Trial 3 was added to the equation and accounted for an additional 0.2% of the variance in Medication Management ratings with results not being statistically significant, $\Delta R^2 = .002, \Delta F(1, 25) = .069, p = .795$. At stage 3, the overall model included Zoo Map, Zoo Map recall, Digit Span, Trail Making Test Trial 4, Rule Shift Trial 4, the Rule Shift Trial 2 and 4 combined score, and Color-Word Trial 3 as additional predictors and accounted for an additional 9.6% of the variance in Medication Management ratings. Again, no further significant results were found, $\Delta R^2 = .096, \Delta F(6, 20) = .448, p = .838$.

**Total ILSI Score (Independent Living Skills Inventory).** At stage 1, Symbol Search significantly accounted for 11.9% of the variance in the Total ILSI Score in schizophrenia patients with cannabis use, $R^2 = .151, R^2_{adj} = .119, F(1, 26) = 4.630, p = .041$. The effect size is considered ‘medium’ ($f^2 = .18$) (Cohen, 1988). At stage 2, Rule Shift Trial 2 and Color-Word Trial 3 were included as additional predictors to the regression equation and accounted for an additional 6.2% of the variance in the Total ILSI Score with the results however, being non-significant, $\Delta R^2 = .062, \Delta F(2, 24) = .938, p = .405$. At stage 3, the overall model included Zoo Map, Zoo Map recall, Digit Span, Trail Making Test Trial 4, Rule Shift Trial 4, and the Rule Shift Trial 2 and 4 combined score as additional predictors and accounted for an additional 12.3% of the variance in the Total ILSI Score. However, again this change was not statistically significant, $\Delta R^2 = .123, \Delta F(6, 20) = .566, p = .753$.

Following post hoc Holm-Bonferroni correction, the abovementioned significant results were found to no longer remain. However, considering the small sample size and extent to the nature of the analyses performed, it is acknowledged that the current study was likely underpowered in order to detect more significant results. Therefore, the
significant results prior to correction will still be reported and further considered in the following chapter.

Table 10 displays a summary of significant regression statistics for the individual ILSI sub-scale models and total ILSI score model.

**Moderation effects on executive function measures for functional outcome.**

The results outlined in Table 7 & Table 8 indicate that the relationships between executive function test performance and functional outcome differ across groups and hence suggestive of possible moderation effects on 8 of the functional outcome sub-domains, namely: Hygiene & Grooming, Clothing, Interpersonal Skills, Home Maintenance, Money Management, Cooking, Resource Utilization, Medication Management, as well as on the Total ILSI Score. Therefore, additional regression analyses were conducted in order to further explore these potential moderation relationships. In this phase of regression analyses, 3 variables were entered into the regression equation in order to examine possible moderation effects. Firstly, a new variable was computed which calculated the interaction between Group (schizophrenia patients with cannabis use and matched-controls with a similar cannabis use history) and the executive function measure of interest. This variable was then entered, in addition to the executive function measure of interest, as well as the Group variable. Once again, only those executive function measures which showed a significant correlation with the functional outcome sub-scale ratings (from the Pearson correlation analyses), or the Total ILSI score, in each of the separate groups (i.e., schizophrenia group with cannabis use and matched-controls group with a similar cannabis use history) were entered into the regression analyses. Regression analyses in this phase were conducted using the overall combined sample ($N = 56$). Once again, before interpreting the results of the regression analyses, assumption tests and checks were
Table 10. Regression models for predicting ILSI ratings

<table>
<thead>
<tr>
<th>Outcome Variable</th>
<th>Predictor Variable</th>
<th>B</th>
<th>Standard error</th>
<th>Beta (β)</th>
<th>Effect size (f^2)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hygiene &amp; Grooming</td>
<td>Digit Span</td>
<td>.150</td>
<td>.062</td>
<td>.429</td>
<td>.23</td>
<td>.023*</td>
</tr>
<tr>
<td>Interpersonal Skills</td>
<td>Symbol Search</td>
<td>.123</td>
<td>.047</td>
<td>.457</td>
<td>.26</td>
<td>.014*</td>
</tr>
<tr>
<td>Cooking</td>
<td>Symbol Search</td>
<td>.141</td>
<td>.054</td>
<td>.456</td>
<td>.26</td>
<td>.015*</td>
</tr>
<tr>
<td>Resource Utilization</td>
<td>Symbol Search</td>
<td>.110</td>
<td>.051</td>
<td>.390</td>
<td>.18</td>
<td>.040*</td>
</tr>
<tr>
<td>Medication Management</td>
<td>Symbol Search</td>
<td>.156</td>
<td>.064</td>
<td>.431</td>
<td>.23</td>
<td>.022*</td>
</tr>
<tr>
<td>Total ILSI Score</td>
<td>Symbol Search</td>
<td>.098</td>
<td>.045</td>
<td>.389</td>
<td>.18</td>
<td>.041*</td>
</tr>
</tbody>
</table>

Note. *p<.05, **p<.01

performed with results indicating assumptions of normality, linearity and homoscedasticity of residuals were met. Further, multivariate outliers and multicollinearity were not found to be an issue.

**Hygiene and Grooming (Independent Living Skills Inventory).** Results indicate that the overall model which included Digit Span significantly accounted for 34.3% of the variance in Hygiene and Grooming ratings on the Independent Living Skills Inventory in the combined sample, $R^2 = .379$, $R^2_{adj} = .343$, $F(3, 52) = 10.591, p < .001$. Digit Span ($B = .297, \beta = 1.33, p = .004$) and Group ($B = 1.76, \beta = 1.61, p = .004$) were found to have a significant impact on Hygiene and Grooming ratings at an individual level. The Group*Digit Span variable was also found to have a significant impact on the outcome variable ($B = -.146, \beta = -2.07, p = .017$), suggesting that a moderation effect between groups on Digit Span was present for Hygiene and Grooming ratings. Figure 1 displays the moderation effect between groups on Digit Span for Hygiene and Grooming ratings. The difference in slopes between groups shown in Figure 1 indicate that Digit Span has more predictive power for the schizophrenia group, than it does for the matched-control group in relation to predicting Hygiene and Grooming ratings.
Figure 1. Moderation effect between groups on Digit Span for Hygiene and Grooming ratings

The overall model which included Rule Shift Trial 2 as the executive function measure of interest, significantly accounted for 22.2% of the variance in Hygiene and Grooming ratings in the combined sample, $R^2 = .264$, $R^2_{adj} = .222$, $F(3, 52) = 6.218$, $p = .001$. However at an individual level, Rule Shift Trial 2 ($B = -.481$, $\beta = -.748$, $p = .362$), Group ($B = -.967$, $\beta = -.884$, $p = .629$), and the Group*Rule Shift Trial 2 variable ($B = .393$, $\beta = 1.748$, $p = .438$) were not found to have a significant impact on Hygiene and Grooming ratings.

Clothing (Independent Living Skills Inventory). The overall model which included Digit Span significantly accounted for 28.2% of the variance in Clothing ratings in the combined sample, $R^2 = .321$, $R^2_{adj} = .282$, $F(3, 52) = 8.201$, $p < .001$. However, results additionally indicate that Digit Span ($B = .155$, $\beta = .781$, $p = .094$), Group ($B = 1.04$, $\beta = .553$, $p = .066$), and the Group*Digit Span variable ($B = -.069$, $\beta = -1.101$, $p = .217$) were not found to have any individual significant impact on Clothing ratings.

Results also indicate that the model which included Rule Shift Trial 2, significantly accounted for 26.1% of the variance in Clothing ratings in the combined
sample, $R^2 = .301, R^2_{adj} = .261, F(3, 52) = 7.467, p < .001$. No further significant results were found at an individual level for Rule Shift Trial 2 ($B = -.537, \beta = .455, p = .244$), Group ($B = -1.127, \beta = -1.153, p = .518$), and the Group*Rule Shift Trial 2 variable ($B = .427, \beta = 2.126, p = .333$).

The model including the Rule Shift Trial 2 and 4 combined score significantly accounted for 25.9% of the variance in Clothing ratings in the combined sample, $R^2 = .299, R^2_{adj} = .259, F(3, 52) = 7.403, p < .001$. At the individual level, no additional significant results were found for Rule Shift Trial 2 and 4 combined score ($B = -.195, \beta = -.658, p = .162$), Group ($B = -.242, \beta = -.248, p = .759$), and the Group*Rule Shift Trial 2 and 4 combined score variable ($B = .121, \beta = 1.271, p = .280$).

**Interpersonal Skills (Independent Living Skills Inventory).** By including Symbol Search as a predictor, the model significantly accounted for 52.1% of the variance in Interpersonal Skills ratings in the combined sample, $R^2 = .547, R^2_{adj} = .521, F(3, 52) = 20.939, p < .001$. In addition, Symbol Search ($B = .252, \beta = 1.152, p = .002$), Group ($B = 1.913, \beta = 1.461, p < .001$) and the Group*Symbol Search variable ($B = -.129, \beta = -1.617, p = .010$) were found to each have a significant impact on the outcome variable. The significant results of the interaction term suggest a moderation effect between groups on Symbol Search for Interpersonal Skills ratings (see Figure 2). Figure 2 displays the difference in the regression slopes between groups which suggest that Symbol Search had better predictive ability for Interpersonal Skills ratings for the schizophrenia group, than for matched-controls.

The model which included Color-Word Trial 3, significantly accounted for 47.7% of the variance in Interpersonal Skills ratings in the combined sample, $R^2 = .506, R^2_{adj} = .477, F(3, 52) = 17.731, p < .001$. Significant individual results for Color-Word Trial 3 ($B = .165, \beta = .887, p = .034$) and Group ($B = 1.741, \beta = 1.330, p = .019$), were
Figure 2. Moderation effect between groups on Symbol Search for Interpersonal Skills ratings also found. However, there were no further significant results for the Group*Color-Word Trial 3 variable ($B = -.099, \beta = -1.289, p = .127$).

Home Maintenance (Independent Living Skills Inventory). Including Rule Shift Trial 2 as a predictor resulted in a model which significantly accounted for 32.5% of the variance in Home Maintenance ratings in the combined sample, $R^2 = .362, R^2_{adj} = .325, F(3, 52) = 9.843, p < .001$. At the individual level, no further significant results were found for Rule Shift Trial 2 ($B = -.639, \beta = -.693, p = .364$), Group ($B = -.988, \beta = -.630, p = .711$), and the Group*Rule Shift Trial 2 variable ($B = .501, \beta = -1.552, p = .459$).

Money Management (Independent Living Skills Inventory). Results indicate that the model including Digit Span, significantly accounted for 30.7% of the variance in Money Management ratings in the combined sample, $R^2 = .344, R^2_{adj} = .307, F(3, 52) = 9.103, p < .001$. However, no significant individual results were found for Digit Span ($B = .126, \beta = .435, p = .338$), Group ($B = 1.060, \beta = .744, p = .187$), and the Group*Digit Span variable ($B = -.044, \beta = -.476, p = .585$).


**Cooking (Independent Living Skills Inventory).** The model including Symbol Search as a predictor, significantly accounted for 41.4% of the variance in Cooking ratings in the combined sample, \( R^2 = .446, R^2_{\text{adj}} = .414, F(3, 52) = 13.972, p < .001. \) Results additionally indicated that Symbol Search (\( B = .308, \beta = 1.311, p = .001 \)), Group (\( B = 2.198, \beta = 1.567, p < .001 \)), and the Group*Symbol Search variable (\( B = -.167, \beta = -1.948, p = .005 \)) were found to have a statistically significant impact on the outcome variable at an individual level. The significant result of the interaction term suggests that a moderation effect between groups on Symbol Search is present for Cooking ratings (see Figure 3). Figure 3 highlights the differences in regression slope between groups showing that Symbol Search had better predictive ability for Cooking ratings in the schizophrenia group, than for the matched-control group.

