Test-Retest Reliability Of A Computerized Cognitive Test Battery: Examining Effect Of Age and Stroke.

BY

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THESIS

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Dedicated to my family – my husband (Yash Nanavati), parents (Harsha and Pankaj Vora) and my parents-in-law (Harsha and Nishat Nanavati). Their constant encouragement and support has been crucial to the successful completion of this thesis.

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JV

CONTRIBUTION OF AUTHORS

Chapter 1 is a literature review that places my dissertation question in the context of the larger field and highlights the significance of my research question. Chapter 2 represents a published manuscript **(Vora J, Varghese R, Weisenbach S, Bhatt T.** Test-retest reliability and validity of a custom-designed computerized neuropsychological cognitive test battery in young healthy adults. Journal of Psychology and Cognition 2016; 1:11-9) for which I was the primary author and major driver of the research. Rini Varghese assisted me in developing the computerized cognitive test battery, the pictorial presentation is shown in Figure 1. Dr. Sara Weisenbach and my research mentor, Dr. Tanvi Bhatt contributed to the writing and editing of the manuscript. Chapter 3 represents a further extension of my second chapter and the manuscript is still under review for which I am the primary author. I primarily worked on data collection and data analyzing along with writing and editing the manuscript with Dr. Sara Weisenbach and my mentor Dr. Tanvi Bhatt. Rini Varghese and Victor patron assisted me in data collection as we have three groups in the study. Chapter 4 is the concluding chapter of my thesis which aims at examining the effectiveness of a novel cognitive-motor training paradigm by assessing the difference in the cognitive response pre-and post-intervention. I anticipate that this line of research will be continued in the laboratory after I leave and that this work will ultimately be published as part of a co- authored manuscript.

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LIST OF ABBREVIATIONS

CCT: Computerized cognitive test

D-KEFS: Delis - Kaplan Executive Function System

CMI: Cognitive-motor interference

CVA: Cerebrovascular accident

MCI: Mild cognitive impairment

I: Ischemic

H: Hemorrhagic

SC: Spot & Click

SRT: Simple reaction time

CRT: Choice reaction time

SPSS: Statistical package for the social sciences

ANCOVA: Analysis of covariance

ICC: Intraclass correlation co-efficient

CI: Class Interval

SD: Standard deviation

WRAT-4: Wide range achievement test- 4

MOCA: Montreal cognitive assessment scale

Cat.N: Category naming

WLG: Word list generation

CN: Color naming

CN-C: Color naming- Congruent slide

CN-IC: Color naming-Incongruent slide

LN: Letter number sequencing task

TT: Triangle tracking

LT: Letter tracking

US: Unveil the star

PG: Peg board game

SUMMARY

Neurocognitive decline is a growing concern, as it results in loss of functional independence in healthy aging individuals' and also in individuals' with neurological impairments. Currently, computerized testing methods are widely used for assessing cognition, as they provide several advantages over the traditional paper-and-pencil testing methods which can be time-consuming, lengthy, and often require specialized training and are prone to manual error. Computerized testing is a more consistent, relatively cost-effective, and more sensitive (in order of milliseconds) tool that is visually appealing. There are numerous well-established computerized batteries that have been developed and reported, however, these can be fairly expensive, limiting their use. Hence we custom-designed a computerized cognitive battery using DirectRT Empirisoft™, which is both affordable and user-friendly.

The main purpose of this thesis was to observe and assess the efficacy and usability of the developed computerized cognitive test (CCT) and to assess the subtle changes in cognition among individuals' with neurological impairment. This purpose was achieved by establishing test-retest reliability and concurrent validity of the CCT primarily in healthy young adults (first study) followed by assessing the same across three different groups including stroke survivors, healthy older adults, and young adults. This project also aimed to examine group differences in neurocognitive performance across the aforementioned three groups (second study). Additionally, we conducted a pilot study to assess whether the developed computerized cognitive test battery is sensitive to reported subtle changes in the cognitive performance of chronic stroke survivors, followed by a novel cognitive-motor intervention (third study).

The first study aimed to develop a custom designed computerized cognitive test battery that assessed different cognitive domains such as working memory, response inhibition and switching, associated learning, and reaction time using DirectRT Empirisoft™. We conducted statistical analyses on the data collected from fifteen healthy young adults to determine test-retest reliability and concurrent

validity. The results indicated that the CCTs administered using DirectRT Empirisoft™ provided measurements that are highly consistent and repeatable on two separate occasions parted by a period of 10-12 days. The data is presented in Chapter II.

