PATTERNS OF ASSOCIATION BETWEEN REAL-WORLD PERFORMANCE AND MEASURES OF EXEUTIVE FUNCTION

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Submitted to the Department of Occupational Therapy

and the Faculty of the Graduate School of the University of Kansas

In partial fulfillment of the requirements for the degree of

Masters of Science

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Acknowledgments

I would like to express my heartfelt gratitude to the following people:

Elaine, who thankfully can read math, but more importantly was always there for me.

My family, the Zayats, the Joneses, and the Voglers, for your unconditional love and encouragement.

Tana Brown, who through her graciousness, direction, and ample patience has helped bring me to this point. I am very grateful for her trust, encouragement, and the indelible mark she has made on my life with two simple phrases - “errorless learning” and “canonical correlation”.

My committee members, Byron Gajewski, Melisa Rempfer, and Tracy Morrison, for their guidance, research expertise, and valuable time.

My colleagues at Rockhurst University and Kansas Rehabilitation Hospital who never wavered in their support and graciously persevered alongside me.

The women of Grace EPC and the small group gals who have faithfully prayed for me and held me accountable throughout this process.

My Firm Foundation who gives me a future and a hope.

Patterns of Association Between Real-World Performance

and Measures of Executive Function

Abstract

This study examined the canonical relationships between a set of real-world performance measures and a set of executive function measures with a sample of community based individuals with schizophrenia (N=80). Participants were given a battery of cognitive tests and evaluated with a real-world performance measure, the Test of Grocery Shopping Skills (TOGSS). Using canonical correlation analysis, executive functions of planning, problem-solving, working memory, and task persistence were significantly related to grocery shopping efficiency and accuracy. Two canonical variates with moderate correlations (.547 and .519) explain that 30% of the variance in the executive function and grocery shopping measures was shared. These results identify patterns of association between executive function performance and the independent living skill of grocery shopping.

Patterns of Association Between Real-World Performance and Measures of Executive Function

Introduction

For people with schizophrenia, successful participation in activities of daily living, such as grocery shopping is often impeded by cognitive impairment. This cognitive impairment may manifest itself as a varied set of behaviors, which can include poor planning, difficulty problem-solving, decreased self-monitoring, delayed or absent initiation, and reduced inhibition. In the literature, these behaviors are referred to as executive functions (Sohlberg and Mateer, 2001).

When problems with executive functions impede successful participation in daily life tasks, it is not useful to simply attribute the problems to a global deficit in executive function. Instead, assessment measures should be used to help identify the specific executive functions causing problems. With this information, treatments can be tailored specifically for an individual's unique deficits, resulting in more focused and effective treatment.

Thus, it is critical to have evaluation tools which measure specific executive functions. Because of the dynamic nature of real-world environments, executive functions may be better elicited in the real-world as opposed to laboratory settings ((Manchester, Priestly, and Jackson, 2004). However, there is limited use of real-world measures to assess executive functions. This thesis examines a real-world performance measure, the Test of Grocery Shopping Skills (TOGSS) (Hamera and

Brown, 2000) to determine if it is a valid measure of the executive functions of planning, problem-solving, task persistence, and working memory for individuals with schizophrenia.

Literature Review

Executive Functions

Executive functions are those capabilities which enable a person to engage successfully in independent, purposive, and self-serving behaviors (Lezak, 1995). They are necessary for complex, goal-directed behavior and adaptation to a range of environmental changes and demands (Collette, Hogge, Salmon, Van Der Linden, 2006; Loring, 1999). A fundamental responsibility of executive functions is the coordination and control of cognitive processes including planning, shifting, and regulation (Cripe, 1996: Denckla, 1996; Elliott, 2003; Katz and Harman-Maeir, 2005; Simon, Giacomini, Ferraro, and Mohr, 2003). Executive functions are involved in the completion of a goal-directed activity that is not overlearned, automatic, and routine (Sohlberg and Mateer, 2001).

Executive Function Components

Between and within the fields that study executive functions, there is some general agreement on functions that can be classified as an executive function (Callahan, 2001). An overview of the classification of executive functions is provided in Table 1. The twenty-six documents included in Table 1 were examined for definitions and descriptions of executive function. In particular the review made note of any behaviors identified as a specific part of executive function. Once

identified, these behaviors were sorted into groups with other similar behaviors. Each group was labeled an executive function component and was named to reflect the most frequently observed executive behavior within the group. Seven separate functions are identified in Table 1: initiation, planning, problem-solving, self-monitoring, inhibition, task persistence, and working memory. The functions were deliberately placed in specific column order in Table 1, to reflect the sequence in which the executive processes usually occur, as well as the way the functions build upon each other.

In the literature the most consistently agreed upon executive functions are initiation, planning, problem-solving, self monitoring, and inhibition (Elliott, 2003; Green, Kern, Braff, and Mintz, 2000; Grieve, 2000; Hamera and Brown, 2000; Lezak, 1995; Loring, 1999; Manchester, Priestly, and Jackson, 2004; Simon et al., 2003). Initiation, the first function identified in Table 1, is the ability to start behavior. It is necessary for carrying out the action plans made to accomplish intentions and goals (Lezak, 1995). This function includes volition, the capacity for intentional behavior and the ability to form a goal. The second function, the ability to plan, was the component most frequently identified across the different models of executive function. Planning includes the ability to order, plan ahead, and organize. It has been shown to be a skill that either appears naturally, laboriously, effectively, or not at all in humans (Lezak, 1995).

The third function identified, has the most disparate terms to describe the ability to problem solve and shift set. This function includes the ability to develop

and execute a new strategy, use abstract thinking and hypothesis testing, and be cognitively flexible. Cognitive flexibility includes the ability to shift ones thinking and is critical for successful completion of purposive action. This function is closely related to self-monitoring and regulation as it is necessary to recognize there is a problem before a solution can be generated (Lezak, 1995). Self-monitoring, like planning and problem-solving, is recognized frequently as a component of executive function. These behaviors include the ability to detect conflict, recognize new information needed for adjusting behavior, self evaluation, and the capacity to use feedback. The fifth function, inhibition, includes the ability to terminate or inhibit unwanted or irrelevant behaviors. Poor impulse control, problems with stopping inappropriate strategies, and difficulty delaying or restraining a response are all reflected in this component of executive function.

Two processes included in Table 1, but not as commonly identified as executive functions are task persistence and working memory. Task persistence, the ability to maintain purposive action, is often considered a part of attention. Lezak (1995) identifies task persistence as complex attention with two distinct mechanisms: a) attention, as seen in the ability to resist distraction, and b) control, the ability to continue with a task without slowing down, losing interest, or giving up. It is the control aspect of task persistence which is being considered in this review as an executive function. According to Sohlberg and Mateer (2001), task persistence is critical for handling nonroutine or novel situations and relies on intact working memory.

Working memory, the ability to maintain and manipulate information for complex tasks, is widely discussed in the literature but not always associated with executive function (Baddeley, 2001; Barch, 2006; Cinan and Tanör, 2002; Denckla, 1995; Donohoe, Corvin, and Robertson, 2005; Hester and Garavan, 2005; McGurk et al., 2004). In the original model of working memory, the central executive was conceived of as a limited capacity pool of general processing resources (Baddeley and Hitch, 1974). Over time, the processes of the central executive were systematically explained by concentrating on its attentional control characteristics, making it standard for the functions of the central executive to be understood through a model of attentional control, the supervisory attention system (SAS) (Norman and Shallice, 1986). The SAS is a high-level attention mechanism (Katz and Hartman-Maeir, 2005), which controls those processes requiring deliberate and conscious allocation of attention resources. Based on the above model, working memory becomes the base upon which supervisory attention is deployed. Executive functions are then the visible, expressed actions and behaviors of the supervisory attentional system (Chan, Chen, Cheung and Cheung, 2004; Evans, Chua, McKenna, and Wilson, 1997). Working memory allows information to be manipulated and maintained until necessary for use in a situation requiring controlled attention (SAS), such as when managing a novel situation or when working out a conflict between an old way and new way of doing things (schema management). The tangible evidence that this process is occurring is in behavior, specifically the behaviors of the executive functions, whether it be inhibiting a thought, or initiating a conversation, or switching

to a different way to complete a task (Baddeley, Della Sala, Papagno, and Spinnler, 1997; Barch, 2003, 2006; Cinan and Tanör, 2002; Donohoe et al., 2005; Repovs and Baddeley, 2006).

These seven functions overviewed in Table 1 represent unique but related and interdependent functions. When executive dysfunction occurs, it may occur in just one of these areas, such as an inhibition disorder, or it can manifest itself in multiple areas, as with reduced initiation, inhibition, and self-monitoring (Sohlberg and Mateer, 2001).