The model including Rule Shift Trial 2, significantly accounted for 30.4% of the variance in Cooking ratings in the combined sample, \( R^2 = .342, R^2_{\text{adj}} = .304, F(3, 52) = 9.013, p < .001. \) However, no further significant results were found for Rule Shift Trial 2 (\( B = -.879, \beta = -1.066, p = .172 \)), Group (\( B = -2.119, \beta = -1.510, p = .384 \)), and the Group*Rule Shift Trial 2 variable (\( B = .750, \beta = 2.600, p = .224 \)), at an individual level.

**Resource Utilization (Independent Living Skills Inventory).** The overall model including Symbol Search as a predictor, significantly accounted for 46.3% of the variance in Resource Utilization ratings in the combined sample, \( R^2 = .492, R^2_{\text{adj}} = .463, F(3, 52) = 16.818, p < .001. \) In addition, Symbol Search (\( B = .218, \beta = .941, p = .013 \)) and Group (\( B = 1.738, \beta = 1.256, p = .002 \)) were each found to have a statistically significant impact on Interpersonal Skills ratings. However, following Holm-Bonferroni adjustment the result related to the individual impact of Symbol Search no longer remained significant. The impact of the Group*Symbol Search variable on the outcome
variable was found to approach significance \((B = -.108, \beta = -1.274, p = .051)\), suggesting a trend towards a moderation effect between groups on Symbol Search for Resource Utilization ratings (see Figure 4). The regression line differences seen in Figure 4 illustrate the higher predictive ability of Symbol Search for Resource Utilization ratings in the schizophrenia group, than in the matched-control group.

By including Digit Span into the regression equation, the model significantly accounted for 38.8% of the variance in Resource Utilization ratings in the combined sample, \(R^2 = .422, R^2_{adj} = .388, F(3, 52) = 12.647, p < .001\). No individual significant results were found for Digit Span \((B = .050, \beta = .178, p = .675)\), Group \((B = .836, \beta = .604, p = .253)\), and the Group*Digit Span variable \((B = -.007, \beta = -.073, p = .929)\).

The model including Rule Shift Trial 2, significantly accounted for 41.1% of the variance in Resource Utilization ratings in the combined sample, \(R^2 = .443, R^2_{adj} = .411, F(3, 52) = 13.813, p < .001\). However, additional results were not significant for Rule Shift Trial 2 \((B = -1.003, \beta = -1.234, p = .087)\), Group \((B = -3.065, \beta = -2.215, p = .167)\), and the Group*Rule Shift Trial 2 variable \((B = .997, \beta = 3.503, p = .077)\), at the individual level.
Including the Rule Shift Trial 2 and 4 combined score in the regression equation, the model significantly accounted for 38.5% of the variance in Resource Utilization ratings in the combined sample, $R^2 = .418, R^2_{adj} = .385, F(3, 52) = 12.456, p < .001$. No additional significant results were found for the Rule Shift Trial 2 and 4 combined score ($B = -.148, \beta = -.354, p = .407$), Group ($B = -.062, \beta = -.045, p = .952$), and the Group*Rule Shift Trial 2 and 4 combined score variable ($B = .134, \beta = .946, p = .356$), when examining individual effects.

**Medication Management (Independent Living Skills Inventory).** With Symbol Search included as a predictor, the overall model was found to significantly account for 43.7% of the variance in Medication Management ratings in the combined sample, $R^2 = .468, R^2_{adj} = .437, F(3, 52) = 15.241, p < .001$. Additional results found Symbol Search ($B = .324, \beta = 1.175, p = .003$), Group ($B = 2.359, \beta = 1.431, p = .001$), and the Group*Symbol Search variable ($B = -.168, \beta = -1.670, p = .013$) to each have a significant impact on the outcome variable. Results suggest a moderation effect between groups on Symbol Search for Medication Management ratings (see Figure 5). Once again, differences in regression slopes are displayed in Figure 5 indicating that Symbol Search
Figure 5. Moderation effect between groups on Symbol Search for Medication Management ratings

Symbol Search has better predictive ability for Medication Management ratings in the schizophrenia group, than for matched-controls.

By adding Color-Word Trial 3 into the regression equation, the model significantly accounted for 37.8% of the variance in Medication Management ratings in the combined sample, $R^2 = .412, R^2_{adj} = .378, F(3, 52) = 12.127, p < .001$. No further individual significant results were found for Color-Word Trial 3 ($B = .189, \beta = .808, p = .076$), and the Group*Color-Word Trial 3 variable ($B = -.114, \beta = -1.173, p = .201$). The individual impact of Group on the outcome variable was found to approach significance ($B = 1.985, \beta = 1.204, p = .050$).

Total ILSI Score (Independent Living Skills Inventory). The overall model which included Symbol Search, significantly accounted for 48.6% of the variance in Total ILSI scores in the combined sample, $R^2 = .514, R^2_{adj} = .486, F(3, 52) = 18.320, p < .001$. Examining individual effects, it was found that Symbol Search ($B = .203, \beta = .995, p = .007$), Group ($B = 1.671, \beta = 1.368, p = .001$), and the Group*Symbol Search variable ($B = -.106, \beta = -1.416, p = .027$) each had a statistically significant impact on
the outcome variable. The significant result of the interaction term suggests a moderation effect between groups on Symbol Search for the Total ILSI score (see Figure 6). The regression line differences shown in Figure 6 demonstrate that Symbol Search has better predictive power for the schizophrenia group regarding the Total ILSI score, than for the matched-control group.

By including Rule Shift Trial 2 as a predictor into the regression equation, the model significantly accounted for 41.4% of the variance in Total ILSI scores in the combined sample, $R^2 = .446$, $R^2_{adj} = .414$, $F(3, 52) = 13.941, p < .001$. No additional individual significant results were found for Rule Shift Trial 2 ($B = -.483, \beta = -.673, p = .345$), Group ($B = -.707, \beta = -.579, p = .715$), and the Group*Rule Shift Trial 2 variable ($B = .394, \beta = 1.567, p = .423$).

The model including Color-Word Trial 3, significantly accounted for 46.1% of the variance in Total ILSI scores in the combined sample, $R^2 = .490$, $R^2_{adj} = .461$, $F(3, 52) = 16.685, p < .001$. Color-Word Trial 3 ($B = .135, \beta = .780, p = .066$), and the Group*Color-Word Trial 3 variable ($B = -.080, \beta = -1.109, p = .194$) were not found to have any individual significant impact on Total ILSI scores. However, Group was found to have a significant impact on the outcome variable ($B = 1.497, \beta = 1.226, p = .033$).

Once again, it is important to note that considering the small sample size and the extent to the nature of the abovementioned analyses performed, it is acknowledged that the current study was likely underpowered in order to detect more significant results following post hoc Holm-Bonferroni correction. Therefore the results that no longer remained significant following adjustment will still be reported and considered.
Figure 6. Moderation effect between groups on Symbol Search for Total ILSI Score

The overall reported regression analyses results indicate, as well as confirm, that Digit Span is a significant predictor of Hygiene and Grooming ratings, and Symbol Search significantly predicts Interpersonal Skills, Cooking, Resource Utilization, Medication Management ratings, as well as the Total ILSI score, for schizophrenia patients with cannabis use. However, results also suggest that these measures have greater predictive power for the schizophrenia group, than they have for the matched-control group, in predicting ratings in the abovementioned ILSI areas, and Total ILSI score.

General Discussion

The current study sought to further our understanding of the neurocognitive profiles associated with schizophrenia patients with cannabis use and more specifically, their distinct profiles in relation to executive function. Previous research has explored this by examining group differences in neurocognitive performance between cannabis-using schizophrenia patients and non-cannabis using schizophrenia patients. However, the literature evaluating these differences has produced contradictory findings. Such
mixed results are likely due to variations in methodology, the failure to account for various indicators of cannabis use (e.g., a range of cannabis use parameters such as frequency, severity/quantity, duration and length of abstinence), a lacking in the examination of clinical ‘impairment’ levels, and varying approaches in classifying cannabis users. The present research aimed to address these issues not by directly investigating the possible additive relationship between cannabis use and schizophrenia on neurocognitive performance, but instead by examining the differential effects of cannabis use on cognitive performance in individuals with schizophrenia in comparison to otherwise healthy subjects with a similar cannabis use history, in relation to one specific neurocognitive system namely, executive function.

While the neurocognitive profiles of individuals with schizophrenia have been already well established in the literature, little is known about specific patterns that may exist in the schizophrenia patient with cannabis use population particularly in relation to the different aspects of executive function. The neurocognitive system of executive function is considered to have particular clinical relevance as executive function deficits have been found to be specifically associated with the illness of schizophrenia (Pantelis et al., 1997; Reichenberg & Harvey, 2007, Shallice et al., 1999), and have also been associated with functional outcome (Greenwood et al., 2005; McClure et al., 2007; Williams et al., 2008).

The current study was divided into two parts. Part A of the research aimed to determine whether differences exist in executive function performance between schizophrenia patients with cannabis use and otherwise healthy controls with a similar cannabis use history. This was achieved by assessing the neurocognitive performance of both groups on several measures of executive functioning which were guided by West’s (1996) theoretical model of executive function. Additional executive function constructs
which appeared to not be described in West’s model, were also included in the study for exploration purposes. In line with this further exploration, the construct validity of West’s theoretical model of executive function in the current sample was also examined. The present research also permits some comment on whether cannabis use status and length of abstinence have an impact on differences in executive function performance. Part B to the study aimed to explore the relationship between executive function performance and functional outcome. Of particular interest was determining whether performance on specific executive function measures predicted performance in different functional outcome sub-domains, as well as overall functional outcome.

Overall, there are four principal findings from Part A of the present study: a) schizophrenia patients with cannabis use demonstrated poorer performances on a range of executive function domains when compared to participants from the matched-control group with a similar cannabis use history; however, a significantly larger proportion of the schizophrenia group with cannabis use demonstrated performances that were not at an impaired level compared to those falling in the impaired range; b) an underlying structure was found to exist on a number of selected tests of executive function, providing partial support for the construct validity of West’s (1996) theoretical model of executive function in the current sample; c) the discontinuation of, or abstinence from, cannabis use was mainly not found to be associated with the recovery of executive functioning; d) longer abstinence periods were mainly not found to be associated with the recovery of executive function.

The main findings from Part B of the study were that: a) performance on two executive function measures were shown to significantly predict specific functional outcome domains, namely Digit Span and Symbol Search, and that: b) moderation effects on the executive function measures were found for 8 of the individual functional
outcome sub-domains, as well as for overall functional outcome. Each of the main findings will now be discussed.

**Part A**

**Group Differences in Executive Function**

With the interpretation of results being conceptually guided by West’s (1996) model, schizophrenia patients with cannabis use were found to have poorer performance in the Temporal Organisation of Behaviour (on the Zoo Map measure only), Retrospective Memory (on both Zoo Map recall and Digit Span measures), Interference Control (on both Symbol Search and Trail Making Test Trial 4 measures), and the Inhibition of Prepotent Responses (on both the Rule Shift Trial’s 2 and 4 and Color-Word Trial 3 measures), when compared to matched-controls with a similar cannabis use history. These differences were found after accounting for the possible effects of estimated premorbid IQ. However, while the Modified Six Elements test was also used to assess the Temporal Organisation of Behaviour domain, no significant differences between the two groups was demonstrated on this particular measure. In addition, no significant differences were found between the two groups in the executive function domains of Prospective Memory (assessed by an event-based prospective memory task), Verbal Fluency (assessed by Letter Fluency), and Emotion-based Decision-making abilities (assessed by the Iowa Gambling Task). Overall these findings could be interpreted as cannabis possibly playing a different role for patients with schizophrenia, in comparison to healthy individuals. The pattern of results found in the current study is somewhat similar to the findings of Jockers-Schrübel and colleagues (2007) showing that overall, cannabis-using schizophrenic patients performed worse than cannabis-using healthy controls in most of the neurocognitive tests administered in their study. Scholes and Martin-Iverson (2010) also found poorer performances across cognitive
tasks in cannabis-using patients relative to healthy cannabis-using controls. In addition to these findings, contrastingly Jockers-Schrübel and colleagues found that cannabis use was however associated with better test performance in schizophrenia patients, and conversely worse performance in healthy control subjects when the regular consumption of cannabis commenced prior to the age of 17.