The second study aimed to further assess the psychometric properties of the same computerized cognitive test battery across different populations; namely stroke survivors (n=15), healthy older adults (n=15) and young adults (n=15) along with examining the effects of aging and neurological impairment on cognitive performance. The results suggest that the test battery provides highly reliable measures of cognitive functioning across the two testing sessions in chronic stroke survivors, healthy older and younger adults. In addition, CCTs were able to detect expected differences in cognition among the three testing groups with stroke survivors performing more poorly than the healthy younger and older adults. This data is presented in Chapter III.

Finally, the third study aimed at examining the effectiveness of a novel cognitive-motor training paradigm by assessing the difference in the cognitive response pre-and post-intervention. The results showed that individual's with stroke did show an improvement in cognition. These data are presented in Chapter IV.

CHAPTER 1

INTRODUCTION

1.1 Background

Stroke is a common disabling neurological condition with a spectrum of sensory, motor, and cognitive deficits that significantly increase the risk of falls (Ageing & Unit, 2008). The incidence of falls among community-dwelling chronic stroke survivors ranges from 40% to 70% each year, which is greater than 30% of falls observed in healthy older adults (Belgen, Beninato, Sullivan, & Narielwalla, 2006; Lamb, Ferrucci, Volapto, Fried, & Guralnik, 2003). Even when falls are avoided, the induced fear of falling affects activities of daily living, community mobility and integration (Baseman, Fisher, Ward, & Bhattacharya, 2010; Lord, McPherson, McNaughton, Rochester, & Weatherall, 2004). Studies have suggested that 64% of the stroke survivors have cognitive impairments unrelated to dementia which can demonstrate marked attention deficiency compared with healthy adults (Jin, Di Legge, Ostbye, Feightner, & Hachinski, 2006) and increase risk of falls.

Recovery from stroke involves re-learning activities that were performed previously. Re-learning these activities can place a significant demand on the limited cognitive resources available post-stroke, which has been observed through dual-task paradigms that focus on simultaneous performance of a motor and a cognitive task. Therefore, a cognitive-motor paradigm can be helpful in capturing interactions between the cognitive and motor systems as result of age, disease or rehabilitation, but for this we require an accurate and sensitive assessment tool. Numerous paper-based tests have been used for cognitive assessment which at times are lengthy, time consuming and requires specialized person for its administration. The use of computerized testing is increasing in popularity and may offer an alternative to some of the conventional testing methods. However, the computerized batteries available are fairly expensive thereby limiting their use.

1.2 Statement of the problem

Cognitive decline is associated with both healthy aging (Troyer et al., 2014) and neuropathology (McDonnell, Bryan, Smith, & Esterman, 2011). Cognitive decline is often not an isolated problem and is known to interfere with everyday motor activities such as walking, driving and much more, referred as cognitive-motor interference (CMI). CMI occurs when a motor and a cognitive task are performed concurrently. There is an abundance of research that has been conducted in order to understand the various patterns of interference, and there is also a lot of evidence suggesting that cognition plays a vital role in facilitating motor performance and improving rehabilitation outcomes (Lauenroth, Ioannidis, & Teichmann, 2016) However, cognitive testing and interventions have not been routinely utilized in clinical rehabilitation settings.

1.3 Significance of the problem

Cognition can be defined as a broad term incorporating an individual's awareness of their surrounding or environment that enables them to make decisions, plan and execute the activities of daily living in an orderly manner (Tatemichi et al., 1994). Age-related or neuropathological disease-related cognitive decline can be investigated in order to design suitable interventions, demanding a need for a suitable and easily reproducible cognitive test battery. Computerized cognitive testing can prove to be a potential alternative as compared to traditional paper-and-pencil methods. Numerous computerized batteries have been reported in the literature however, they are fairly expensive thereby limiting their use.

1.4 Purpose of the study

The primary purpose of this thesis was to examine the effect of aging and neuropathological disease such as stroke, on individuals' cognitive abilities using a reliable and efficient computerized cognitive test battery. Secondly, we also wanted to understand the proficiency of the battery to measure the change in cognitive abilities post-intervention. To fulfill the purpose of this thesis, we performed a set of three experiments. The first study was designed to develop and establish reliability and validity for the methods used to assess cognition in healthy young adults. The second experiment utilized the tested methods to observe the psychometric properties of the test battery and compare the cognitive abilities across three different populations; chronic stroke survivors, healthy older adults and healthy young adults. Lastly, in the third experiment, after establishing the reliability of the test battery across different populations, we employed similar methods to assess the change in cognition pre-post a novel dual-task tapering intervention. Hence the overall purpose of the thesis was split into three primary aims:

Aim 1 - The purpose of the first experiment was to establish test-retest reliability and validity of a custom-designed computerized cognitive test battery in young healthy adults.