Executive Dysfunction in the Schizophrenic Population

It is accepted that executive dysfunction is one of the "most ubiquitous features" of schizophrenia (Bowie and Harvey, 2005). Kraepelin (1919) was the first to note the importance of recognizing executive dysfunction as a component of schizophrenia. He ascribes difficulties in judgment and attention to an underlying deficit in the "process of volition" in people with schizophrenia. The disease itself is often described with terms that indicate problems with executive function. For example, Frith (1992) and Semkovska, Bedard, Godbout, Limoge, and Stip (2004) describe schizophrenia as a disorder of willed action, self-monitoring, and monitoring the intention of others. They highlight additional problems with disturbed planning, reduced cognitive flexibility, lack of inhibition, and poor problem-solving. Barch (2003) attributes the cognitive struggles of people with schizophrenia to a disturbance in executive control processes. It is these processes that are critical to representing and maintaining context information.

Limitations in executive function performance in schizophrenia are related to functional outcomes (Green et al., 2000; Reed, Harrow, Herbener, Martine, 2002). Executive function is predictive of basic self-care skills (Velligan, Bow-Thomas, Mahurin, Miller, and Halgunseth, 2000), instrumental activities of daily living (IADL) (Rempfer, Hamera, Brown, and Cromwell, 2003; Semkovska et al., 2004), work/productivity and social competence (Velligan et al., 2000).

While executive function deficits are quite common among individuals with schizophrenia (Barch, 2003; Palmer and Heaton, 2000), the population does demonstrate different degrees of executive dysfunction as some perform in the normal range and others show severe impairment contributing to functional dependence (Simon et al., 2003). The heterogeneous nature of the population is one reason why accurate evaluation of executive functions is important.

Measurement of Executive Function

Individuals with schizophrenia perform poorly on traditional psychometric tests of executive function such as the Wisconsin Card Sort Test (WCST), the Trailmaking Test, and the Test of Verbal Fluency, as well as tests sensitive to frontal lobe lesions (Palmer and Heaton, 2000). In contrast, some people with schizophrenia have been observed succeeding on neuropsychological measures but then struggling in everyday life. Because different people with schizophrenia will have different types and levels of executive dysfunction, detailed assessment will always be needed (Evans et al., 1997; Hamera, Brown, Rempfer, and Davis, 2002). While there are measures designed to screen for executive dysfunction, they are limited in their

ability to specifically identify a deficit in a particular component of executive function. In addition, standardized psychometric measures have been criticized because they are not sufficiently sensitive to identify executive dysfunction and are poor predictors of everyday behaviors and dysfunctions (Manchester, Priestly, and Jackson, 2004). Cripe (1998) and Shallice and Burgess (1991) suggest that executive assessments administered in real-world environments may provide valid indicators of individuals' daily deficits experienced outside clinical settings. The environment in which standard measures are administered is typically quiet and distraction-free. Test administration is controlled: the examiner tells the client when to begin (initiate), how to do the task (plan), when to end the task (termination), and the overall goal is made explicit to the individual. This controlled environment may actually assist client performance through subtle expectant cues from the test administrator and a test format which limits the need to inhibit perseverative behaviors (Callahan, 2001; Krabbendam, de Vugt, Derix, Jolles, 1999; Manchester et al, 2004; Semkovska et al., 2004). Real-world assessments provide an opportunity to see a reflection of a client's ability to respond in a dynamic, novel, and unpredictable environment. While measures which mimic real-world situations have been shown to be capable of assessing executive function (McKibbin Brekke, Sires, Jeste & Patterson, 2004), measures which occur in a real-world environment may allow us to better discern specific executive functions.

One such real-world measure is the Test of Grocery Shopping Skills (TOGSS; Hamera and Brown, 2000). The TOGSS was developed to measure the

effectiveness of grocery shopping in individuals with schizophrenia. This context-based assessment requires a client to locate 10 items in an actual community grocery store. Performance is assessed on two primary outcomes: accuracy, which includes finding the correct item, in the correct size at the lowest price; and efficiency, which includes redundancy (how often shoppers return to an aisle or go down an aisle that does not contain a needed item), and time (total time needed to complete the test) (Brown, Rempfer, and Hamera, 2002).

The TOGSS has been examined for reliability and validity as a context-based community function measure (Hamera and Brown, 2000); for construct validity (Hamera, Brown, Rempfer, and Davis, 2002); for how a mediator, knowledge of grocery shopping, influences cognition and community functioning (Brown, Rempfer, Hamera, and Bothwell, 2006); and for relationships between cognition and the IADL of grocery shopping (Brown, Rempfer, and Hamera, 2002; Rempfer et al., 2003). However, these previous studies have not explicitly focused on the role of executive function in grocery shopping as measured by the TOGSS. When Greenwood, Landau and Wilkes (2005) used the TOGSS as their community function outcome measure they modified the measure to explicitly reflect executive processes thought to underlie performance. This was accomplished by specifically considering route taken around the store in both the redundancy outcome and with a new outcome, strategy, which captures number of items selected on a particular route. Building on these prior works, this present research was undertaken to be the first focused examination of the relationship between executive function and performance

on the TOGSS. While the TOGSS considers executive processing as a key component to successful performance in community based skills, it was not designed as a measure of executive function but as a measure of grocery shopping. It may be possible to use the TOGGS to assess specific executive functions and in doing so identify which particular problems with executive function interfere with the performance of grocery shopping.

Understanding that impaired executive functions are highly prevalent in schizophrenia and current cognitive measures vary in their ability to adequately assess executive dysfunction (Donohoe et al., 2005), the intent of this study was to examine the Test of Grocery Shopping Skills (TOGSS) to determine if it is a valid measure of the executive functions of planning, problem-solving, task persistence, and working memory for individuals with schizophrenia. Using a multivariate analysis approach, two general hypotheses were examined:

Hypothesis 1: A relationship would be found between the set of neuropsychological measures of executive function and the TOGSS outcomes variable set, suggesting that the TOGSS can be used as a valid measure of executive function.

Hypothesis 2: Specific patterns of association will emerge from within the observed relationships between the cognitive measures set and the TOGSS outcome set, representing planning, problem-solving, persistence, and working memory.

Methods

This study is a retrospective secondary data analysis examining the relationships between cognitive measures of executive function and the functional outcomes on the Test of Grocery Shopping Skills in people with schizophrenia. The data for this project is from a dataset collected between 2003 and 2006 for a study examining the relationship of learning potential and community outcome in people with schizophrenia.

Participants

Participants were recruited from three community mental health centers in the Kansas City area. Diagnosis was confirmed using the Structured Clinical Interview for DSM-IV (First, Spitzer, Gibbon, and Williams, 2002). Individuals with co-morbidities that affected cognition (e.g., a diagnosis of mental retardation, substance abuse) or other significant physical co-morbidities that affected task performance (e.g., blindness) were excluded from the original study. Eighty individuals with schizophrenia (N = 47) or schizoaffective disorder (N = 33) were included in this study from the original dataset of one hundred and twenty seven participants, exclusion was based on incomplete datasets.

Of the 80 participants, 41 were females (51%) and 39 were males (49%) and the average age was 42.67 years (S.D. = 8.47; range 24-63 years) with three participants not identifying their age. Forty five participants identified themselves as African-American (57%), twenty seven as white (34%), and three as multi-racial (4%), two as Hispanic (3%), one as American Indian (1%), one as Asian (1%), and

one did not identify a racial/ethnic background. A majority of the participants had never been married (59%; n = 47). Fifty participants lived independently, seventeen lived with relatives but were largely independent, five lived with relatives but were heavily dependent for personal care, four lived in supervised care housing with live in staff, one was homeless and two did not identify their living situation. Their educational backgrounds extended from eighth grade or below (4%; n = 3), to some high school (23%; n =18), high school graduate (27%; n = 21), post high school training (1%; n = 1), college courses (37%; n = 29), bachelor's degree (6%; n = 5), and post-graduate education (1%; n = 1). 85% (n = 67) of the participants were not working in a paid employment situation at the time of the study (see Table 2).

Measures and Procedures

The cognitive measures were administered in the Grayhawk Lab at the University of Kansas Medical Center by a trained research assistant. The TOGSS was administered to all participants in an unfamiliar grocery store, one located at a considerable distance from the neighborhoods of the participants.

Cognitive Measures of Executive Function

A total of nine measures of cognition were chosen for inclusion in this study. Each of the nine measures was selected to assess specific components of executive function, however with the complexity of executive function there is ambiguity and overlap. Table 3 identifies the aspect(s) of executive function each measure assess.

Rey-Osterreith Complex Figure Test (CFT) (Lezak, 1995). This test measures perceptual organization and visual memory. Participants are asked to copy a complex

geometric figure. In an immediate recall trial, they are asked to draw the figure from memory. The scoring system includes eighteen separate units with each unit worth two points. One point for correct placement and one point for correct recall. The maximum score possible is 36. According to Lezak (1995) several studies have demonstrated that the way a participant goes about copying the complex figure relates to their ability to organize and conceptualize a task.