It is difficult to compare the current study’s findings when evaluating group differences in neurocognitive performance as we did not aim to specifically examine additive effects. However, despite schizophrenia patients with cannabis use demonstrating poorer performance on a number of executive function measures relative to controls, a significantly larger proportion of the schizophrenia group with cannabis use demonstrated performances in the normal range and were not reflective of even probable neurocognitive impairment. This was determined following examining their performances against normative mean criteria. As the current study compared the neurocognitive performances of individuals with schizophrenia to individuals without a mental illness (with cannabis use being controlled for), it would be reasonable to interpret the current results as potentially reflecting the effects of schizophrenia alone. However, as schizophrenia patients have been found to demonstrate neurocognitive performance on a variety of tests at 1.0 - 2.0 standard deviations below the norm of healthy populations (Heinrichs & Zakzanis, 1998; Wilk, Gold, Humber, Dickerkson, Fenton, & Buchanan, 2004), the significantly larger proportion of the schizophrenia group with cannabis use in the current study demonstrating performances falling in the normal range is contrary to such observations. Therefore, the current findings are unlikely to be reflective of just the simple effects of the illness of schizophrenia on neurocognitive performance alone. If the current findings specifically related to the schizophrenia group with cannabis use are considered to be a mere reflection of the
effects of the illness of schizophrenia alone, then one would expect performances falling even in the probable impairment range. However, this was not the case in the present study.

Despite there being mainly poorer neurocognitive performances demonstrated by schizophrenia patients with cannabis use on a number of executive function domains in comparison to those in the matched-control group, there were no significant differences shown in performance in the domains of Prospective Memory, Verbal Fluency and Emotion-based Decision-making. These results potentially suggest that schizophrenia patients with cannabis use show nominal disruptions in performance in these particular executive function domains. In the current literature review, no research to date has been located where measures assessing the domain of Prospective Memory have been used to directly examine the neurocognitive performance of schizophrenia patients with cannabis use in particular. Therefore, a comparison of the results on this executive function domain to past findings is difficult. However, in a meta-analytic review of 11 studies examining prospective memory performance in schizophrenia patients, impairments were found on time-, event-, and activity-based prospective memory tasks compared to controls (Wang, Cui, Chan, Deng, Shi, Hong et al., 2009). In addition, performances on time-based prospective memory tasks were demonstrated to be more impaired than performances on event-based tasks. It was considered by the authors that time-based prospective memory measures may require a greater level of self-initiation than tests of event-based prospective memory. Therefore, while the present findings may suggest that schizophrenia patients with cannabis use show nominal disruptions in this domain, in alternative it could also indicate that the event-based prospective memory measure used may not have sufficiently loaded onto prospective memory abilities. Previous research has also found no difference in
performance amongst cannabis-abusing patients in verbal fluency in comparison to non-
abusers (Mata et al., 2008; Schnell et al., 2009). The current results involving emotion-
based decision making abilities were somewhat inconsistent with Sevy and colleagues’ 
study (2007), where it was reported that both schizophrenia groups (i.e., both cannabis 
users and non-users) were found to be more cognitively impaired, and demonstrated 
worse performance on the Iowa Gambling Task, when compared to healthy controls. 
However, the healthy participants in this study were not matched for cannabis use and 
included six individuals who reported smoking marijuana less than 10 times in their 
lifetime, as well as individuals who did not report any cannabis use history. Therefore, it 
is possible that the measures selected in order to assess these domains may actually be 
sensitive enough measures in detecting deficits in executive function, but do not 
demonstrate specificity in identifying differences in this particular schizophrenia sub-
population.

While the Temporal Organisation of Behaviour was also measured by the 
Modified Six Elements test in the current study, a lack of significant difference in 
performance between groups on this measure may suggest that this particular test was 
also perhaps not sensitive enough, nor did not sufficiently load onto this particular 
executive function domain, in order to detect differences in these samples. It is also 
possible that the samples recruited in the current study may have high heterogeneity,
thus creating more variability within groups and making differences between groups 
harder to locate. However, as group differences were demonstrated on another measure 
of the Temporal Organisation of Behaviour (namely the Zoo Map task), as well as many 
other measures tapping into additional executive function domains, it is unlikely that 
this was the case. In addition, estimated premorbid IQ was found to have an impact on 
Modified Six Elements task performance and this could suggest that while this test may
assess an aspect of executive function, it may also rely upon other cognitive abilities specifically related to premorbid IQ. There has also not been any research located to date directly examining the performance of cannabis-using schizophrenia patients in particular on the Modified Six Elements test which limits the ability to compare and contrast the current results with previous findings.

**Level of executive function impairment between groups.** The different performances of the two groups, requires further comment. Due to the lack of clinically impaired performances observed in a significant proportion of the schizophrenia group with cannabis use and the expected performance of 1.0 - 2.0 standard deviations below the norm for cannabis-naive schizophrenia patients, it appears that cannabis use in schizophrenia may have relatively nominal clinical effects on executive function performance when compared to normative criteria. A possible explanation for this result may be due to cannabis use in schizophrenia being potentially associated with outcomes of a more preserving nature. Cannabinoids have been shown to possess characteristics serving to protect individuals from brain insult and are associated with improvements in a range of illnesses which are considered neurodegenerative in nature (Sarne & Mechoulam, 2005). Thus, the findings of the present study may be reflective of differential effects of cannabis on the brain of individuals with schizophrenia, as opposed to a healthy brain, potentially as a consequence of neuroprotective effects.

As the examination of impairment level was based on normative criteria, it is also reasonable to consider that schizophrenia patients with cannabis use may represent a distinct schizophrenia sub-population that has specific executive function abilities remaining at a non-impaired level when compared to individuals with schizophrenia who are cannabis naive. It has been postulated that the onset of psychosis in this subgroup may be aetiologically different to non-using schizophrenic patients, such that
Cannabis use may serve as a catalyst to the onset of the illness in these individuals who may already possess better premorbid adjustment, social skills and hence a better prognosis, than their non-using counterparts (Dixon et al., 1991; Leeson et al., 2011; Rodríguez-Sánchez et al., 2010). It has also been suggested that this sub-group may have a lower vulnerability to the illness compared to those patients whose illness onset occur independent of the context of cannabis use (Schnell et al., 2009). Therefore, it is possible that such individuals already have better cognitive abilities due to not possessing as many neurodevelopmental risk factors, as well as having more enhanced prognostic characteristics (Leeson et al., 2011). Findings from Kumra and colleagues’ study (2005) showed that a history of cannabis use/dependence was associated with better FSIQ, as well as better VIQ, scores which also suggests the presence of better cognitive adjustment in cannabis-using schizophrenics. The lack of clinical impairment demonstrated by schizophrenia patients with cannabis use in the current research is consistent with the theme that has emerged from previous studies suggesting better neurocognitive performances in this group when compared to non-using schizophrenia patients.

The Effect of Cannabis-Use Status on the Recovery of Executive Function

Cannabis-use status (i.e., current users and non-current users) was mainly not found to have an impact on executive function performance, when controlling for the effects of duration of use (although there were a few notable exceptions to this, as discussed below). In other words, in general, cannabis use cessation or abstinence was not associated with the recovery of executive function. These results are also somewhat consistent with previous findings indicating no significant differences between patients with current cannabis dependence and patients without a current cannabis dependence diagnosis (which included both former users and those with minimal or no use) (Rabin
et al., 2013). However, in the present study this was not the case for performance on Letter Fluency, such that current cannabis users demonstrated better performance on this task compared to non-current users. A possible explanation for this contrasting result may be related to premorbid IQ being shown to significantly influence performance on the Letter Fluency measure, in the earlier analyses of the current study. Therefore, this finding could provide possible further evidence for current cannabis users representing a group of individuals with better premorbid IQ, independent of whether or not they have the illness of schizophrenia. Further, it is plausible that individuals with better premorbid IQ may be more likely to continue cannabis use due to possessing the abilities required to continually seek avenues in order to maintain their drug use. In a recent study which specifically compared the relationship of cannabis use to premorbid IQ in a group of first episode psychosis patients, results showed that those patients who had ever smoked cannabis in their lifetime had higher premorbid IQ than those who had never used cannabis in their lifetime (Ferraro, Russo, O’Connor, Wiffen, Falcone, Sideli et al., 2013). However, as the current study controlled for premorbid IQ through the matching process, the findings may not solely be related to premorbid IQ (as measured by an estimated verbal premorbid IQ measure). Another possible explanation for these results are in line with previous suggestions that this subgroup of schizophrenia appears to demonstrate characteristics of having a less severe form of the illness in relation to neurocognitive abilities and therefore remain relatively cognitively preserved once psychosis develops potentially in the presence of early cannabis use. Findings from Barnett, Salmond, Jones, and Sahakian’s (2006) study indicated that superior cognitive function (i.e., cognitive reserve) may act as a protective function from cognitive decline. Cognitive reserve is defined as the ‘individual differences in how people process tasks which allow some to cope better than others with brain
pathology’ (Stern, 2009, p. 2016). In other words, individuals with higher cognitive reserve are less affected by the same extent of neurological damage caused by either the effects of the normal aging process, or from the effects of unhealthy aging (i.e., the result of illnesses which may serve to compromise cognitive function). Barnett and colleagues (2006) concluded from their results that this higher level of cognitive function may impact on neuropsychiatric disorders by either influencing the risk for developing the disorder, the expression of illness symptomatology, or the functional outcome of the individual. Therefore, the current results suggest that it may not be that cannabis is neuroprotective in nature, but instead findings implicate the possibility of a higher overall cognitive reserve in individuals who may belong to this specific schizophrenia subgroup.

**The Effect of Length of Abstinence on the Recovery of Executive Function**

The findings of the current study also showed that the length of abstinence was mainly not associated with the recovery of executive function, independent of duration of use. More specifically, shorter abstinence periods were not related to poorer performance even after duration of use was taken into account. Surprisingly, it was additionally found that former cannabis users with an abstinence period of less than 5 years demonstrated better skills in the Temporal Organisation of Behaviour compared to former cannabis users with an abstinence period of equal to, or greater than, 5 years, although this result was shown for performance on the Zoo Map measure only. This is somewhat consistent with previous findings which showed that in addition to frequency, recency of cannabis use was also associated with better neurocognitive performance related to attention/processing speed and executive function in schizophrenia patients (Coulston et al., 2007). Stirling and colleagues (2005) also found that schizophrenia patients who had sustained their cannabis use at follow-up demonstrated better
neurocognitive performance on a variety of measures (i.e., design memory, verbal fluency, object assembly, block design, picture completion, picture arrangement, face recognition memory), than those individuals who did not continue their use until this time. An explanation for this finding may involve the possibility that those individuals with more recent use may still possess intact temporal organisational skills even after cannabis use cessation. It could also be considered that perhaps these abilities begin to reduce over time from the lack of exposure to drug-obtaining and drug use maintenance activities, as well as the lack of rehearsal of the behaviours necessary to achieve these objectives. This is a plausible explanation considering the temporal organisation of behaviour involves temporally organizing steps of a process which serve as a guide in selecting appropriate behaviors required to complete tasks (Fuster, 1989). It could be also speculated that such processes are considered to be involved in the perpetuation of drug use. Results of the current study suggest that these abilities also appear to be intact, irrespective of the presence or absence of the illness of schizophrenia.