Hypothesis 1 - We hypothesized that all of the test variables obtained from the custom-designed computerized test battery would establish good to moderate concurrent validity on comparison with gold standard tools and would be reliable between the two testing sessions.

Aim 2 – The purpose of the second experiment was primarily to establish the test-retest reliability of a custom-designed, computerized cognitive test battery (CCT) in stroke survivors and healthy older and young adults. The secondary aim was to understand the effect of aging and neurologic disorder due to stroke on cognitive functioning amongst healthy individuals' and stroke survivors.

Hypothesis 2- We hypothesized that 1) all the test variables obtained would demonstrate good to moderate reliability and concurrent validity across different populations'; and 2) cognition assessed using the CCT's would be significantly impaired in the participants with stroke as compared to healthy older adults and young adults.

Aim 3 – The purpose of the final experiment was to examine the efficacy of a novel cognitive training paradigm among chronic stroke survivors that combined virtual reality for balance training among stroke survivors, but here we primarily focused on improvement observed in cognition assessed using the computerized cognitive test battery.

Hypothesis 3 – We hypothesized that a significant improvement would be observed in the test scores post-cognitive training intervention due to its engaging and motivational aspects.

1.5 Organization of thesis

The thesis is organized into four chapters. Chapter I provided an overview of the background, purpose and significance of the study. Chapters II, III, and IV test the aims of the three experiments; they describe the background, methods, results, discussion, and the conclusions, along with further clinical implications for each experiment respectively.

CHAPTER II

AIM 1: TEST-RETEST RELIABILITY AND VALIDITY OF A CUSTOM-DESIGNED COMPUTERIZED NEUROPSYCHOLOGICAL COGNITIVE TEST BATTERY IN YOUNG HEALTHY ADULTS.

The data presented in this chapter is currently published in a peer-review journal as:

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2.1 Introduction

Cognitive decline is prevalent in both healthy aging (Troyer et al., 2014), and in individuals with neuropathological diagnoses (McDonnell et al., 2011) and is among the strongest determinants of real world functioning and quality of life in affected individuals (Bartels, Wegrzyn, Wiedl, Ackermann, & Ehrenreich, 2010)Although cognitive decline is not preventable, it can be slowed with timely and accurate testing and appropriate training. Feasible methods of neuropsychological assessment are thus crucial in enhancing the quality of care available for these individuals.

However, cognitive decline is often not an isolated problem and is known to interfere with everyday motor activities such as walking, driving, manipulating objects etc. (Owsley, Ball, Sloane, Roenker, & Bruni, 1991; P. Patel & Bhatt, 2014). This is referred to as cognitive-motor interference and occurs when a motor and a cognitive task are performed concurrently, resulting in poor performance on one or both tasks. These effects are attributed to competing demands of the two systems for either limited attentional resources or limited processing capacity (Lundin-Olsson, Nyberg, & Gustafson, 1998; Plummer et al., 2013). Dual task assessments, using a cognitive-motor paradigm, can be helpful in capturing changes in the normal interaction of these two systems as a result of age, disease or rehabilitation, but require accurate and sensitive assessment tools that can be employed even while performing motor activities.

Traditionally, cognitive function has been evaluated using paper-based tests, which are lengthy, time-consuming, often require special training and are prone to manual error (Boringa et al., 2001; Heaton, 1993; Lowe & Rabbitt, 1998). Furthermore, by nature, these measures are also not feasible for use in cognitive-motor dual task paradigm, limiting their overall usability in rehabilitation settings.

Computerized cognitive testing (CCT) is a new and developing approach that may offer a potential alternative to some of these conventional methods of testing. CCT has many advantages over conventional methods; they are more consistent, in terms of administration and scoring, afford sensitive measurement, in the order of milliseconds, allow precise stimulus control, are relatively cost efficient, can be visually appealing and can be used to create and maintain digital records (Gualtieri & Johnson, 2006). Numerous computerized batteries have been developed and reported in the literature, however, these can be fairly expensive, limiting their use.