The d2 Test of Attention Concentration (d2) (Brickencamp and Zillmer, 1998). This measure assesses processing speed, rule compliance, and quality of performance. It requires the participant to visually scan, demonstrate vigilance, and sustained attention. The d2 has been used to measure planning, organization, accuracy, and task persistence (Lezak, 1995; Loring, 1999). The test requires the participant to mark all "d"s that have two strokes within an array of 14 lines, with 20 stimuli per line. They must discriminate between similar stimuli: "d"s with one or more than two strokes and "p"s with strokes. There are eleven calculated scores in the d2 test and in this study the outcome measures of interest are errors of commission, concentration performance (number of error of commission from number of required relevant items), rule compliance (total errors from total number of items processed).

Trail Making Test (TMT). This measure tests complex visual scanning with a psychomotor component. It assesses visual scanning speed, working memory, the ability to follow a mental sequence, and to shift/switch attention (Part B). Part A of the TMT requires the participant to connect numbers in ascending sequence, while being timed. For TMT Part B, which is also timed, requires the participant to deal

with more than one stimulus at a time. The participant draws a line to connect alternating numbers and letters, also in ascending sequence. The outcome measures of interest for the TMT are number of errors on TMT B and the adjusted duration of test (time). The adjusted duration of test score controls for psychomotor effects by subtracting the time score of TMT A from the time score of TMT B (Chaytor, Schmitter-Edgecombe, and Burr, 2006). The more time a participant takes to complete the test is associated with worse alternating attention (Loring, 1999).

Wisconsin Card Sorting Task (WCST) (Heaton, Chelune, Talley, Kay and Curtiss, 1993). This frequently used test is a measure of hypothesis testing, abstract reasoning, ability to shift set and maintain cognitive processes necessary for correct responding (Loring, 1999). It is best viewed as a global measure of executive function which relies on the integration of multiple neural areas (Cinan and Tanör, 2002). During the test, participants are presented four stimulus cards and asked to match addition cards to the stimulus cards. The participant is told whether their match is right or wrong but the rule for the match is not revealed. The sorting rule is changed after the participant successfully sorts ten consecutive trials. The outcome measures of interest are perseverative errors, total categories correct, and number of trials to the first category. The last outcome measure provides insight into how long it takes the participant to figure out the sorting rule.

Controlled Oral Word Association Test (COWAT) (Benton and Hamsher, 1976). This measure of verbal fluency has been used to assess cognitive flexibility and initiation. The FAS version of verbal fluency was used. In the first trial

participants are asked to say as many F words as they can recall in a one-minute time limit. In the next two trials the letters A and S were presented. The outcome measure of interest is the total words generated for the three trials.

California Verbal Learning Test (CVLT) (Delis, Kramer, Kaplan, and Ober, 1987). This measure is designed to examine semantic clustering in learning and memory (Loring, 1999). The participant is presented with 16 words from four semantic categories (tools, fruit, clothes, and insects), four words per category. The words are presented in a pseudo random order such that no two words from the same category are presented sequentially. The participant is asked to name all the words he/she can recall. This is repeated three times. As the words on the list are categorizable, a participant may use this feature to assist in recall of the presented group of words by imposing an organization on the list of words according to shared semantic features. This measure provides information on learning strategies and the participant's capacity for concept formation. The outcome measure of interest is total score.

Letter Number Sequencing (LNS). This subtest of the Wechsler Adult Intelligence Scale –III (WAIS-III) (Wechsler, 1997) measures working memory by requiring the participant to mentally track and manipulate familiar sequences. The participant is asked to listen to strings of alternating letters and numbers of increasing length and repeat them by first sorting the numbers in ascending order, followed by the letters in alphabetical order. The outcome measure of interest is the total number of strings correctly repeated (Donohoe et al., 2005).

Digit Span Backward (DSB). Another subset of the WAIS-III (Wechsler, 1997), this measure of attentional capacity requires the participant to attend to an orally presented string of numbers and then repeat them in order backwards. The digit span backwards assesses working memory. The test is scored by number recalled, with possible scores ranging from 0-14. A higher score indicates a better working memory.

*Months Ordering Test of Working Memory (MO) (*Almor, Kempler, MacDonald, Andersen, and Tyler, 1999). In this test of working memory, participants are required to put increasingly long sets of months into correct calendar sequence. This test requires a controlled, conscious process rather than an automatic process. Months Ordering has been used to measure working memory as it demands simultaneous storage and manipulation of verbal information. The outcome measure of interest is the total number of correct answers with a possible score between 0-20. A higher score indicates better working memory.

Real-world Assessment

Test of Grocery Shopping Skills (TOGSS) (Hamera and Brown, 2000). The Test of Grocery Shopping Skills is a real-world measure of life skill performance. The TOGSS measures an individual's ability to find grocery items at the lowest price. Two alternate forms of the TOGSS require participants to locate grocery items, in an actual grocery store. The TOGSS measures grocery shopping accuracy, redundancy, and time. Previous research with the TOGSS indicates adequate interrater, test-retest, and equivalent forms reliability (Hamera and Brown, 2000). Additional TOGSS

outcome measures included in this study are route, task persistence, sequential shopping, assistance sought, and accuracy to cost. These new outcome measures were developed from data that was collected when the TOGSS was administered to the participants, but as of yet has not been calculated or used in a statistical analysis.

Original TOGSS Outcome Measures

Shopping Efficiency This measure examines how efficiently a participant completes the shopping task. This outcome is calculated by determining the number of aisles or sections of the store that the participant enters, and subtracting from this the actual number of aisles required to most efficiently find the 10 items on the list. A lower score represents a more efficient grocery shopping approach as a lower number of unnecessary aisles are entered. Unnecessary aisle are those aisles where there is not a target item or an aisle the participant has already been down.

Accuracy The accuracy outcome is based on a participant's ability to accurately select the correct item, correct size, and lowest price for all ten target item on the grocery list. This outcome is measured on a score of 0 – 30, with a higher score indicating better accuracy in target selection.

New TOGSS Outcome Measures

Route Route examines if a participant retrieves target items following a given list, which would pre-determine their route, or if a participant diverts from the list and creates their own plan/route for item retrieval. This outcome is scored by counting the number of times a participant diverts from the set list. This outcome is not

designed to measure quality or efficacy of the route, just if the participant establishes their own.

Persistence Task persistence observes if a participant retrieves all ten target items. It is solely designed to account for a participant's ability to exert attentional control and stick with an activity until completion. This outcome is measured by counting the number of items selected. Scores can range from 0-10, with a higher score indicating better task persistence. This outcome is not designed to measure effective persistence which would take into account accuracy to target item specifications (item, cost, size).

Assistance Sought Assistance sought measures the number of times a participant asks for assistance from someone within the context of the store (participants were not allowed to seek help from the research assistant). The score for this outcome is calculated by counting the number of times a participant appropriately asks for assistance. A higher score reflects problem-solving through use of a strategy.

Sequential Shopping Each version of the TOGSS test has an aisle where at least two items are located on the same aisle. With this outcome measure, the participant's ability to retrieve multiple items on one row is observed. The score for this measure is calculated by counting the number of items retrieved correctly on the multiple item row and dividing this by the number of items possible to retrieve correctly on the multiple item row. A higher score would reflect more efficient problem-solving for grocery shopping.

Accuracy to Cost This outcome is designed to measure a participant's ability to retrieve the lowest price item. When calculating this outcome the other accuracy components (item and size) are not taken into account. The grocery list a participant is given at the start of the TOGSS, lists all ten target items they are to retrieve. Included on the list is the name of the item and the size requested. The only item qualifier missing from the list is lowest price, as this is a transient feature that can change regularly. The ability to attend to the correct price of an item in this situation requires working memory. This is seen through the participant's need to retain the rules of the task (retrieve item at lowest price) without a visual cue. Additionally the participant may be required to manipulate information in determining which item is the lowest priced. Accuracy to cost will be scored by counting the number of target items where the lowest priced item was chosen out of ten possible. A higher score reflects better accuracy to cost.

Procedures

Recruitment Participants were recruited through community mental health centers using flyers and announcements during meetings. An agency recruiter at each site was utilized to assist with recruitment. Once individuals indicated an interest in the study, a research assistant obtained informed consent. The Structured Clinical Interview for DSM-IV (First, Spitzer, Gibbons, and Williams, 1997) was administered and the chart was reviewed to insure that the participant was eligible for participation. All participants were allowed to keep the groceries from the TOGGS testing.

Administration of the measures After giving informed consent, each individual was administered the cognitive measures in this order d2, MO, TMT B, LNS, DS, COWAT, WCST, and CVLT. The cognitive measures were administered in a single session with breaks between each measure. These measures were administered in the Grayhawk Lab at the University of Kansas by a trained research assistant. This was followed on a subsequent day, by the administration of the real-world assessment, the Test of Grocery Shopping Skills (TOGSS) in a community grocery store. Each of the testing sessions was conducted by a separate researcher, who was blind to the performance in the other testing session.