The Validity of West’s Theoretical Model of Executive Function

While there was no specific hypothesis outlined regarding the construct validity of West’s (1996) theoretical model of executive functioning, findings indicated the presence of an underlying structure on a number of selected tests of executive function in the current study. The executive function measures which significantly loaded onto factor 1 (namely Mental Control and Self-Regulation) were those which were guided by West’s theoretical model. In addition, the executive function measures which were added for exploration due to not appearing to be accounted for in West’s model (i.e., Verbal Fluency and an Emotion-based Decision-making task) seemed to either load onto a separate component or failed to meet criterion for PCA. The overall results appear to not only in part, confirm the construct validity of West’s theoretical model of
executive function, but also provide support for the convergent validity, as well as divergent validity, of the model. Such results are also in part, supported by Num’s (2006) findings. It is possible that the additional executive function domains that weren’t accounted for in West’s model are not in fact, reflective of ‘pure’ executive function domains due to having loaded onto a different component or not being able to be included in PCA. This may be due to such measures tapping into other neurocognitive domains in addition to those falling under the executive function umbrella. While tests of verbal fluency (namely phonemic fluency) are one of the most frequently utilised measures in the assessment of executive function (Baddley, 1996; Baldo et al., 2001; Stuss & Levina, 2002), they also are known to activate non-frontal brain areas (Frith, Friston, Herold, Silbersweig, Fletcher, Cahill et al., 1995; Paulesu, Goldacre, Scifo, Cappa, Gilardi, Castiglioni et al., 1997). Interestingly, an additional factor was produced as an outcome of the analysis, namely ‘Maintenance of Intention for Future Action’. A possible explanation for why the event-based prospective memory task loaded onto a different factor to factor 1 in the PCA, may have been due to the specific measure that was selected in the current study not being sensitive enough to tap into the true prospective memory construct. Similar to Wang et al.’s (2009) conclusions, time-based prospective memory tasks have been thought to place a greater demand on self-initiation for successful performance due to the lack of external cues provided in such a measure and consequently more heavily relies on executive functioning processes (McDaniel & Einstein, 1993). In addition, the result of Kinch and McDonald’s (2001) study, suggest that successful performance in an event-based prospective memory task was primarily attributed to retrospective memory abilities. Therefore, it is possible that the abilities assessed by this particular type of prospective memory task may not just reflect a more crucial underlying executive function process
such as retrospective memory, but in addition may tap into abilities falling outside of the executive function domain alone. It is also reasonable to consider that Trial 3 of the Color-Word Interference subtest of the D-KEFS may not just reflect the inhibition of more dominant, habitual responses, but also measure the maintenance of information required to perform a future action.

It has been argued that while various neuropsychological measures may have good face validity, demonstrated high construct validity is imperative in order for such measures to represent a construct accurately (Salthouse et al., 2003). Therefore, results suggest that the majority of the executive function measures which loaded onto factor 1 demonstrate an ability to be sensitive to the executive processes conceptualised by West’s model, but in addition they also demonstrate specificity in being able to tap into these specific neurocognitive processes as opposed to others.

In order to conduct the PCA, the sub-samples were combined due to their small sizes. As it was considered in previous literature (e.g., Solowij & Michie, 2007) that cannabis users demonstrate deficits on cognitive measures similar to those shown in schizophrenia patients, there is a chance that the sub-samples in the current study are not all that dissimilar in cognition factor structure. Therefore, combining the samples would be appropriate. However, it is considered that if the sub-samples are indeed dissimilar to each other then this may help to explain why some executive function measures did not load onto factor 1. Considering the PCA was intended to be exploratory in nature, the results of this analysis were also not used in further analyses and therefore, the interpretation of results should only be considered on a theoretical basis. Prospective studies with larger samples should seek to further examine the factor structure of cognition in schizophrenia patients with cannabis use, and cannabis users with a similar cannabis use history, in order to clarify any similarities or dissimilarities.
It is also acknowledged that the current study did not aim to examine the actual hierarchy of functions from West’s (1996) hierarchical model of executive function. However, was considered that an analysis of this type would require much larger samples. Future studies should look to examine the hierarchy of functions in West’s model in patient populations in order to assist in further evaluating the validity of the hierarchical nature of the model.

As the current study is the only study to date to have utilised this theoretical model of executive function to guide test selections in order to assess the executive functioning of individuals with schizophrenia, further studies are warranted to replicate the present findings. Taking into account the abovementioned results, future investigations should also consider the use of a time-based prospective memory measure in order to better clarify the role, as well as confirm or disconfirm the inclusion, of this particular cognitive domain in the executive function model. However, the assessment methodology of the current study may provide a more effective approach to future research, particularly when attempting to comprehensively assess and fractionate the executive function system.

Part B

The Relationship Between Executive Function and Functional Outcome

Findings from the present study not only showed that different aspects of executive functioning were predictive of ‘real world’ functional outcome in schizophrenia patients with cannabis use, but that these aspects also moderated the level of functional outcome in different groups. From the variety of executive function measures administered in the current research, it was found that performance on the specific measures of Digit Span and Symbol Search significantly predicted performance
in particular areas of functional outcome for schizophrenia patients with cannabis use, in comparison to that for the matched-control group.

Findings suggest that performance on Digit Span (a measure used to assess Retrospective Memory), was significantly related to those functional outcome skills associated with hygiene and grooming. It can be speculated why this aspect of executive functioning would be related to this particular functional outcome sub-domain. It is reasonable to consider that Retrospective Memory, which involves the maintenance of task-relevant information online and provides a reference by which a task sequence is formed (Fuster, 1989), has particular importance in maintaining adequate independent skills in hygiene and grooming. Schroots, Dijkum, and Assink (2004) define retrospective autobiographical memory as the ability to retrieve certain memories, experiences, or past events in the present time. Dritschel et al. (1998) argued that participants with traumatic brain injury would be able to plan further activities more easily if they first tried to retrieve specific autobiographical memories of where they have executed similar activities in the past and described step-by-step what they did. In addition, Burgess and Shallice (1997) argued that the application of retrospective memory processes, in particular those that are implicated in the recollection of previous experiences play a critical part in prospective memory (i.e., the set of abilities that enable an individual to carry out a future intention or plan-following behaviour). In support of this, Kinch and McDonald (2001) also considered that a crucial component of remembering the intention to commit a future action or task (i.e., prospective memory) is considered to be largely retrospective in nature. Therefore, it appears that retrospective memory processes in some form have the capacity to assist individuals to carry out planned future intentions and one could expect such processes to be involved in the daily requirements of hygiene and grooming activities.
While in the current study retrospective memory has been considered a component of executive function in West’s (1996) theoretical model of executive function, it is acknowledged that the retrospective memory does include some more general cognitive abilities that are not necessarily specific to the frontal lobe system. However, Fuster (2000) refers to retrospective memory as short-term memory or sensory working memory and uses the term ‘active short-term memory’ to encompass the construct (p. 67). It has also been well documented that short-term active memory involves prefrontal neurons (e.g., Funahashi, 1989; Fuster, 1973; Niki, 1974). In addition, West (1996) conceptualises retrospective memory in his model as involving the retrieval and maintenance of information that is task-relevant from its storage in memory and is conceptualised to be similar to working memory. Much consistency between the types of memory deficits experienced by patients with lesions of the frontal lobe and by healthy older adults has been observed due to both types of subjects demonstrating deficits on measures of memory which are thought to heavily require processes that are strategic in nature and hence, executive functioning (Moscovitch & Winocur, 1992). Further, it is important to note there have been a number of measures utilised when assessing retrospective memory abilities in the literature. Some of these include span, working memory, recall and recognition type measures. In the current study, two measures were used in an attempt to assess retrospective memory abilities, namely Digit Span (forwards assessing span, and backwards assessing working memory) and Zoo Map recall (assessing free recall). While it is acknowledged that total Digit Span provides a combination of span, as well as working memory abilities, previous research has also utilised forward Digit Span as one approach to assessing retrospective memory abilities (Maylor, Smith, Della Salla, & Logie, 2002). The authors described retrospective memory being usually assessed by tasks that involve the
presentation of information that is subsequently required to be recalled or recognized following a cue. In addition, the results of Maylor and colleagues’ (2002) factor analytic study showed that more traditional Retrospective abilities (as measured by free recall and recognition) and working memory abilities (as measured by Digit Span and Sentence Span) loaded highly on one factor in a sample patients with Alzheimer’s Disease and healthy older adults.

It is noted that the findings of Dickinson et al.’s (2008) study indicate that the neuropsychological impairments associated with the illness of schizophrenia relative to healthy control subjects is largely mediated through a common ability factor and that further analyses revealed direct diagnosis effects on verbal memory and processing speed. Therefore, it is reasonable to consider that processing speed and simple maintenance working memory may have a more direct impact on the everyday outcomes of schizophrenia patients based on such results. However, it may be erroneous to apply the same conclusions about the cognition of schizophrenia patients with cannabis use, particularly because the current study’s results related to impairment levels (in conjunction with previous findings) suggest that this subgroup of the schizophrenia patients may be dissimilar with regard to cognitive abilities.

Findings also showed that performance on Symbol Search (used to assess Interference Control) is predictive of performance in the functional outcome areas of interpersonal skills, cooking, resource utilization, medication management, as well as overall functional outcome. These results are suggestive that the ability to deal with interference or conflict from recently presented information that was once relevant, but is now irrelevant, could be necessary to maintain independence in the abovementioned areas and that these specific areas may also be important to the overall functional outcome of this particular subgroup of individuals with schizophrenia. This could be
due to the possibility that poorer interference control abilities may limit the capacity of individuals with schizophrenia to filter out previously attained information (that is no longer relevant to the situation at hand) and adapt to new situations. It has been considered that interference control abilities help to clear inappropriate information to the task at hand from retrospective memory storage (West, 1996). It is possible that the abovementioned sub-domains of functional outcome (as opposed to the sub-domains of personal management, clothing, basic skills, home maintenance, money management, and general occupational skills) may be more related to interference control deficits in this particular schizophrenia sample. One could assume that such independent living skills are not entirely guided by routine, but instead may involve modified action sequences depending on the individual’s day-to-day circumstances (i.e., presenting the individual with new information or demands). For example, this could occur when an individual receives a phone call in the middle of following a recipe. Whereas the other sub-domains not predicted by interference control abilities could either possibly subscribe to more basic cognitive skill functions or even those cognitive abilities that were not assessed for in the current study. It is also considered that proactive interference is a major contributing factor to memory failure and in an attempt to resolve the effects of interference from prior learning or encoding, individuals will typically slow down and employ some type of cognitive control strategy (Persson & Reuter-Lorenz, 2008). For example, this may involve either efforts to make a mental note of where the individual left off before the interference/distracttion, or even using a compensatory approach such as marking the recipe at the interrupted step. Gaining a better understanding of the nature of the neurocognitive domains which may serve to significantly contribute to performance in specific functional outcome areas has the
potential to more effectively guide cognitive rehabilitation efforts and ultimately increase their effectiveness and success.

Interestingly, the predictors identified as being significantly related to outcome in the current study are in fact the variables that are not specific to executive functions alone. While Symbol Search involves a measurement of interference control, it is also a measure of processing speed. In this test, the participant is required to match a symbol to an identical target that is displayed among several distractor stimuli that share similar physical features. Interference control is assessed through the selection of correct matches identified from the variety of distractors and speed is assessed by the number of correct items the participant completes within the time limit. Definitions of interference control commonly involve reference to the selection of relevant information and the ignoring of irrelevant information (Dempster, 1993; Harnishfeger, 1995; Nigg, 2000). In a study examining the relationship between inhibition and interference control, the authors assessed ‘resistance to distractor interference’ with tasks in which participants were required to select targets that were presented with irrelevant distracters (Friedman & Miyake, 2004). For example, the authors utilised the Eriksen flanker task (Eriksen & Eriksen, 1974) to measure this construct in which participants were required to identify a target letter that was presented either alone or with response-incompatible letters beside it, as quickly as possible without sacrificing accuracy. It is considered that ‘resistance to distractor interference’ is being assessed when distracting information is presented simultaneously with the target information and is irrelevant to the response required (Friedman et al., 2004). It would be reasonable to assume that the approach in which to quantify interference control abilities would inevitably involve not only determining one’s ability to control interference/distraction (i.e., by calculation of accuracy via a number of errors score), but also the efficiency of one’s ability to control
interference/distract (i.e., by calculation of the speed in which one can complete the task). Therefore, the examination of one’s performance on such measures in the context of both accuracy and speed seems fitting to determine an individual’s success on these tasks. As the current findings also indicate that Trail Making Test performance (which was also used as measure of Interference Control) did not significantly predict functional outcome, this may suggest that interference from distraction could be more directly related to the functional outcome domains of interpersonal skills, cooking, resource utilization, medication management, as well as overall functional outcome, compared to abilities that involve more of an active suppression process.