In this study, we developed an affordable alternative for computerized cognitive testing that may also have other potential applications. The cognitive battery was designed using the DirectRT Empirisoft (Jarvis, 2014) and consisted of tasks that measured domains directly relevant to dual tasking, such as executive functions, working memory, fluency, and attention span. The DirectRT software used in this study is cost-effective, user-friendly and allows customizable test designs, making it very feasible to develop and administer a variety of cognitive tests without specialized training. Nonetheless, before this tool can be used clinically, it is important to determine its psychometric properties. The purpose of this study, therefore, was to establish the test-retest reliability and concurrent validity of a custom designed computerized neurocognitive battery in healthy young adults using the commercially available Direct RT™ Empirisoft.

2.2 Methods

2.2.1. Participants

Fifteen healthy young adults (23.87 yrs±1.35, 16.80±1.47 years of education) were recruited for the study via informational flyers posted across the University campus. Participants were included if they had no self-reported physiological, neurological and psychiatric conditions. Approval from the University Institutional Review Board was obtained prior to the start of the study. All participants signed an informed consent form before participating in the study.

Participants completed three paper-and-pencil measures (Verbal Fluency, Color-Word Interference and Tower of Hanoi Test) drawn from the Delis Kaplan Executive Function System™ (D-KEFS) (Delis, Kramer, Kaplan, & Holdnack, 2004), which is a commonly used neuropsychological battery that assesses different aspects of executive function with a good to moderate internal consistency. Participants also completed a computerized neurocognitive battery test administered using DirectRT™, Empirisoft. The outcome variables for each these batteries are presented in Tables I and II.

2.2.2 Protocol

All testing was completed in a silent room in order to avoid external disturbances or distractions. The D-KEFS tests were administered by a trained examiner who sat across from the participant and read aloud the standard instructions from the manual. Depending on the test, the time of completion or responses generated were noted by the examiner as outcome measures. For the computerized testing, the screen was positioned to be in front of the participant and noise-cancelling headsets with a microphone were used to record the responses. Each test was preceded by an instruction slide and the participant was instructed to press a key when ready to begin testing. Participants were instructed to provide quick and accurate responses to each of the tests in the battery, and all tests were administered in a randomized order at two sessions separated by a 10-12 day interval. The D-KEFS items (i.e. Verbal Fluency, Color- Word Interference and Tower Test) were performed at the first session and in the same order as the computerized testing.

2.2.3 Cognitive Test Battery

Computerized Cognitive Testing (CCT)

a) Category Naming (Cat.N) and Word List Generation test (WLG): Semantic fluency was assessed by providing a category cue to the participant (i.e. Animals, boys' names or countries), while phonemic fluency was measured by providing a letter cue to the participant (i.e. F, A or S). Participants were given one minute to provide as many words as possible and instructed not to list any proper nouns such as the name of places or people. Voice responses were recorded by the computer (Boringa et al., 2001). (Fig 1-a)

b) Color Naming test (CN): This test is an adaptation of the classic Stroop paradigm measuring inhibition and cognitive flexibility. This version consisted of two conditions, with the first condition recording the amount of time it takes the participant to read the color in which the word is printed (congruent condition). Condition 2 required the participant to name the ink (color) in which the color word was printed (incongruent condition). The accuracy and total time to complete the task were recorded (Stroop, 1935). (Fig 1-b)

c) Letter-Number Sequencing test (LN): This is the oral version of the paper-and- pencil Trail Making Tests A & B wherein the participant hears a pair of a letter and a number. This test is a measure of working memory but also has an added component of assessing one's cognitive flexibility as they are instructed to loudly narrate the next letter and number (e.g. if they hear "A-2" their response would be B-3, C-4, and D-5 and so on till they hear the second cue. Each cue is presented for 15 seconds and three trials are collected. Each trial started with a different cue pair. The total number of correct responses were averaged across the three trials (Grigsby & Kaye, 1995).