Data Collection Records from the testing sessions for each participant were stored in the University of Kansas Occupational Therapy Department. Each participant's TOGSS Form and TOGSS Scoring Map was examined and data extracted for the new TOGSS outcome measures (route, task persistence, accuracy to cost, sequential shopping, and assistance sought). Data from the cognitive outcome measures of interest along with the TOGSS data was entered into the SPSS statistical package for analysis.

Statistical Analysis SPSS for Windows, Version 13 was used to analyze the data. Evaluation of assumptions was conducted, screening for normality, linearity, homoscedasticity, outliers, missing data, and multicollinearity. Missing data was estimated for variables with less than 10% missing values. Data reduction analysis was conducted on each variable set. Descriptive statistics and frequencies were computed for all remaining variables in each set. A multivariate statistical technique,

canonical correlation analysis (CCA), was applied to explore the relationship between the two sets of variables. Tests of statistical significance, Wilk's Lambda and Chi Square analysis, and the Stewart-Love index, a measure of shared variance, were run to aid in the interpretation of the meaningfulness and statistical significance of the canonical relationships.

Results

The canonical correlation analysis is appropriate when a situation requires simultaneous assessment of the number and nature of the relationships between two sets of variables (McLaughlin & Otto, 1981; Stevens, 2002). In this study, canonical correlation was used to examine the relationship between measures of executive function (Rey-Osterreith Complex Figure Test; d2 Test of Attention and Concentration; Trailmaking Test; Wisconsin Card Sort Test; Controlled Oral Word Association Test; California Verbal Learning Test, Letter Number Sequence, Digit Backwards, and Months Ordering) and outcome measures from the Test of Grocery Shopping Skills (Shopping Efficiency, Shopping Accuracy, Persistence, Accuracy to Cost, Assistance Sought, Route, and Sequential Shopping).

The relationship between the two variable sets was evaluated by examining the number of reliable canonical functions, the magnitudes of the canonical correlations, the significance of the canonical correlations, and the structure of each variable set that maximizes the relationship between the sets (Hair, Anderson, Tatham, & Black, 1998).

Description of the Sample

Before analysis, the variables were screened for normality, linearity, missing data, and outliers. Skewness, kurtosis, and outlier effect were found to be within an acceptable range and not in violation of the assumptions of multivariate analysis. A missing value analysis was computed for each variable and two cases (2%) were found to have missing data in digit backwards; six cases (7%) were found to have missing data in d2 rule compliance, d2 concentration performance, Trailmaking B time score, and the CFT recall score. Missing data was estimated and replaced with the variable's mean value score. Assumptions regarding within-set multicollinearity were met.

Data reduction through principal component analysis resulted in the extraction of two variables from each variable set (.30 cutoff). From the executive function set, the d2 error of commission variable (-.297) and the CVLT variable (.295) were extracted, and from the TOGSS set, the route variable (.039) and assistance sought variable (-.095) were removed. In addition, redundant variables (i.e. a variable which comprises a portion of another variable) were extracted, which included TMT B time (executive function set), as it is a component of the TMT B-A variable and accuracy to cost (TOGSS set), as it is a portion of the shopping accuracy variable. After examining the communality coefficients (h^2) the TMT B error variable (executive function set) was removed due to a communality coefficient near-zero ($h^2 = .01$). Lastly, the remaining new TOGSS outcome variables, persistence and sequential shopping were extracted. It was decided that with the statistical removal of the other new TOGSS outcomes, it would be more parsimonious in the analysis to examine just

the original TOGSS variables included in the study, shopping efficiency and shopping accuracy.

Means, standard deviation, and Pearson correlations between the executive function measures and TOGSS outcomes are presented in Table 4. The large standard deviations for several of the executive function variables (d2 rule compliance, d2 concentration performance, TMT B-A, WCST perseverative errors, WCST trials to category 1, and FAS total score) reflect the heterogeneity found within the schizophrenia population (Evans, Chua, McKenna, & Wilson, 1997; Palmer & Heaton, 2000).

Examination of Research Questions

A canonical correlation analysis was used to examine the two hypothesis of this research study. The primary hypothesis was a relationship would be found between a set of neuropsychological measures of executive function and a set of outcome measures from the real-world assessment, TOGSS, suggesting that the TOGSS could be used as a valid measure of executive function. The canonical correlation was performed between the set of executive function variables and the set of TOGSS variables using SPSS CANCORR. In the first set, the remaining executive function variables included CFT recall, d2 rule compliance, d2 concentration performance, TMT B-A, WCST perseverative error, WCST trials to category 1, WCST total correct, FAS total score, LNS, DSB, and MO. The scoring of these measures indicates that a higher score reflects better performance on the CFT recall, d2 rule compliance, d2 concentration performance, WCST total correct, FAS total score,

LNS, DSB, and MO; and a lower score reflects better performance on the TMT B-A, WCST perseverative error, and WCST trials to category 1.

In the second set, the remaining TOGSS variables include shopping efficiency and shopping accuracy. Lower scores on shopping efficiency signify more efficient shopping while higher scores on shopping accuracy indicate better shopping accuracy.

The maximum number of canonical functions for the present analysis was two (i.e. the number of variables in the smallest set). The first canonical correlation was .547 (30% overlapping variance) and the second canonical correlation was .519 (27% overlapping variance). With both canonical correlations included, χ^2 (22) = 48.11, p = .001 and with the first canonical correlation removed, χ^2 (10) = 22.56, p = .013. Thus both pairs of canonical variates account for the significant relationships between these two sets of variables.

Data on the two pairs of canonical variates appear in Table 5. Shown in the table are standardized correlation coefficients (canonical weights), correlations between the variables and the canonical variates (canonical loadings), within-set variance accounted for by the canonical variates (percent of variance), redundancies, and canonical correlations. The two variates from the executive function set explain 11% of the variance in the TOGSS outcome variables and the two variates in the TOGSS set explain 28% of the variance in the executive function variables. These levels of redundancy are acceptable given the strength of the canonical correlations, significance levels, and percent of variance within-set.

The variables that were interpreted for each of the variates have canonical weights greater than or equal to .30 and are identified with an asterisk (see Table 5). The variables in the executive function set which demonstrate a meaningful contribution to the first canonical correlation were WCST perseverative errors (.961), WCST total correct (.677), DSB (.596), LNS (-.526)), d2 rule compliance (-.457), CFT recall (-.396), WCST trials to category 1 (.343), d2 concentration performance (.316). One variable in the TOGSS set demonstrates a meaningful contribution to the first canonical correlation, shopping efficiency (1.016). Based on these associations, the first pair of canonical variates indicates that less cognitive flexibility, better divergent thinking better; both more and less working memory, less rule compliance, less planning and more persistence contributes to shopping inefficiency. This list of executive function abilities directly reflects the order in which the measures contribute to the canonical variate.

The variables of the executive function set which demonstrate a meaningful contribution to the second canonical correlation are WCST total correct (-.748), WCST trials to category 1 (-.529), WCST perseverative error (-.432), and MO (-.416). One variable in the TOGSS set demonstrates a meaningful contribution to the second canonical correlation, shopping accuracy (-1.005). The second pair of canonical variates indicates that more problem solving and more working memory contributes to better shopping accuracy.

A secondary hypothesis of this study was that specific patterns of association would emerge from within the observed relationships between the cognitive measures

set and the TOGSS outcome set, representing planning, problem-solving, persistence, and working memory. The configuration of meaningful variables (.3 >) from the canonical coefficients indicates that no one executive function emerges to represent the relationship between the two variable sets. Instead the configuration of each canonical function shows a mixed pattern of association of two or three executive functions and one TOGSS outcome. The results of the canonical correlation analysis are consistent with the pattern observed in the simple correlation in Table 4. Both the correlations in table 4 and the canonical analysis identify a significant effect on shopping accuracy from the working memory variables and a significant effect on shopping efficiency from the problem solving and planning variables.

This canonical correlation analysis produced theoretically interpretable results for both pairs of canonical variates as the magnitude of the canonical correlations reflects a good relationship between the sets and both are statistically significant. Examination of the maximized variable sets produced in the analysis allows both research questions of this study to be answered. A discussion of these results follows.

Discussion Section

The purpose of this study was to examine the real-world assessment, the Test of Grocery Shopping Skills, to determine if it is a valid measure of the executive functions of planning, problem solving, task persistence, and working memory, in individuals with schizophrenia. The main findings in this study support the primary hypothesis that a relationship would be observed between the executive function measures and the TOGSS outcomes measures. It was shown that the executive

functions of planning, problem-solving, task persistence, and working memory, as measured by a group of neuropsychological tests, are associated with grocery shopping efficiency and accuracy, as measured by the TOGSS. Thus, the TOGSS could be considered for development as a real-world measure of executive function for individuals with schizophrenia.

The following discussion will focus on the nature of the associations observed between the measures of executive function and TOGSS outcomes measures, and the implications of these results for future research and current practice.