In addition, it is acknowledged that while there are some functional outcome domains assessed by the Independent Living Skills Inventory that apply more to a patient population, the current study required an inventory that was considered a valid instrument to utilise in the assessment of this specific clinical population. As mentioned previously the purpose of the regression analyses was to identify whether there is potential for improvements to specific cognitive abilities which in turn may affect associated functional outcome. Without a comprehensive assessment of a number of functional outcome domains, the clinical relevance of potentially targeting the specific functional outcome domains deemed to be involved in patient independent living skills would be lost.

These results are not only in line with previous research suggesting a significant relationship between executive functioning and functional outcome, but also extend previous findings by being able to identify which specific aspects of executive function (according to a theoretical model of executive function) significantly predict particular sub-domains of functional outcome. By using a range of measures to assess the different theoretical components of executive function and identifying which of these have better
predictive ability in relation to ‘real world’ functional outcome, we were able to more comprehensively evaluate this relationship as well as potentially increase the ability to detect differences between groups on this multi-faceted and complex neurocognitive domain.

The results demonstrating moderation effects indicate that the abovementioned measures in particular also have greater predictive power for schizophrenia patients with cannabis use than they have for healthy matched-controls with a similar cannabis use history. One explanation for this finding could be related to previous research suggesting that cannabis may have differential effects on individuals with schizophrenia, in comparison to healthy individuals (Jockers-Schrübl et al., 2007). Due to a potential higher cognitive reserve (as suggested by their cannabis use history), it would be expected that any preservation in cognitive performance would translate to relative preservations in functional outcome areas. Therefore, it is possible that those with more preserved outcome (across similar functional outcome sub-domains) in this subpopulation may possess more preserved retrospective memory and interference control abilities. Such findings suggest that the measures assessing these specific executive function domains could be considered as useful tools in predicting the functional outcome of this subgroup of individuals with schizophrenia, particularly in relation to identifying areas for improvement regarding the associated day-to-day independent living skills.

**Practical Applications of the Findings**

Given the significant association between cognition and functional outcome in schizophrenia, over-and-above the effects of positive, negative and disorganisation symptoms (Green, 1996; Green et al., 2000), it is considered imperative that both researchers and clinicians look to develop specific and effective strategies in order to
improve cognitive function in this clinical population. The current study demonstrates that through comprehensive and more construct-targeted assessment approaches, it is possible to identify appropriate strategies that are both practical and customised to the individual’s specific deficits. The treatment of cognition in schizophrenia has been largely influenced and inspired by the field of neurological impairment rehabilitation (Medalia & Choi, 2009). The cognitive problems associated with the ‘dysexecutive syndrome’ are considered to represent a major challenge to the functional adaptation and recovery of individuals affected by such deficits and consequently, serve as crucial rehabilitation targets (Hewitt, Evans, & Dritschel, 2006). Therefore, clinical neurocognitively-based rehabilitation techniques, particularly those focused on the training of executive skills, are ideally suited to address the relationship between cognitive dysfunction and functional outcome.

The present findings have value in that the current neurocognitive assessment methods utilised can help to possibly attribute performance in a number of functional outcome areas, specifically to difficulties in retrospective memory and interference control abilities in schizophrenia patients with cannabis use. The results also indicate that this relationship mainly exists between retrospective memory and interference control, and various functional outcome areas, in comparison to the other executive function domains assessed. Such findings suggest that targeting these specific executive function domains in rehabilitation efforts may not only facilitate improvements in performance on measures assessing these particular executive function domains, but may also translate to performance improvements in day-to-day real-world functional outcome areas in this subgroup. This notion is supported in the literature which proposes that cognitive enhancement in individuals with schizophrenia may not just generalise to neurocognitive task performance, but may also be observed in an
individual’s performance across everyday activities particularly if the skills required in such activities tap into similar neurocognitive domains (for discussion, see Medalia & Choi, 2009).

There are a number of rehabilitation programs which have been developed in order to remediate cognitive impairments more specific to executive function, in schizophrenia patients. The intention of cognitive remediation approaches is to assist individuals to develop cognitive skills which are deemed fundamental in helping to improve their function in day-to-day activities (Medalia & Choi, 2009). Some cognitive rehabilitation interventions have been designed to target a number of neurocognitive domains which include those that involve executive function abilities (Bell, Bryson, Greig, Corcoran, & Wexler, 2001; Bellack, Dickinson, Morris, & Tenhula, 2005). Other intervention approaches are tailored in order to target more specific executive processes, such as working memory, cognitive flexibility, and planning abilities (Wykes, Reeder, Landau, Everitt, Knapp, Patel, & Romeo 2007), and problem-solving abilities (Medalia, Revheim, & Casey, 2002). A well-validated intervention aimed at the rehabilitation of those executive function abilities involved in the self-regulation of behaviour is Goal Management Training (GMT) (Levine, Robertson, Clare, Carter, Hong, Wilson et al., 2000; Levine, Stuss, Winocur, Binns, Fahy, Mandic et al., 2007; Robertson, 1996; Robertson, Levine, & Manly, 2005). GMT is a theoretically derived cognitive training protocol based on Duncan’s theory of ‘goal neglect’ (Duncan, 1986; Duncan, Emslie, Williams, Johnson, & Freer 1996), which describes deficits in strategic self-regulation associated with the dysexecutive syndrome. The approach is a standardised, interactive manual-based cognitive rehabilitation program that aims at improving an individual’s attentional and organisation skills in order to improve the ability to achieve goal-directed plans. The program provides a specific focus on goal-directed behaviours found
in everyday contexts. GMT procedures encompass training 5 steps, with each emphasizing and corresponding to an important aspect of goal-directed behaviour. The strategy involves training individuals as a first step to ‘stop and think’ by taking pauses during the task at hand and direct their awareness to pertinent goals. Once relevant goals are selected at step two, the individual is then required to subdivide the goal into smaller and more manageable subgoals at step three. The fourth step trains the individual to encode and maintain the goal, and more simple subgoals, in memory. At step five, the outcome is then compared with and checked against the intended goal. This approach is repeated in the event that the action outcome is mismatched with the original goal.

GMT is considered to be a top-down approach that aims to train processes across several neurocognitive domains and incorporate different aspects involved in the stages of goal management such as attention and task orientation, goal definition, problem-solving, encoding, retention and retrieval strategies, and monitoring (Levine et al., 2000, 2007; Levaux, Larøi, Malmedier, Offerlin-Meyer, Danion, & Van der Linden, 2012). Such an approach aims to promote generalisation where different behaviours or activities that may not specifically be targeted in the actual GMT intervention may be also subject to improvements, or the skills trained can be applied to various other contexts that require the formulation of goal-directed plans (Levaux et al., 2012).

Levaux and colleagues (2012), sought to apply this method to a patient with schizophrenia suffering from executive deficits in a case study. In their research they applied the GMT strategies across three steps: (1) psychoeducation and learning GM steps; (2) training GM principles on pencil-and-paper tasks; and (3) training in practical, real-life situations. Results of the study showed improvements in planning and dominant verbal response inhibition, as well as increased care and attention to tasks (with the patient taking more contextual information into account). Progress was found
to be maintained 2 years later and continued to evolve, and generalisation of the effect of GMT was observed on both non-trained laboratory and non-trained everyday tasks. A significant increase in the patient’s self-esteem score was also found. Overall, the results of the case study suggest that GMT is a promising technique for the rehabilitation of everyday executive difficulties in people with schizophrenia. However, it was important to note that there was no change in impaired flexibility, response inhibition and attentional functions following the GMT intervention. In addition, working memory and language flexibility remain preserved, and non-verbal process speed remained slowed.

Beneficial effects on a number of executive function deficits have been demonstrated in patients with traumatic brain injury and older adults (Levine et al., 2000, 2007; van Hooren, Valentijn, Bosma, Ponds, Van Boxtel, Levine et al., 2007), as well as potentially for schizophrenia patients (Levaux et al., 2012), as a result of GMT interventions. However, the approach has rarely been utilised in the context of substance abuse. Alfonso and colleagues (2011), developed a program which not only included methods derived from the GMT protocol, but in addition also incorporated aspects of mindfulness-based meditation. Mindfulness-based meditation was considered to serve as an effective compliment to traditional GMT training methods in order to improve attention scanning and ‘reading’ of emotional signals involved in adaptive decision-making. Mindfulness-based mediation practices promote paying attention to the present moment, in a purposeful, non-judgemental, and emotionally aware manner (Kabat-Zinn, Massion, Kristeller, Peterson, Fletcher, Pbert, Lenderking, & Santorelli, 1992; Segal, Williams, & Teasdale, 2002). The use of mindfulness techniques has been considered a promising approach for the treatment of problematic substance-use related behaviours and supporting relapse prevention efforts (Bowen, Chawla, Collins, Witkiewitz, Hsu, Grow et al., 2009; Bowen & Marlatt, 2009; Witkiewitz, Bowen, Douglas, & Hsu, 2013).
Results of the study showed that the GMT and mindfulness meditation program significantly improved performance on working memory, selective attention/response inhibition and decision-making. The authors concluded from the findings of the study that improving competence in executive abilities may have the capacity to improve the clinical prognosis of substance abusers. However, it is important to note that there were no significant improvements in the neurocognitive domains of planning and flexibility following the GMT and mindfulness meditation program. It was considered by the authors that a possible explanation for this may perhaps involve the presence of impairments in other more basic, underlying skills. Shallice, Burgess and Robertson (1996) consider that an important process that serves to assist in appropriate strategy generation and planning is episodic memory retrieval. In other words, retrospective episodic memory processes. It is plausible that the recollection of previous similar experiences would be beneficial when attempting to formulate solutions to unfamiliar situations. It has been reported that retrieving more specific memories when devising strategies to low frequency activities (i.e., unfamiliar situations), is associated with more effective solutions as well as solutions containing more relevant steps (Dritschel et al., 1998). This suggests that the recollection of previous similar experiences can be beneficial for planning and problem-solving contexts. Einstein and McDonald (1990) propose that the aspect of an activity that involves retrospective memory relates to one’s ability to maintain information regarding action and context. Burgess and Shallice (1997) also consider the view that the earlier stages of intention creation are not only facilitated by executive control systems, but that such systems mediate the development of intentions which involve complex retrieval. These findings are once again, consistent with the view that retrospective memory processes play an important role in strategy generation and planning future intentions.
The current study is believed to be an important first step in evaluating the applications of more comprehensive neuropsychological assessment which has been guided by a theoretical model of executive function (West, 1996). Considering the potential practical applications of the current findings, further research is required in order to demonstrate whether rehabilitation methods aimed at training specific executive function deficits can improve performance in more practical, everyday situations. It has been consistently found that cognitive remediation efforts aimed at specific cognitive abilities is an effective approach for cognitive enhancement (Green & Harvey, 2014). However, it is considered that such improvements may not necessarily translate to functional change. With the view to improve the functional outcomes of individuals with the illness, it is considered that the treatment of cognitive dysfunction as a sole approach may fall short in its effectiveness (Harvey, 2007). To enable a more effective translation of cognitive improvements into successful functional change, it is proposed that other forms of intensive support or assistance may be required which target those factors outside the illness that appear to also influence outcomes (e.g., demographics and psychosocial variables) (Harvey, 2007). Bell and colleagues (2008) conducted a study evaluating the effects of Neurocognitive Enhancement Therapy (NET) in conjunction with a supported employment program (VOC) on the enhancement of functional outcomes in patients with schizophrenia and schizoaffective disorder. The NET+VOC program consisted of computer-based cognitive training, work feedback and a social information information-processing group. Findings from the study suggested that the combination of cognitive retraining methods with additional skills training in other areas has the capacity to promote more beneficial functional gains. In a recent study conducted by Bowie, McGurk, Mausbach, Patterson, and Harvey (2012), individuals with schizophrenia living in community settings were randomly assigned to
either a cognitive remediation, functional skills training, or combined treatment group. It was reported that those patients who either received cognitive remediation, or the combined treatment, showed improved neurocognitive test performance from baseline to end of treatment. At a 12-week durability assessment, these effects were observed to be maintained. However, improvements in neurocognitive performance were not observed following the functional skills training alone intervention. Those individuals who either received functional skills training, or the combined treatment, demonstrated improved social competence (as measured by the Social Skills Performance Assessment) from baseline to end of treatment. In addition, patients who either received functional skills training, or the combined treatment, showed improvements in functional competence (as measured by a computed composite score from three measures of everyday functional skills) from baseline to end of treatment. However, the functional competence improvements demonstrated following functional skills training were no longer significant at the 12-week durability assessment when compared to baseline. It was noted that greater and more durable functional competence improvements were demonstrated in those patients who were assigned to the combined treatment group. Improvements in real-world community activities (as measured by the Specific Levels of Functioning Scale; Schneider & Struening, 1983) were found to be greater in patients who received the combined treatment, compared to the functional skills training group. Patients who were assigned to the either the functional skills training group, or the combined treatment group, showed improvements in real-world occupational skills (also measured by the Specific Levels of Functioning Scale) at baseline to end of treatment and these effects were maintained at the durability assessment. However, the treatment effects in the combined treatment group were found to be significantly larger than the functional skills group and the cognitive remediation
group. Overall findings from the study suggest that cognitive enhancement strategies in isolation do not result in functional improvements in real-world behaviour. The authors concluded that the transfer of cognitive improvements to everyday functioning is more likely to occur in the context of receiving supplementary functional skills training in addition to cognitive remediation intervention. While previous findings have indicated that the use of cognitive remediation strategies as a standalone treatment may be insufficient in translating to improvements in functional behaviour, it is considered that an ideal approach may involve treating professionals placing additional focus on the most appropriate avenues in supporting the efforts of schizophrenia patients and for empirical studies to aim to identify which of these support methods are most effective (Harvey, 2007).