Specificity of Relationships

Green (1996) stated that the challenge for studies exploring the functional consequences of neurocognitive deficits in schizophrenia was to move beyond a general level of investigation and instead examine "whether specific neurocognitive processes are linked to specific functional outcomes" (p. 321). Thus, research in this area has progressed from identifying broad-spectrum relationships between neurocognition and functional outcomes, to discerning specific aspects of executive function and community outcomes. This effort to increase the understanding of the specificity of relationships between different executive functions and living skills has involved investigations with specific executive functions (Evans, Heaton, Paulsen, Palmer, Patterson, & Jeste, 2003), specific community outcomes (Rempfer et al., 2003; Semkovska et al., 2004; Velligan et al., 2003), or both, as is the case with this present study.

In this study it was found that the executive functions of planning, working memory, task persistence, and problem-solving associated with grocery shopping efficiency and accuracy in both expected and unexpected ways. It was expected that shopping efficiency would show an association with executive function performance (Rempfer et al., 2003), and that the executive function of planning would correlate with shopping efficiency as purported by Hamera et al. (2002). It was unexpected that shopping efficiency and accuracy would split between the canonical functions. However, this fact does provide a clearer examination of the associations between executive function performance and grocery shopping behavior, unlike McClure et al. (2007) whose functional capacity measures loaded on a single factor making differential associations difficult between the functional domains and neuropsychological measures. In addition, the function split between shopping efficiency and accuracy underscores the lack of intercorrelations observed among the TOGSS outcome measures; signifying each is capturing a different aspect of the shopping task (Rempfer et al.).

The results of this study are consistent with Evans et al. (2003), who found that elements of problem-solving, cognitive flexibility and abstraction were strong predictors of IADL performance and Semkovska et al. (2004) who significantly associated overall executive function ability with the IADL task of meal planning, shopping, and meal preparation. The results of the current study are congruent with Rempfer et al. (2003), having also observed a relationship between executive function and shopping efficiency. Rempfer et al. specifically explored the relationship

between executive function and community outcome by examining the relationship between aspects of cognition and explicit components of grocery shopping – shopping efficiency (redundancy) and shopping accuracy. As in the current study, they observed executive function performance was significantly related to shopping efficiency. Additionally, the findings of this present study extend previous knowledge of the specificity of relationships between executive function and living skills by simultaneously demonstrating significant patterns of association between particular executive functions and explicit aspects of grocery shopping.

In the first function, shopping efficiency is observed in association with problem-solving as measured by the three outcomes on the WCST; planning as measured by the CFT and d2 rule compliance outcome; task persistence as measured by the d2 concentration performance; and working memory as measured by the LNS and DSB. In the second function, shopping accuracy associates with problem-solving as measured by the WCST outcomes; and working memory, as measured by MO. These results are consistent with Greenwood et al. (2005) who observed a similar pattern of association when using the TOGSS as a community function measure. Their findings linked LNS (working memory) with shopping efficiency performance and strategy (problem-solving) with shopping accuracy.

Patterns of Association

There are several interesting patterns of associations in these results. First, all four of the executive functions studied associated with shopping efficiency, while only two associated with shopping accuracy. This supports Hamera et al. (2002)

argument that shopping accuracy may not be as demanding a cognitive process as shopping efficiency and that shopping efficiency is a more sensitive measure of executive function performance. Shopping efficiency may involve more executive function ability as it requires an individual to navigate the store in an effective manner which reduces repetition and time in store, while simultaneously keeping track of the status of the shopping list.

Second, the fact planning associated with shopping efficiency and not shopping accuracy substantiates the suggestion that poor shopping efficiency is directly related to difficulty with planning and organizing (Hamera et al.; Rempfer et al., 2003). Working memory and problem solving however, contribute to both shopping efficiency and shopping accuracy. This shared association reflects the critical role cognitive flexibility and working memory have for functional success in complex behaviors such as grocery shopping in the community (Hanks, Rapport, Millis, Deshpande, 1999). It is of interest to note that the two working memory measures (DSB and LNS) contributing to the first canonical variate demonstrated a differing effect. It was anticipated that both working memory variables would show a similar pattern of association. Instead, one performs as expected (LNS), with more working memory associating with more shopping efficiency, while the other performs in the opposite direction (DSB), less working memory with more shopping efficiency. No definitive explanation can be offered for this pattern of association but it is speculated that perhaps the exploratory and descriptive nature of the canonical correlation analysis is characterizing both the unity and diversity of executive

function processes (Collette et al., 2006), or reflecting the heterogeneity of the schizophrenia population (Donohoe et al., 2005).

A second hypothesis of this study was specific patterns of association would emerge from within the observed relationships between the cognitive measures set and the TOGSS outcome set. These patterns of association would represent the specific executive functions of planning, problem-solving, persistence, and working memory. This expectation was not supported by the findings of the study, as no singular executive function pattern emerges from within each canonical correlation as it does with the TOGSS. The fact that the canonical functions are more distinguished by the TOGSS outcomes than the different executive functions suggests that shopping accuracy and efficiency are more separable than the executive functions of planning, problem-solving, working memory and persistence.

Utilization of the TOGSS

Not only do the findings of this present study indicate the capability of the TOGSS to capture specific executive function performance, but they also support prior utilization of the TOGSS as a measure of executive functioning. Greenwood et al. (2005) used specific TOGSS outcome measures to reflect executive processes believed to underlie performance in a shopping task. Hamera et al. (2002) in a study examining the capacity of a community function measure to discriminate between individuals with psychiatric disabilities and those without psychiatric disabilities chose the TOGSS for their community function measure. They did so on the basis of

grocery shopping's association with higher level cognition or executive functioning and the TOGSS ability to measure grocery shopping.

Implication for Current Theory and Literature

The results of this study support current theory and literature regarding the nature of executive function and the capabilities of canonical correlation. At this time it is fully acknowledged and understood, in both the literature and current theory, that there is overlap and ambiguity in executive function. This is fully demonstrated in this research project, as in each of the canonical functions, there are at least two or more executive functions significantly contributing to the relationship between sets. It is because of the canonical correlation analysis (CCA) that we are able to observe these simultaneous relationships. Single order analysis is more often the typical choice for studies of this nature. However with the more sophisticated process of the CCA, we are given insights into the synergy between executive function and community outcomes.

Another discussion currently occurring in the literature is the use of performance measures versus real-world measures (McClure et al., 2007; McKibbin, et al, 2004). This study utilized a real-world performance measure. Arguments against the use of such measures include the logistics of administering an assessment in the natural environment and the potential influence on performance results from other factors including the environment. While acknowledging these inherent limitations, it is critical to note that for occupational therapists, the logistics of testing in a real-world environment is neither unfamiliar nor unusual. Moreover, while

performance of certain cognitive skills such as verbal learning or memory may be particularly vulnerable to other factors when studied in a real-world setting, it is specifically this type of complex, dynamic environment in which executive function is best observed.

Limitations of Study

The fact that there are multiple executive functions contributing to each canonical function limits interpretation of direct relationships between the individual variables. The statistical technique utilized in this research project is best considered a descriptive technique or a screening procedure (Tabachnik & Fidell, 2001). So while this allows us to observe significant relationships between the two sets, further analysis would have to be done to clarify the specific impact of one measure on another. Another possible limitation of this study is the sample size. While this study's sample size is adequate for canonical correlation, some researchers prefer ten cases for every variable run in the analysis (10:1 ratio) (Tabachnik & Fidell). In this study, thirteen variables were run with eighty cases, making the ratio less than ideal (6:1). However, in research where the reliability of the variables is very high a lower ratio of cases to variables is accepted.

Recommendations for Further Research

Chaytor and Schmitter-Edgecombe (2003) emphasize the need to develop structured, objective methods for assessing the cognitive demands of a client's environment. The results of this study support the continued exploration of the TOGSS for this purpose. In order to fully realize the use of the TOGSS as a measure

of executive function for occupational therapy practice, the new TOGSS outcome measures included in this study: route, asking for assistance, sequential shopping, task persistence, and accuracy to cost, should be studied for validity and reliability.

The evidence in this study for specific relationships between executive function and grocery shopping performance is moderate and requires replication. A bootstrap canonical analysis which examines the replicability of a study using a canonical analysis is recommended for future investigations, as it is currently outside the scope of this project. It is also suggested to replicate this study as a prospective analysis, including measures for executive functions not included in this current study, such as inhibition, and with a different population to see if similar association patterns between executive function and community outcomes emerge.

Lastly, it is recommended that further research be conducted on the mechanisms of the relationships between problem-solving, working memory, planning, persistence, and grocery shopping efficiency. It would be interesting to see if there are any mediator effects occurring between the executive functions, which may explain how or why they are influencing community outcomes in people with schizophrenia (Brown, Rempfer, Hamera, & Bothwell, 2006).

Implications for Occupational Therapy Practice

Assessment Development

This study provides further insights into the role of executive function in the performance of the instrumental activity of daily living (IADL) of grocery shopping. In addition it provides support for an ecologically valid measure of executive function

such as the TOGSS. Brown, Moore, Hemman, and Yunek (1996) encourage occupational therapists to make clinical judgments based on performance in real-world environments. They argue that assessments in artificial settings may not capture the complexity and relevance of performance in natural environments. With the development of the TOGSS as a measure of executive function, an occupational therapist will be able to reliably observe an individual's performance in grocery shopping and associate these behaviors to underlying executive functions.