In order for cognitive rehabilitation efforts to be optimal in their effectiveness, there is also a need to better profile the patient samples of interest and the precise nature of the deficits needing to be addressed. Identifying different intervention factors that might serve to maximise the effectiveness of cognitive remediation efforts is also an area that has the potential to optimise the efficacy of future intervention efforts (e.g., different instructional techniques, learning and presentation formats, and materials used). There is also a need for the continued development of appropriate outcome measures to ensure that interventions translate into meaningful changes in real-world functioning. Further, future research should also not only aim to determine whether training in executive processes can be effectively translated into benefits in daily life, but to assess whether these benefits are maintained over time.

Finally, as only a little more than half of the variance of a number of functional outcome areas were explained by performance on Digits Span or Symbol Search in the current research, this suggests that other variables which were not examined in this
study could also have a significant impact on functional outcome. Therefore, our results should be regarded as preliminary in nature. In addition, such results suggest that if only certain aspects of executive function are significantly related to various areas in the functional outcomes of schizophrenia patients with cannabis use, then other neurocognitive domains may serve to also be targeted or emphasized in a strength-based approach to cognitive training efforts. In other words, effective cognitive rehabilitation protocols involving this particular clinical population should not only involve cognitive training in identified deficits areas, but should also focus on making use of their intact neurocognitive abilities. The current findings have clinical importance in that they support the concept of developing interventions to treat neuropsychological deficits that may contribute to the more successful functional outcomes of such patients.

**Limitations and Future Directions**

The results reported in the present research need to be assessed and interpreted within the context of its limitations. Firstly, findings of the study should be considered to be exploratory in nature considering the small sample sizes. However, unlike some of the previous studies, the current research sought to collect more detailed information about potential confounding variables which have been found to have a relationship with cognitive impairment. These factors include cannabis use parameters such as frequency, severity/quantity, duration and time since cannabis use cessation (i.e., recency). Also, individuals with other neuropsychiatric or neuromedical illnesses were excluded from the study. Since the recruitment of participants also involved recruiting suitable matched-pairs (based on a strict matching criteria on a range of variables in order to restrict the possible impact of these potential confounds), the end result of smaller sample sizes was difficult to avoid but arguably, offset by the reduction in
extraneous variation in the sample. Prospective studies with larger sample sizes that maintain this strict matching process will help to extend the current findings.

Another potential limitation in the current study involves combining both former users and current users in the primary ANCOVA analyses (due to small sub-sample sizes). However, as previously mentioned a carefully matched-controls design was used in an attempt to control for any confounding influence contributed to by variations in crucial cannabis-use indices (which have been considered to have an impact on cognitive performance) across individuals. Future studies could look to further examine the separate cannabis status groups across the executive function measures of interest. However, it is acknowledged that there would be difficulty in doing so reliably given that the time since cessation variable is largely self-report in nature. In addition, it is important to note the impact of small sample sizes on the validity of specific statistical approaches such as PCA and multiple regression analyses. However, the sample size was deemed sufficient for exploratory PCA. While findings from some of the multiple regression analyses failed to reach statistical significance, it is still considered important to particularly consider the effect sizes of all correlational analyses as indicated by the shared variance statistic. It is acknowledged that as \( p \) values are heavily influenced by small sample sizes and also do not provide an indication of the size or importance of the observed effect, future studies with larger samples may inevitably produce additional statistically significant results. As the shared variances found in the current study are notably similar to Green et al.’s (2000) meta-analytic findings regarding the range of detected effect sizes for the relationship between cognition and everyday outcomes in schizophrenia patients, the results of the present research are in support of previous findings. Therefore, future research with larger samples is also warranted for further evaluation of similar effect sizes. The small samples size of the current study also inevitably reduces
the statistical power of being able to detect what could possibly have been significant relationships. However, as mentioned the results of the present research are not all that dissimilar from previous findings.

While the Holm-Bonferroni correction method is not considered as conservative in controlling for family-wise Type I error as the Bonferroni approach, as with all corrections the likelihood of Type II error is also increased. Therefore, truly important clinical differences may be deemed non-significant following correction. It is considered that the non-significant results emerging from the current study following Holm-Bonferroni adjustment are plausibly a consequence of the small sample size and reduced power, instead of reflective of the fact that none of these relationships exist. Given the similar effect sizes reported in previous research related to the amount of variance contributed to functional outcome by cognitive variables in the schizophrenia population (and thus, raising question against the likelihood that the null hypothesis is actually true), it is thought that it is entirely plausible for such relationships to not only exist, but also have statistical significance. Therefore, those results which had reached significance prior to Holm-Bonferroni correction have still been interpreted in the current study, with the precaution that at least some of these results may be truly reflective of Type I error. It is also considered that due to the small sample size, once again it is recommended that effect sizes be taken into account not just the overall significance level. Prospective studies should look to conduct similar comparisons with larger samples sizes in order to detect results of larger statistical significance and robustness.

It is also acknowledged that as the current study included matched-control subjects with cannabis use as a comparison sample, it is difficult to differentiate between exceptional performance and cannabis use associated impairment. In other words, the minimal impairment
shown in the present study could indeed be a reflection of schizophrenia patients with cannabis use being more likely to be cognitively intact. However, it may also be that the matched-control sample could be in some way cognitively impaired due to their cannabis use and that the patient sample was exceptional in their performance. In addition, it is possible that the cognitive signal for long-term cannabis use is relatively small in comparison to the signal for schizophrenia such that additional increments are difficult to detect. The latter would not be implausible as the cognitive deficits associated with chronic or heavy cannabis use are similar to those seen in schizophrenia, which could serve to narrow the gap between controls and patients. Although the similarities referred to here are related to deficits, the current study’s results indicate a significantly larger proportion of schizophrenia patients with cannabis use demonstrating performances in the clinically non-impaired range. While the current study did not aim to examine the cumulative effects of schizophrenia and cannabis use, future studies adopting a similar matched-control design, as well as including the addition of a cannabis-naive schizophrenia patient sample would help to further elucidate these relationships.

While it is acknowledged above that the current study did not have a cannabis naive schizophrenia group or a cannabis-naive healthy control group for comparison, this is the first study to directly compare between schizophrenic and non-schizophrenic samples with carefully matched cannabis use histories. We also categorised our subjects according to their current cannabis use status (i.e., currently using schizophrenia patients with cannabis use, non-currently using schizophrenia patients with cannabis use, currently using healthy controls with a similar cannabis use history and non-currently using healthy controls with a similar cannabis use history) in subsequent analyses. Rabin and colleagues (2013), also parsed their participants in terms of current cannabis use status, but in addition included a group of patients containing 8 subjects
with minimal/no lifetime use. The current study also recruited a similar group, but instead found individuals with no reported historical use at all (i.e., not even to a minimal extent). The general pattern of recruited schizophrenia subjects in the present research included either those patients who reported regular current or former use, or no lifetime use at all. However, only 4 cannabis-naive individuals with schizophrenia were recruited over a period of well over a 24-month timeframe. The small sample size of this similar type of subgroup in Rabin and colleagues’ study may be reflective of related difficulties faced when recruiting from this population. It is not entirely clear why such limited numbers in this particular subgroup sample were achieved. One possible explanation is that similarly to Rabin and colleagues’ (2013) study, recruitment was community-based with only outpatients being included in these studies. It is reasonable to consider that the cohort of individuals who are cannabis-naive may have much smaller numbers in the community due to differing illness presentation, than there are in the inpatient settings. The current study did not attempt to recruit individuals with schizophrenia from an inpatient setting in order to reduce the likelihood of the acute effects of the illness influencing results. The premise suggesting that schizophrenia patients with cannabis use have better premorbid adjustment, social skills and prognosis, supports this possibility. Future studies including all possible comparison groups (i.e., patients with cannabis use (both current and former users), cannabis-naive patients, healthy matched-controls with a similar cannabis use history (both current and former users), and cannabis-naive healthy normals), will not only allow for more informative between-subject comparisons, but will overall increase the generalisability of findings. In addition, prospective investigations ascertaining the population dispersion in both inpatient and outpatient settings in relation to patients with cannabis use versus patients with no reported historical use, may help to provide a better
understanding of the overall schizophrenia population characteristics, but may also
serve to either additionally confirm or disconfirm the hypothesis related to better
premorbid adjustment in the cohort with cannabis use. Due to the cognitive
heterogeneity associated with this particular disorder (Joyce & Roiser, 2007), future
research should also look to adopt longitudinal designs that use within-subjects
approaches to statistical analyses so that not just cannabis use status, but the cumulative
effects of cannabis use over time, can be further examined within each of these groups.

A common limitation across many of the studies, including this one, when
investigating the relationship between cannabis use and neurocognitive performance
involves the ability to adequately measure the variability regarding different
concentrations of Delta-9-tetrahydrocannabinol (Δ⁹-THC). Over the years the Δ⁹-THC
content in cannabis has been seen to progressively increase with the average level of Δ⁹-
THC content from the 1960’s to 1980’s reported to approximate 1.5–3.5%, with
modern efforts to enhance its potency resulting in concentrations reaching up to 20%
(for discussion, see Adams & Martin, 1996). In addition to this, through more frequent
and deeper inhalation techniques experienced cannabis users are able to modify the dose
if desired, thus further altering concentration levels (Iversen, 2000). This issue poses
challenges regarding the range of variability in Δ⁹-THC concentration across users and
the difficulty in controlling for this factor in empirical research. However, by
controlling for differences in frequency, severity/quantity, duration of use and length of
abstinence through the matching process in the current study, the present research aimed
to address at least those measurable cannabis-use parameters which are associated with
variability in cannabis use. The objective measurement of Δ⁹-THC concentration in
future studies would help to address this issue and allow for more control when
considering the variations in cannabis use as a potential confound.
In the current study, we also did not directly examine the effects of frequency of use and severity/quantity on neurocognitive performance. However, as mentioned above, the present research did allow for the assessment of these parameters and attempted to control for any possible differences via the matched-pairs design. While the importance of taking into account the possible effects of these particular parameters in cannabis use research is acknowledged, previous research has suggested that duration of use may place more of a significant contribution to the development of neurocognitive impairment when compared to the cannabis use parameters of frequency of use or quantity (Solowij et al., 2002). Future investigations should look to closely examine the possible effects of frequency, severity/quantity, duration of use, and time since last use across all of the abovementioned relevant comparison groups in order to determine whether these parameters have differential effects depending on group membership.