Given the relationship between executive function performance and shopping efficiency in this study, occupational therapists need to also consider the importance of assessing efficiency of performance. Most performance measures focus exclusively on accuracy as an outcome. While accuracy may be an easier skill to measure and access, on the basis of the results of this study, efficiency may be a more sensitive measure of impairment in executive function.

Intervention

It is an intention of this study to advance the ability to accurately measure underlying impairment affecting real-world performance (Green, 1996). With this knowledge, occupational therapists can design intervention programs which target specific skill sets affecting functional outcomes. For example, it would be consistent with the findings of this study to develop interventions focusing on the executive functions of problem-solving and working memory, but not planning, for individuals with schizophrenia who demonstrate difficulty with shopping accuracy. Davalos, Green, and Rial (2002) understood this when they developed a cognitive

rehabilitation program to specifically remediate executive function skills for individuals with schizophrenia, based on the results of functional assessments shown to capture executive function impairment. This is a direction occupational therapy practice should continue to move toward, real-world assessments capable of measuring functional capacity and underlying impairment so well-delineated treatment interventions can be developed.

Conclusion

This study continues the exploration of the relationships between cognition and functional outcomes, specifically between executive function and the independent living skill of grocery shopping. The results of this study provide strong evidence of a relationship between executive function performance and grocery shopping efficiency and accuracy as measured by the TOGSS, in individuals with schizophrenia. The ability to better understand the underlying mechanisms of impairment is critical for the development of interventions that can improve independent living. This study is one step in the process of being able to assess executive function ability with the TOGSS, for individuals with schizophrenia.

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Table 1 *Overview of Executive Function Constructs from Selected Literature*

Authors	**Initiation**	**Planning**	**Problem-Solving**	**Self-Monitoring**	**Inhibition**	**Task Persistence**	**Working Memory**
Bowie & Harvey 2005	Goal directed behavior		Adaptation to environmental changes; solve problems; use abstract thinking				
Burgess et al. 1998	Intentionality (planning, decision making, lack of insight, distractibility, knowing – doing disassociation	Intentionality (planning, decision making, lack of insight, distractibility, knowing – doing disassociation		Intentionality (planning, decision making, lack of insight, distractibility, knowing – doing disassociation	Inhibition (response suppression problems, impulsive, no concern feeling/rules, disinhibition, impaired abstract	Executive memory (confabulation, temporal sequencing problems, perseveration)	Executive memory (confabulation , temporal sequencing problems, perseveration)

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Callahan 2001	Initiation			Self-regulation	Termination		
Chan et al. 2004	Control of information on tasks involving initiation	Planning	Mental set-shifting, strategy allocation	Monitoring	Inhibition		
Cinan & Tanör 2002			Concept formation; regulation & response to environment; generate new hypothesis, set shifting	Regulation & response to environment; use of feedback	Inhibition		Working memory (maintenance & manipulation of different information)

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Collette et al. 2006	Initiation	Planning of action	Hypothesis generation, cognitive flexibility, judgment, decision making	Feedback management	Inhibition		
Cripe 1996	Direction	Planning Organization					Control
Denkla 1996	Initiate		Shift	Self-monitoring	Inhibit –stop	Sustain	Working memory
Donohoe et al. 2005			Set shifting		Inhibition	Sustained attention	Working Memory

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Elliott 2003		Planning	Shifting; solving novel problems; generate strategies or complex actions	Regulation; modify behavior in light of new information			
Godefroy 2003	Response initiation	Planning	Cognitive flexibility; rule deduction; problem-solving; strategy		Response suppression		

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Goldstein & Silverman 2005	Go - Initiative / agency		How to go – Set acquisition, maintenance, shifting	How to go – Conflict detection; conflict resolution	No go – Inhibitory control		
Green et al. 2000	Volition	Planning		Self-monitoring		Purposive action	
Grieve 2000	Formulate goals	Set & organize plans	Determine information relevant for decision making with plan change	Monitor tasks			

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Hamera & Brown 2000		Planning	Cognitive flexibility		Self evaluation		
Homack et al. 2005		Planning	Cognitive flexibility, problem-solving, concept formation, abstract thinking, creativity in verbal & spatial modes			Inhibition, impulse control	

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Lezak 1995	Volition: form goal/intention; purposive action,; initiation	Planning	Purposive action,; switch sequences	Effective performance; ability to monitor; self-correct & regulate	Purposive action: stop sequences	Purposive action: maintain	
Loring 1999		Plan	Anticipate outcomes; cognitive flexibility	Self-monitoring & self-awareness as necessary for behavioral flexibility & appropriateness			

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Manchester et al. 2004	Formulation of goals	Planning how to achieve goals				Carrying out plans effectively	
Miyake et al. 2000			Shifting	Updating	Inhibiting		
Reed at al. 2002			Conceptual flexibility; abstract reasoning; maintenance & shifting of set; hypothesis testing	Self-monitoring			

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Shallice & Burgess 1991	Goal articulation	Plan formation		Evaluation	Marker creation (anticipation) & marker triggering (inhibition)		
Simon et al. 2003		Planning complex behaviors	Generation strategic approach to problem	Monitoring performance	Revision of inappropriate strategies / behaviors	Execution of complex behaviors	
Singer & Bashir 1999	Setting goals	Planning future actions; organizing	Maintaining and shifting set		Inhibiting irrelevant actions; restraining and delaying responses		Holding plans in working memory until executed

Authors	Initiation	Planning	Problem-Solving	Self-Monitoring	Inhibition	Task Persistence	Working Memory
Sohlberg & Mateer 2001	Initiation; drive; starting behavior	Organization of actions and thoughts	Generative thinking – creativity, fluency, cognitive flexibility		Response inhibition – stopping behavior	Task persistence – maintaining behavior	
Stuss & Benson 1986	Goal selection; initiation	Pre-planning; planning; sequencing; organization	Anticipation	Monitoring; use of feedback; regulation		Drive	

Table 2 *Demographic Data*

Domain	Variable	N	%
Gender	Female	41	52
	Male	39	49
Age	24-44 years	40	50
	45-63 years	37	46
	Unidentified	3	4
Ethnicity	African-American	45	57
	White	27	34
	Multiracial	3	4
	Hispanic	2	3
	American-Indian	1	1
	Asian	1	1
Marital Status	Never Married	47	59
	Divorce/Annul	24	30
	Widow	2	3
	Separated	2	3
	Married	4	5
Living Situation	With Relatives – Heavily Dependent for Personal Care	5	6
	With Relatives – Largely Independent for Personal Care	17	22

	Supervised Care – Live in Staff	4	5
	Independent Living	50	63
	Homeless	1	1
	Other	2	3
Education	Up to Eight grade	3	4
	Some High School	18	23
	High School Graduate	21	27
	Post High School Training	1	1
	College Courses	29	37
	Bachelor Degree	5	6
	Post-Graduate Education	1	1
Employment	Not currently in paid employment	67	85
	Currently in paid employment	18	15

Table 3 *Executive Function Measures and TOGSS Outcomes A priori Assignment to Executive Function*

	Initiation	**Planning**	**Problem-Solving**	**Inhibition**	**Task Persistence**	**Working Memory**
Executive Function Measures						
CFT		√				
d2		√		√	√	
TMT			√		√	√
WCST			√			√
COWAT	√		√			
CVLT		√	√			
LNS						√
DSB						√ √
MO						√

	Initiation	Planning	Problem-Solving	Inhibition	Task Persistence
TOGSS Outcome Measures					
Shopping Efficiency		√			
Shopping Accuracy			√		
Route		√		√	
Assistance Sought			√		
Sequential Shopping			√		
Accuracy to Cost					
Task Persistence					√

Table 4 *Means, standard deviations, and correlations between executive function measures and TOGSS outcomes*

Variable	Mean	(s.d)	Shopping Efficiency	Shopping Accuracy
Set 1- Outcome Measures of Executive Function				
CFT Recall	9.42	(4.95)	-0.238*	0.235*
d2 Rule Compliance	121.99	(37.97)	-0.126	0.199
d2 Concentration Performance	271.30	(79.78)	-0.076	0.179
TMT B time – TMT A time	91.36	(50.31)	0.062	-0.325*
WCST Perseverative Errors	18.19	(10.91)	0.382**	-0.093
WCST Trials to Category 1	30.26	(22.14)	0.323**	-0.046
WCST Total Correct	34.53	(11.10)	-0.313**	0.222*
COWAT	27.20	(11.15)	-0.152	0.190
LNS	7.19	(2.80)	-0323**	0.395**
DSB	4.15	(1.96)	-0.048	0.339**
MO	7.29	(3.47)	-0.133	0.422**
Set 2 – Outcome Measures of TOGSS				
Shopping Efficiency	4.60	(3.37)	1.000	-0.170
Shopping Accuracy	23.52	(4.02)	-0.179	1.000

** Correlation is significant at the .01 level

* Correlation is significant at the .05 level

Table 5 *Standardized Canonical Coefficients, Canonical Loadings, Percent of Variance, Redundancies, and Canonical Correlations between Executive Function and TOGSS Variables and Their Corresponding Canonical Variates*

	First Canonical Variate		Second Canonical Variate	
	Canonical Coefficient	Canonical Loading	Canonical Coefficient	Canonical Loading
Executive Function Set				
CFT Recall	-.396*	-.377	-.050	-.442
d2 Concentration Performance	.316*	-.091	-.089	-.342
d2 Rule Compliance	-.457*	-.179	.125	-.378
d2 Error of Commission	.000[a]	----	----[a]	----
TMT B time – TMT A time	.236	.026	.268	.626
TMT B Time	.000[a]	----	----[a]	----
TMT B Error	.000[a]	----	----[a]	----
DS	.962*	.684	-.432*	.157
WCST Trials to Category 1	.343*	.588	.529*	.070
WCST Total Correct	.677*	.521	.748*	-.412
COWAT – FAS version	-.210	-.230	-.029	-.359
CVLT	.000[a]	----	----[a]	----
LNS	.526*	-.490	-.297	-.747
DSB	.596*	.004	-.084	-.655
MO	.077	-.130	-.416*	-.809
Percent of Variance (Total, .399)	.143		.256	
Redundancy Analysis (Total, .112)	.043		.069	

	First Canonical Variate		Second Canonical Variate	
	Canonical Coefficient	Canonical Loading	Canonical Coefficient	Canonical Loading
TOGSS Set				
Shopping Efficiency	1.016*	.989	-.030	.149
Shopping Accuracy	.152	-.030	-1.005*	-1.000
Route	.000[a]	----	----[a]	----
Assistance Sought	.000[a]	----	----[a]	----
Sequential Shopping	.000[a]	----	----[a]	----
Accuracy to Cost	.000[a]	----	----[a]	----
Task Persistence	.000[a]	----	----[a]	----
Percent of Variance (Total, .1.00)	.489		.511	
Redundancy Analysis (Total, .283)	.146		.137	
Canonical Correlation	.547††		.519†	

[a] Set to zero as this coefficient was not included in the final analysis; see variable screening routine in results section

*Cutoff for interpretation .30

†† $p = .001$

† $p = .013$

Appendix A

Comprehensive Literature Review and References

Literature Review

This literature review will examine definitions and descriptions of executive function, perspectives on the various components or functions considered part of executive function, the nature of executive dysfunction in the people with schizophrenia, current assessment methods for measuring executive function behavior, and the need for real world assessments to capture an accurate picture of specific executive functions.

Executive Functions

Executive functions are those capabilities which enable a person to engage successfully in independent, purposive, and self-serving behaviors (Lezak, 1995). They are necessary for complex, goal-directed behavior and adaptation to a range of environmental changes and demands (Collette, Hogge, Salmon, Van Der Linden, 2006; Loring, 1999). A fundamental responsibility of executive functions is the coordination and control of cognitive processes including planning, shifting, and regulation (Cripe, 1996: Denckla, 1996; Elliott, 2003; Katz and Harman-Maeir, 2005; Simon, Giacomini, Ferraro, and Mohr, 2003). Executive functions are involved in the completion of a goal-directed activity that is not overlearned, automatic, and routine (Sohlberg and Mateer, 2001). This is reinforced by Godefroy (2003), who describes

executive functions as "high order functions operating in non-routine situations, such as novel, conflicting, or complex tasks (p. 1)."

The literature devoted to executive function ability reflects its complexity and its resistance to a single conceptualization or definition (Lyon and Krasnegor, 1996). Elliott (20030 reports that there is no lay concept of executive function as there is for domains like memory and attention (Elliott, 2003). Two basic perspectives emerge when trying to classify executive function. One perspective is those which describe executive function without fractionating specific processes (Bell-McGinty, Podell, Franzen, Baird, and Williams, 2002). A second, broader, more comprehensive perspectives, identifies and defines particular executive functions (Katz and Harman-Maeir, 2005). It is important to note that the vocabulary used within the executive function literature is inconsistent as the terms and definitions vary and remain ambiguous. For example, the term inhibition is also called termination, inhibitory control, response suppression, and stopping behavior. All of these 'executive functions' are terms that convey the same behaviors. Some authors have created their own labels or names for executive functions (Goldstein and Silverman, 2005; Sohlberg and Mateer, 2001; Burgess, Alderman, Evans, Emslie, and Wilson, 1998). Another example, Goldstein and Silverman's identify executive functions or initiation as "go", the executive function of shifting as "how to go", and the executive function of inhibition as "no go". In addition to using a variety of terms to define a singular concept, the plural and singular form of executive function is occasionally used to describe the same thing. For example, executive function is used when describing all

the responsibilities that the separate executive functions have together, and it is also used when preparing to describe a particular executive function. It is important in each case to look at the context of the sentence to see what the author is trying describe, whether it is the construct of executive function or a component of executive function.

Executive Function Components

Between and within the fields that study executive functions, there is some general agreement on functions that can be classified as an executive function (Callahan, 2001). An overview of the classification of executive functions is provided in Table 1. The twenty-six documents included in Table 1 were examined for definitions and descriptions of executive function. In particular the review made note of any behaviors identified as a specific part of executive function. Once identified, these behaviors were sorted into groups with other similar behaviors. Each group was labeled an executive function component and was named to reflect the most frequently observed executive behavior within the group. Seven separate functions are identified in Table 1: initiation, planning, problem-solving, self-monitoring, inhibition, task persistence, and working memory. The functions were deliberately placed in specific column order in Table 1, to reflect the sequence in which the executive processes usually occur, as well as the way the functions build upon each other.

In the literature the most consistently agreed upon executive functions are initiation, planning, problem-solving, self monitoring, and inhibition (Elliott, 2003;

Green, Kern, Braff, and Mintz, 2000; Grieve, 2000; Hamera and Brown, 2000; Lezak, 1995; Loring, 1999; Manchester, Priestly, and Jackson, 2004; Simon et al., 2003). Initiation, the first function identified in Table 1, is the ability to start behavior. It is necessary for carrying out the action plans made to accomplish intentions and goals (Lezak, 1995). This function includes volition, the capacity for intentional behavior and the ability to form a goal. The second function, the ability to plan, was the component most frequently identified across the different models of executive function. Planning includes the ability to order, plan ahead, and organize. It has been shown to be a skill that either appears naturally, laboriously, effectively, or not at all in humans (Lezak, 1995).

The third function identified, has the most disparate terms to describe the ability to problem solve and shift set. This function includes the ability to develop and execute a new strategy, use abstract thinking and hypothesis testing, and be cognitively flexible. Cognitive flexibility includes the ability to shift ones thinking and is critical for successful completion of purposive action. This function is closely related to self-monitoring and regulation as it is necessary to recognize there is a problem before a solution can be generated (Lezak, 1995). Self-monitoring, like planning and problem-solving, is recognized frequently as a component of executive function. These behaviors include the ability to detect conflict, recognize new information needed for adjusting behavior, self evaluation, and the capacity to use feedback. The fifth function, inhibition, includes the ability to terminate or inhibit unwanted or irrelevant behaviors. Poor impulse control, problems with stopping

inappropriate strategies, and difficulty delaying or restraining a response are all reflected in this component of executive function.

Two processes included in Table 1, but not as commonly identified as executive functions are task persistence and working memory. Task persistence, the ability to maintain purposive action, is often considered a part of attention. Lezak (1995) identifies task persistence as complex attention with two distinct mechanisms: 1) attention, as seen in the ability to resist distraction, and 2) control, the ability to continue with a task without slowing down, losing interest, or giving up. It is the control aspect of task persistence which is being considered in this review as an executive function. According to Sohlberg and Mateer (2001), task persistence is critical for handling nonroutine or novel situations and relies on intact working memory.

Working memory, the ability to maintain and manipulate information for complex tasks, is widely discussed in the literature but not always associated with executive function (Baddeley, 2001; Barch, 2006; Cinan and Tanör, 2002; Denckla, 1995; Donohoe, Corvin, and Robertson, 2005; Hester and Garavan, 2005; McGurk et al., 2004). In the original model of working memory, the central executive was conceived of as a limited capacity pool of general processing resources (Baddeley and Hitch, 1974). Over time, the processes of the central executive were systematically explained by concentrating on its attentional control characteristics, making it standard for the functions of the central executive to be understood through a model of attentional control, the supervisory attention system (SAS) (Norman and Shallice,

1986). The SAS is a high-level attention mechanism (Katz and Hartman-Maeir, 2005), which controls those processes requiring deliberate and conscious allocation of attention resources. Based on the above model, working memory becomes the base upon which supervisory attention is deployed. Executive functions are then the visible, expressed actions and behaviors of the supervisory attentional system (Chan, Chen, Cheung and Cheung, 2004; Evans, Chua, McKenna, and Wilson, 1997). Working memory allows information to be manipulated and maintained until necessary for use in a situation requiring controlled attention (SAS), such as when managing a novel situation or when working out a conflict between an old way and new way of doing things (schema management). The tangible evidence that this process is occurring is in behavior, specifically the behaviors of the executive functions, whether it be inhibiting a thought, or initiating a conversation, or switching to a different way to complete a task (Baddeley, Della Sala, Papagno, and Spinnler, 1997; Barch, 2003, 2006; Cinan and Tanör, 2002; Donohoe et al., 2005; Repovs and Baddeley, 2006).