As the current study only required the minimum of a 24-hour period of cannabis use abstinence, it is possible that for the individuals that were current users their results only represent the early stages of neurocognitive recovery, or quite possibly the remaining effects from intoxication. However, following Δ⁹-THC inhalation peak plasma concentrations and the associated psychotropic effects are thought to reach their maximum level within 15-30 minutes and that the intoxication effects of the drug begin to diminish within 2-3 hours (Grotenhermen, 2003). Previous studies have also adopted a 24-hour abstinence period in an attempt capture the narrow window which occurs between intoxication and drug withdrawal (Coulston et al., 2007; DeRosse et al., 2010). In a study conducted by Budney and colleagues (2003) the withdrawal symptoms and patterns following cannabis use abstinence were examined. Findings showed that the onset of withdrawal symptoms usually occurred during the first day following cannabis
use cessation and that the peak of withdrawal symptom effects occurred between 2 and 6 days. It was also found that most effects lasted between 4 and 14 days. However, the current study did aim to investigate effects associated with different lifetime use categories (i.e., across current users and abstinent users) and therefore a much longer period of abstinence prior to testing would have inevitably ruled out the ability to compare performance with ‘current’ users.

Another limitation of the current study is that the history of drug consumption was assessed using the self-report of subjects. Given the variability in cannabis use across individuals, it would be difficult to precisely calculate an individual’s history and pattern of substance use across their lifetime. Adherence to the 24-hour abstinence period was also assessed using self-report. However, it has been reported that information given by subjects about their drug use tends to be relatively reliable (Brown, Kranzler, & Del Boca, 1992; Harrison, Haaga, & Richards, 1993; Pope et al., 2001). Self-reports of substance use have also been found to correspond with urine screen results (Fowler, Carr, Carter, & Lewin, 1998; Pope et al., 2001). In addition, the quantification of various cannabis use parameters was also based on self-report. While it has been identified that self-reporting bias is a potential limitation of the current study, reporting the different aspects of their use is the best proxy that was available (for example, reporting time since cessation in comparison to actual measurement of this variable via longitudinal design). It is also acknowledged that the determination of the validity and reliability of self-report measures of drug use in people with schizophrenia is currently lacking. This may be particularly problematic given their difficulties with memory and other cognitive abilities. Future studies aiming to replicate the current study’s findings should consider the utilisation of drug-usage screening processes in
order to supplement the information provided in user self-reports and help to provide an overall more accurate picture of actual use.

**Conclusions**

The main aims of the present study were to examine the patterns of executive functioning of schizophrenia patients with cannabis use in comparison to otherwise healthy matched-controls with a similar cannabis use history. An examination of these complex neurocognitive profiles has clinical significance due to the reported relationship between executive function and the functional outcome of individuals with the illness. An additional aim was to also investigate the relationship between level of executive functioning and ‘real world’ functional outcome. The identification of specific functional outcome predictors is also considered a research area with important clinical applications due to its potential in not only being able to more effectively guide rehabilitation plans, but ultimately increasing their efficacy by offering specific information regarding possible practical rehabilitation modifications. For example, in order to better assist and support individuals with retrospective memory deficits, strategies aimed at improving hygiene and grooming skills may not only involve more structured approaches, but that these approaches could be chunked into smaller parts in order to reduce the number of cognitive and behavioural units held online and ultimately facilitate the more effective recall and implementation of these learned strategies. In addition, for those with difficulties in interference control, strategies aimed at improving interpersonal, cooking, resource utilisation and medication management skills could involve once again more structured approaches, but also include the repeated practice and rehearsal of scenarios where there are changing or interfering circumstances, or even with distractors present. Such rehearsal could help to enhance more fluency in behavioural adaptation to differing/interfering environmental demands
and possibly reduce the tendency for responses to be based on task-inappropriate habitual behavioural patterns.

The strengths of the current study lie in the comprehensive assessment of a multi-faceted neurocognitive construct thought to be related to functional outcome. While the results are encouraging, this study also highlights the difficulties and complexities associated in adequately assessing executive function. This is the first study to use this type of assessment methodology in a clinical population such as schizophrenia. The present findings also reinforce the importance of considering executive function as a complex cognitive construct that is not always adequately tapped into via the use of traditional executive functioning measures and this may help to explain the previous mixed findings. Despite the noted limitations in the present study, the comprehensive assessment of executive function has afforded an extension to the existing knowledge about the neurocognitive profiles of schizophrenia patients with cannabis use. This study also builds upon previous research by examining the relative contribution of different components of executive function in explaining performance in functional outcome. Specifically, the findings of this study suggest that schizophrenia patients with cannabis use reported to demonstrate inadequate functional outcome in the particular areas of hygiene and grooming, interpersonal skills, cooking, resource utilization, and medication management, as well as overall functional outcome related to independent living skills, may be partially due to less intact or poorer retrospective memory and interference control abilities.

The neurocognitive measures used in the current study represented a theoretical hierarchical model of the construct of executive function, allowing us to tap into a wide range of executive processes. However, what remains unclear is which particular facets of executive function contribute to the most crucial areas of functional outcome. Given
this identified gap, future research is needed in order to determine which aspects of functional outcome are the most important to successful independent living.

While further research is required to replicate the study’s findings, the current work suggests that neuropsychological evidence can be instrumental in identifying specific neurocognitive domains and their likely functional outcome correlates. The results of the present study and the applications of its findings, also suggest that tailoring rehabilitation plans utilising neurocognitive information specific to particular clinical subgroups has the potential to improve the functional outcomes of patients. Prospective studies should endeavour to build upon such approaches and while the future of research in the area may present its associated challenges, it also has the potential to offer considerable promise. ‘Schizophrenia in the past was a grim diagnosis with a poor prognosis. At the present time, it can probably be better described as a serious condition, with plenty of reasons to be hopeful’ (Green & Harvey, 2014, p. 7). The methodological approach of the current study is considered a first step in the development of neurocognitive process-specific training protocols for this particular subgroup of the schizophrenia population.
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Appendices

Appendix A: Structured Interview

Demographic Information
“I’d like to ask you a few questions regarding some personal information about yourself”

(1) What is your age? _____ years _____ months (DOB: _________)

(2) Gender       Male ☐   Female ☐

(3) How many years of full-time education have you completed? _____ years
What grades (on average) did you achieve? ______

(4) Have you experienced any of the following medical conditions/disabilities:

- Head/Brain injury ☐   specify ______________________
- Neurological conditions (e.g. epilepsy, MS) ☐   specify ______________________
- Mental Illness ☐   specify ______________________
- Intellectual disability/learning difficulties ☐   specify ______________________
- Stroke ☐
- Cardiac Arrest ☐

(5) Are you currently using medication? Yes ☐   No ☐
If yes, please specify______________________________

Approximately, how long have you been taking this medication? ____________

(6) Do you use drugs/alcohol (including cigarettes)? Yes ☐   No ☐
If yes:
Please specify and how often? ______________________(days per week)

Approximately, how much of the drug do you use per using-day ________(e.g., cones, joints)

Approximately, how long have you been using the drug _________(months/years)

When was the last time you used the drug?___________

Has your use of drugs/alcohol ever:

- Had a negative effect on your interpersonal relationships ☐   specify ______________________
- Interfered with your ability to attend/persist with work/school activities ☐   specify ______________________
- Put your physical safety (e.g. while driving a vehicle or operating machinery), at risk ☐   specify ______________________
- Resulted in legal issues (e.g. arrests for substance related disorderly conduct) ☐   specify ______________________
Appendix B(i): Advertisement for Clinical Participants – Cannabis Users

**RESEARCH STUDY**

Do you want to contribute to valuable new research???

This study is about schizophrenia, cannabis use and thinking processes. Your contribution would be most appreciated.

We’re asking for adults, both male and female aged between 18 and 55 years with a diagnosis of schizophrenia (no other mental illness diagnoses included), and who are also regular cannabis users (but do not use any other illicit drug), to come and be a part of this research. Participation is voluntary and confidentiality will be strictly maintained!!

If you agree to volunteer, you will be asked some questions about you (e.g., age, gender, educational level, health status, symptoms, and cannabis use), as well as asked to fill out a questionnaire about your mood. In addition you will also be asked to complete a range of tasks involving solving puzzles, planning trips and card games.

As a token of appreciation for your participation you will receive a $25 voucher for Coles-Myer.

The researcher Khristin Highet (Doctor of Psychology (Clinical) student), can be contacted on the following email address for more information:

k.highet@murdoch.edu.au

or on:

0415 494 551

OR

Alternatively, you can leave your contact details on the form provided at the reception desk, in order for the researcher to contact you.
Appendix B(ii): Advertisement for Clinical Participants – Non-drug Users

**RESEARCH STUDY**

Do you want to contribute to valuable new research???

This study is about schizophrenia, cannabis use and thinking processes. Your contribution would be most appreciated.

We’re asking for adults, both male and female aged between 18 and 55 years with a diagnosis of schizophrenia (no other mental illness diagnoses included), and who do not use any illicit drug, to come and be a part of this research. Participation is voluntary and confidentiality will be strictly maintained!!!

If you agree to volunteer, you will be asked some questions about you (e.g., age, gender, educational level, health status, and symptoms), as well as asked to fill out a questionnaire about your mood. In addition you will also be asked to complete a range of tasks involving solving puzzles, planning trips and card games.

As a token of appreciation for your participation you will receive a $25 voucher for Coles-Myer.

The researcher Khristin Highet (Doctor of Psychology (Clinical) student), can be contacted on the following email address for more information:

k.highet@murdoch.edu.au

or on:

0415 494 551

OR

Alternatively, you can leave your contact details on the form provided at the reception desk, in order for the researcher to contact you.
PARTICIPANT INFORMATION SHEET

Title: Relationships between schizophrenia and cannabis use on everyday adjustment

Application Number: 2009010

INVITATION TO PARTICIPATE
We invite you to participate in a study which we believe is of potential importance to people with schizophrenia. But, before you decide whether you wish to participate, we need to be sure that you understand:

why we are doing it, and
what it would involve if you agreed.

So, please read the following carefully and be sure to ask any questions you have. I will be happy to discuss it with you and answer your questions. You are also free to discuss it with others if you wish (i.e., family, friends, your local Doctor and / or your clinical treatment team).

You do not have to make an immediate decision.

PARTICIPATION IS VOLUNTARY
This is a research project and you do not have to be involved. Your medical care or clinical treatment will not be affected in any way if you choose not to participate. Also, if you agree to participate, you are free to change your mind and withdraw at any stage.

BACKGROUND TO THE STUDY

What is the research about?
My name is Khristin Highet. I am completing this research as part of my Doctor of Psychology (Clinical) degree through Murdoch University in Western Australia. I’m looking at the relationship between schizophrenia, cannabis use, thinking processes and everyday life skills.

Who is sponsoring it, and are they paying the researcher or her department to do the research?
I’m a post-graduate student of Murdoch University and the university is sponsoring this study. I will not be paid for conducting this research.

Why is the research being done?
I hope that the study will help treating professionals to make better informed decisions about treatment plans for people with schizophrenia. In addition, it may be of help when developing treatment plans for patients who may also use cannabis.
Who can participate?
I’m inviting both male and female adults with schizophrenia, aged between 18 and 55 years, and who do NOT have a history of serious head/brain injury, mental illness diagnoses other than schizophrenia, learning disability, chronic substance use (other than cannabis use), stroke and/or a neurological condition, to take part in the study.