These seven functions overviewed in Table 1 represent unique but related and interdependent functions. When executive dysfunction occurs, it may occur in just one of these areas, such as an inhibition disorder, or it can manifest itself in multiple areas, as with reduced initiation, inhibition, and self-monitoring (Sohlberg and Mateer, 2001).

Executive Dysfunction in the Schizophrenic Population

It is accepted that executive dysfunction is one of the "most ubiquitous features" of schizophrenia (Bowie and Harvey, 2005). Kraepelin (1919) was the first to note the importance of recognizing executive dysfunction as a component of schizophrenia. He ascribes difficulties in judgment and attention to an underlying deficit in the "process of volition" in people with schizophrenia. The disease itself is often described with terms that indicate problems with executive function. For example, Frith (1992) and Semkovska, Bedard, Godbout, Limoge, and Stip (2004) describe schizophrenia as a disorder of willed action, self-monitoring, and monitoring the intention of others. They highlight additional problems with disturbed planning, reduced cognitive flexibility, lack of inhibition, and poor problem-solving. Barch (2003) attributes the cognitive struggles of people with schizophrenia to a disturbance in executive control processes. It is these processes that are critical to representing and maintaining context information.

Limitations in executive function performance in schizophrenia are related to functional outcomes (Green et al., 2000; Reed, Harrow, Herbener, Martine, 2002). Executive function is predictive of basic self-care skills (Velligan, Bow-Thomas, Mahurin, Miller, and Halgunseth, 2000), instrumental activities of daily living (IADL) (Rempfer, Hamera, Brown, and Cromwell, 2003; Semkovska et al., 2004), work/productivity and social competence (Velligan et al., 2000).

While executive function deficits are quite common among individuals with schizophrenia (Barch, 2003; Palmer and Heaton, 2000), the population does demonstrate different degrees of executive dysfunction as some perform in the

normal range and others show severe impairment contributing to functional dependence (Simon, Giacomini, Ferrero, and Mohr, 2003). The heterogeneous nature of the population is one reason why accurate evaluation of executive functions is important.

Measurement of Executive Function

Individuals with schizophrenia perform poorly on traditional psychometric tests of executive function such as the Wisconsin Card Sort Test (WCST), the Trailmaking Test, and the Test of Verbal Fluency, as well as tests sensitive to frontal lobe lesions (Palmer and Heaton, 2000). In contrast, some people with schizophrenia have been observed succeeding on neuropsychological measures but then struggling in everyday life. Because different people with schizophrenia will have different types and levels of executive dysfunction, detailed assessment will always be needed (Evans et al., 1997; Hamera, Brown, Rempfer, and Davis, 2002). While there are measures designed to screen for executive dysfunction, they are limited in their ability to specifically identify a deficit in a particular component of executive function. In addition, standardized psychometric measures have been criticized because they are not sufficiently sensitive to identify executive dysfunction and are poor predictors of everyday behaviors and dysfunctions (Manchester, Priestly, and Jackson, 2004). Cripe (1998) and Shallice and Burgess (1991) suggest that executive assessments administered in real-world environments may provide valid indicators of individuals' daily deficits experienced outside clinical settings. The environment in which standard measures are administered is typically quiet, and distraction-free.

Test administration is controlled: the examiner tells the client when to begin (initiate), how to do the task (plan), when to end the task (termination) and the overall goal is made explicit to the individual. This controlled environment may actually assist client performance through subtle expectant cues from the test administrator and a test format which limits the need to inhibit perseverative behaviors (Callahan, 2001; Krabbendam, de Vugt, Derix, Jolles, 1999; Manchester et al, 2004; Semkovska et al., 2004). Real-world assessments provide an opportunity to see a reflection of a client's ability to respond in a dynamic, novel, and unpredictable environment. While measures which mimic real-world situations have been shown to be capable of assessing executive function (McKibbin Brekke, Sires, Jeste & Patterson, 2004), measures which occur in a real-world environment may allow us to better discern specific executive functions.

One such real world measure is the Test of Grocery Shopping Skills (TOGSS; Hamera and Brown, 2000). The TOGSS was developed to measure the effectiveness of grocery shopping in individuals with schizophrenia. This context-based assessment requires a client to locate 10 items in an actual community grocery store. Performance is assessed on two primary outcomes: accuracy, which includes finding the correct item, in the correct size at the lowest price; and efficiency, which includes redundancy (how often shoppers return to an aisle or go down an aisle that does not contain a needed item), and time (total time needed to complete the test) (Brown, Rempfer, and Hamera, 2002).

The TOGSS has been examined for reliability and validity as a context-based community function measure (Hamera and Brown, 20000); for construct validity (Hamera, Brown, Rempfer, and Davis, 2002); for how a mediator, knowledge of grocery shopping, influences cognition and community functioning (Brown, Rempfer, Hamera, and Bothwell, 2006); and for relationships between cognition and the IADL of grocery shopping (Brown, Rempfer, and Hamera, 2002; Rempfer et al., 2003). However, these previous studies have not explicitly focused on the role of executive function in grocery shopping as measured by the TOGSS. When Greenwood, Landau and Wilkes (2005) used the TOGSS as their community function outcome measure they modified the measure to explicitly reflect executive processes thought to underlie performance. This was accomplished by specifically considering route taken around the store in both the redundancy outcome and with a new outcome, strategy, which captures number of items selected on a particular route. Building on these prior works, this thesis project intends to be the first focused examination of the relationship between executive function and performance on the TOGSS.

While the TOGSS considers executive processing as a key component to successful performance in community based skills, it was not designed as a measure of executive function but as a measure of grocery shopping. It may be possible to use the TOGGS to assess specific executive functions and in doing so identify which particular problems with executive function interfere with the performance of grocery shopping.

Problem Statement

Impaired executive functions are highly prevalent in schizophrenia. A critical reason for understanding the impact of executive function deficits in schizophrenia is the strong relationship between cognitive performance, functional skills, and functional outcomes (Bowie and Harvey, 2005). However, current cognitive measures vary in their ability to adequately assess executive dysfunction (Donohoe et al., 2005). Green et al. (2000) recommends that tests designed and selected for assessing related capacities may be more useful when trying to observe relationships to functional outcomes. The Test of Grocery Shopping Skills is such a measure.

The purpose of this study is to examine the Test of Grocery Shopping Skills (TOGSS) to determine if it is a valid measure of the executive functions of planning, problem-solving, task persistence, and working memory for individuals with schizophrenia. Using a multivariate analysis approach, the proposed project will test two general hypotheses:

Hypothesis 1: A relationship will be found between the set of neuropsychological measures of executive function and the TOGSS outcomes variable set, suggesting that the TOGSS can be used as a valid measure of executive function.

Hypothesis 2: Specific patterns of association will emerge from within the observed relationships between the cognitive measures set and the TOGSS outcome set, representing planning, problem-solving, persistence, and working memory

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Appendix B

Data Collection Form

TOGSS Data Collection

Participant # _____

TOGSS Form Used (circle) 1 2

TOGSS OUTCOME	MEASURE	PARTICIPANT DATA		ENTRY
Task Persistence Retrieve all 10 items on list	# of total items collected x/10			
Route Number of times participant diverts from the list and creates own path	# of times participant diverts from list x/10	10th (Last) Item =		
Sequential Shopping Ability to retrieve items in sequence on multiple item row Form 1 = 2 items Form 2 = 3 items	# of items retrieved in sequence in multiple item row / Total # of items available to retrieve on multiple item row Form 1 = x/2 Form 2 = x/3	Form 1 Muffin ____ Taco ____ / =	Form 2 S. Joe ____ Tuna ____ Soup ____ / =	
Accuracy Total Attend to three accuracy features: item, size, and cost	Selects correct item At correct size At lowest price x/30			
Accuracy Cost Attends to the lowest price for an item	Accuracy with lowest price x/10; Compare cost accuracy to size/item accuracy LA – lowest accuracy score MA – mid accuracy score HA – high accuracy score	Circle: LA MA HA		
Assistance Sought Participant seeks help from someone in store (not research assistant)	# of times participant seeks help			
Redundancy Amount of unnecessary aisles participant enters	# Aisles entered - # Aisles containing target items / Total aisles in the store			