How many other people have been asked to consider participating?
Around 60 participants will be included in the study. This will include people with schizophrenia who attend The Queen Elizabeth Hospital and the Lyell McEwin Hospital, or any other affiliated public mental health service under CNAHS.

What is involved if I choose to participate?
If you agree to participate, a testing session will be scheduled. During this session, I will then ask some questions about you (e.g., your age, gender, years of education, health status, cannabis use, symptoms) and your mood. This will take about 30-45 minutes. Afterwards, I will ask you to do some tasks looking at your reading abilities, memory, planning, attention and everyday skills, which will take about 60-90 minutes. Most people find these tasks enjoyable and you can have a break at any time.

With your permission, I will also ask a member of your treatment team, or your community support worker (if applicable), to fill in a questionnaire outlining your everyday skills. If you do not want your treatment team or support person to be involved, this will not stop you from being involved in the study. A family member or significant other may answer the questions related to your everyday skills.

Discomforts, Risks and Side Effects
Who should I contact if I am worried about any effects that I experience?
No risks or side effects are anticipated as a result of the current research. But, if you should experience undue emotional distress, or I observe a significant change in your condition during the research process, you can stop the session, and I will encourage you to contact your clinical treatment team for consultation. You can recommence the study at a later stage if you wish to.

What will happen to the information collected?
All information you give is confidential. No names or other information that might identify you will be used in any publication arising from the study. The information collected from the research will be stored in locked cabinets located at Murdoch University. Only my research supervisors and I will have access to the data.

What are my rights?
If you become injured during this study, and your injury is a direct result of the effects of study procedures, The Queen Elizabeth Hospital will provide reasonable medical treatment. Your participation in this study shall not affect any other right to compensation you may have under common law. Should you wish to obtain more information about your rights as a participant, you can contact the Executive Officer of the Ethics Of Human Research committee, on (08) 8222 6841.
IS THERE ANY PAYMENT FOR PARTICIPATION?
We understand that involvement in this study requires a time commitment and we are extremely appreciative of your participation and time given. As a token of appreciation for your participation you will receive a $25 voucher for Coles-Myer.

BENEFITS OF THE RESEARCH
I hope that this study will assist in helping people with schizophrenia to successfully transition out of hospital care and return to community living. However, these benefits may not directly affect you.

WHAT IF I HAVE A QUESTION ABOUT THE STUDY?
If you have any questions or concerns about your involvement in the study, you may contact the chief project supervisor, Dr Marjorie Collins via email: m.collins@murdoch.edu.au

The Central Northern Adelaide Health Service Ethics of Human Research Committee (TQEH & LMH) has approved this study.

Should you wish to speak to a person not directly involved in the study in relation to
• matters concerning policies,
• information about the conduct of the study
• your rights as a participant, or
should you wish to make a confidential complaint, you may contact The Executive Officer of this committee, on (08) 8222 6841.

Thank you,

Khristin Highet
Appendix D: Advertisement for Control Participants

**RESEARCH STUDY**

Do you want to contribute to valuable new research??

This study is about schizophrenia, cannabis use and thinking processes. Your contribution would be most appreciated.

We’re asking for adults, both male and female aged between 18 and 55 years who do not have any mental illness diagnosis and are regular cannabis users (but do not use any other illicit drug), to come and be a part of this research. Participation is voluntary and confidentiality will be strictly maintained!!!

If you agree to volunteer, you will be asked some questions about you (e.g., age, gender, educational level, health status, and cannabis use), as well as asked to fill out a questionnaire about your mood. In addition you will also be asked to complete a range of tasks involving solving puzzles, planning trips and card games.

As a token of appreciation for your participation you will receive a $25 voucher for Coles-Myer.

The researcher Khristin Highet (Doctor of Psychology (Clinical) student), can be contacted on the following email address for more information:

k.highet@murdoch.edu.au

or on:

0415 494 551
Appendix E: Control Participant Information Form

PARTICIPANT INFORMATION SHEET
Title: Relationships between schizophrenia and cannabis use on everyday adjustment
Permit Number: 2008/168

INVITATION TO PARTICIPATE
We invite you to participate in a study which we believe is of potential importance to people with schizophrenia. But, before you decide whether you wish to participate, we need to be sure that you understand:
- why we are doing it, and
- what it would involve if you agreed.
So, please read the following carefully and be sure to ask any questions you have. We will be happy to discuss it with you and answer your questions. You are also free to discuss it with others if you wish (i.e., family, friends, and/or your local Doctor).

You do not have to make an immediate decision.

PARTICIPATION IS VOLUNTARY
This is a research project and you do not have to be involved. Participation is voluntary. Also, if you agree to participate, you are free to change your mind and withdraw at any stage.

BACKGROUND TO THE STUDY
What is the research about?
My name is Khristin Highet. I am completing this research as part of my Doctor of Psychology (Clinical) degree through Murdoch University in Western Australia. I’m looking at the relationship between schizophrenia, cannabis use, thinking processes and everyday life skills.

Who is sponsoring it, and are they paying the researcher or her department to do the research?
I’m a post-graduate student of Murdoch University and the university is sponsoring this study. I will not be paid for conducting this research.

Why is the research being done?
I hope that the study will help treating professionals to make better informed decisions about treatment plans for people with schizophrenia. In addition, it may be of help when developing treatment plans for patients who may also use cannabis. Please note: The involvement of participants without a mental illness, such as yourself, will help me to better understand the effects of both cannabis use and schizophrenia, in comparison to the effects of cannabis use alone (i.e., your results will be used in a comparison group; comparing your results to those who have schizophrenia, but also use cannabis in addition).
Who can participate?
I’m inviting both male and female current or past regular cannabis users, aged between 18 and 55 years, who do NOT have a history of serious head/brain injury, mental illness diagnosis, learning disability, chronic substance use (other than cannabis use), stroke and/or a neurological condition, to take part in the study.

How many other people have been asked to consider participating?
Around 60 participants will be included in the study. This will include individuals with schizophrenia who use cannabis, as well as members of the community who do not have a mental illness diagnosis who are either current or past cannabis users.

What is involved if I choose to participate?
If you agree to participate, I will initially ask you some questions via telephone about you (e.g. your age, gender, years of education, health status, cannabis use) in order to determine your eligibility for the study. This will take about 10-15 minutes. If you are considered eligible for the study, you will be invited to a testing session where you will be asked some questions about your mood, as well as I will ask you to complete some tasks looking at your reading abilities, memory, planning, and attention, which will take about 45-60 minutes. Most people find these tasks enjoyable and you can have a break at any time.

DISCOMFORTS, RISKS AND SIDE EFFECTS
Who should I contact if I am worried about any effects that I experience?
No risks or side effects are anticipated as a result of the current research. But, if you should experience undue emotional distress, you can stop the session, and I will encourage you to contact your local doctor for consultation. You can recommence the study at a later stage if you wish to.

WHAT WILL HAPPEN TO THE INFORMATION COLLECTED?
All information you give is confidential. No names or other information that might identify you will be used in any publication arising from the study. The information collected from the research will be stored in locked cabinets located at Murdoch University. Only my research supervisors and I will have access to the data.

IS THERE ANY PAYMENT FOR PARTICIPATION?
We understand that involvement in this study requires a time commitment and we are extremely appreciative of your participation and time given. As a token of appreciation for your participation you will receive a $25 voucher for Coles-Myer.

BENEFITS OF THE RESEARCH
I hope that this study will assist in helping people with schizophrenia who may use cannabis to successfully transition out of hospital care and return to community living. However, these benefits may not directly affect you.

WHAT IF I HAVE A QUESTION ABOUT THE STUDY?
If you have any questions or concerns about your involvement in the study, you may contact the chief project supervisor, Dr Marjorie Collins via email: m.collins@murdoch.edu.au
If you have any ethical concerns about the project or questions about your rights as a participant, please contact The Murdoch University Human Research Ethics Committee on (08) 9360 6677 or e-mail: ethics@murdoch.edu.au

Thank you,

Khristin Highet
Appendix F: Consent Form for Clinical Participants

CENTRAL NORTHERN ADELAIDE HEALTH SERVICE (CNAHS)
The Queen Elizabeth Hospital & Lyell McEwin Hospital

CONSENT FORM

Title: Relationships between schizophrenia and cannabis use on everyday adjustment.

Researcher’s name: Khristin Highet
Supervisor’s name: Dr Marjorie Collins

Protocol Number: 2009010

I, the undersigned ................................................................................................................ hereby consent to my involvement in the research project explained above.

- I have read the information sheet, and I understand the reasons for this study. The researcher has explained the ways in which it will affect me. My questions have been answered to my satisfaction. My consent is given voluntarily. I am also aware that I may change my mind and stop at any time without this affecting my treatment, either now or in the future.
- I have been given the opportunity to have a family member, a friend or a member of my clinical treating team present while the project was explained to me.
- I understand that I may not directly benefit from taking part in the study.
- I understand the statement on the information sheet concerning payment for taking part in this study.
- I understand that parts of the testing session will be audio-taped and that all records and responses (including those audio-taped) will be kept in a safe and secure place at Murdoch University where only the researcher and supervisors will have access.
- I understand that all information provided is treated as confidential and will not be released by the researcher unless required to do so by law.
- I agree that research data gathered for this study may be published provided my name or other information which might identify me is not used.

PATIENT SIGNATURE.................................................. DATE …./…./……

WITNESS (optional).......................................................... DATE …./…./……

I have provided information about the research to the research participant and believe that he/she understands what is involved.

RESEARCHER............................................................... DATE …./…./……
Appendix G: Consent Form for Control Participants

MURODCH UNIVERSITY
School of Psychology

CONSENT FORM

Title: Relationships between schizophrenia and cannabis use on everyday adjustment

Researcher’s name: Khrisitin Highet
Supervisor’s name: Dr Marjorie Collins

Permit Number: 2008/168

I, the undersigned .................................................................................................. hereby consent to my involvement in the research study explained above.

- I have read the information sheet, and I understand the reasons for this study. The researcher has explained the ways in which it will affect me. My questions have been answered to my satisfaction. My consent is given voluntarily. I am also aware that I may change my mind and stop at any time without this resulting in prejudice, either now or in the future.
- I understand that I may not directly benefit from taking part in the study.
- I understand the statement on the information sheet concerning payment for taking part in this study.
- I understand that parts of the testing session will be audio-taped and that all records and responses (including those audio-taped) will be kept in a safe and secure place at Murdoch University where only the researcher and supervisors will have access.
- I understand that all information provided is treated as confidential and will not be released by the researcher unless required to do so by law.
- I agree that research data gathered for this study may be published provided my name or other information which might identify me is not used.

PARTICIPANT’S SIGNATURE.......................................................... DATE ……./……./…….

__________________________________________________________________________________________

I have provided information about the research to the research participant and believe that he/she understands what is involved.

RESEARCHER........................................................................... DATE ……./……./…….
Appendix H: Debrief Information

ABOUT THIS STUDY

Thank you for participating in this study. Your time and efforts are much appreciated.

The aim of the research is to examine the relationship between schizophrenia, cannabis use, and ‘executive functions’. Executive functions are a group of thinking processes that generally involve planning, problem solving, self-monitoring, and stopping a response that is not the best one for the task at hand. The tasks you have undertaken today are thought to assess such processes.

Another aim of our research is to look at the relationship between these thinking abilities and everyday skills. We hope that the results of the research project will help to better inform treating professionals in developing more effective treatment plans for individuals with schizophrenia who may present with cannabis abuse issues.

If any aspect of the research process has raised any concerns, we encourage you to consult with your clinical treatment team/doctor. You may also contact the following service for help if necessary:

Assessment & Crisis Intervention Service (ACIS) - 24 hour Emergency Mental Health Service Ph. No: 13 14 65

Thank you once again for your contribution and participation in our project.