d) Triangle (TT) and Letter Tracking (LT) test: This is a measure of working memory in which the participant is presented with a sequence of stimuli, one at a time, and is asked to indicate when the current stimulus matches the one from n-steps earlier in the sequence. We used 1 and 2 steps earlier for the current protocol. Two different sets of tests were used. In the first set the participant tracked a triangle that moved to different positions in a grid, and they were asked to respond when they saw the triangle in the same position as in the previous trial i.e.1 trial back or 2 trial back. The second set was similar, but involved letters that were presented to the participant and they were asked to respond when they saw the same letter repeating 1-trial or 2-trial back (Owen, McMillan, Laird, & Bullmore, 2005). (Fig 1-c)

e) Unveil the Star test (US): This test measures the retention and manipulation of visuospatial information wherein the participant was asked to search for a star in multiple boxes. Once the star in one box was found he or she continued to look for the star in other boxes but had to remember not to click in the same box where the star was found earlier. There were three levels in the games with increasing difficulty wherein participants' were asked to find three stars in level 1, progressing to five stars in Level 2 and eight stars in level 3 demanding more attention and concentration in order to minimize the errors. (Fig 1-d)

f) Spot & Click test (SC): This test measures the amount of time taken by the examinee to respond after the stimulus is presented. Both Simple Reaction time (SRT) and Choice Reaction time (CRT) were assessed. The participants' were presented with a stimulus (yellow circle) after which they were asked to respond by pressing the corresponding key on the number pad representing the location of the stimulus (Hyman, 1953). (Fig 1-e)

g) Peg Board Game (PG): This test assesses problem-solving capacity along with spatial working memory. Participants were asked to move disks in order to arrange them in a predetermined position using the number pad with fewest moves possible. Pictorial representation of the computerized cognitive test battery is seen in Figure 1.

Conventional Cognitive Testing: D-KEFS™

a) Verbal Fluency Test: This measure assessed semantic and phonemic fluency by providing a category cue and a letter cue to the participant (i.e. Animals, Boy's name and letters F, A or S). Participants were given one minute to provide as many words as possible, the responses were noted by the examiner. For the phonemic fluency task, participants were instructed not to list proper nouns (Delis et al., 2004).

b) Stroop Test: This measure consists of three conditions, relying to various extents on processing speed and inhibitory control. Condition 1 and condition 2 are baseline conditions that consist of basic color naming, or reading color names printed in black ink, respectively. Condition 3 is the traditional Stroop test in which the participant is asked to name the dissonant ink color and inhibit reading the color words that is printed. Each condition consisting of 45 stimuli. The reliability correlation stated for the color naming test ranged between moderate to high (Delis et al., 2004).

c) Tower of Hanoi Test: This test is required to measure the participant's, memory, problem-solving, planning and decision-making abilities. The main objective of the test was to move the disks of varying size (i.e. small, medium, or large) across three pegs to build a designated tower in the fewest number of moves. At the start of every test the starting position of the disks was predetermined while the ending position was shown to the participant and they were asked to match it to the target tower. The manual mentioned that the test-retest correlation for this test was within the moderate range (Delis et al., 2004).

2.2.4 Statistical Analysis

All the statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) (version 22) for Windows. Descriptive statistics (mean ± SD) were performed for all the cognitive test variables using paired sample t-tests and are reported in the text. Intra-class correlation coefficients (ICC) were used to determine the reliability of each of the tests in the cognitive battery. Bland-Altman plot was constructed to display the level of agreement between the differences in means of the two testing sessions. One-sample t-test was used to analyze if these differences (i.e. bias) were significantly different from zero. The Pearson's product moment correlation (r) and coefficient of determination (r2) were used to quantify the strength of the relationship between the data from sessions 1 and 2 as shown in Table III.

2.3 Results

Paired t-tests showed no significant difference between the two testing sessions in performance among the different variables for each test: the Spot & Click task, simple reaction time ($t = 0.007$, $p = 0.994$) and choice reaction time ($t = 0.226$, $p = 0.825$), for the total number of responses in the Category Naming Task ($t = -0.338$, $p = 0.740$), Word List Generation ($t = -0.133$, $p = 0.896$), Letter Number Sequencing ($t = -0.425$, $p = 0.677$), the Triangle Tracking Task i.e. 1-back ($t = -0.00$, $p = 1.0$), 2-back ($t =-1.79$, $p =0.09$) and similarly for the Letter Tracking Task i.e. 1-back ($t = 1.17$, $p = 0.26$) and 2-back ($t = 0.42$, $p = 0.69$).The total time of completion for the Color Naming task i.e. the congruent slide (t = 1.54, p = 0.145) and incongruent slide (t = 1.02, p = 0.32), for Unveil the Star Task (t = 1.70, p = 0.11) and the Peg Board Task (t = 2.25,p = 0.04). The total number of errors calculated for Unveil the Star Task (t = 0.44, p = 0.67) and the Peg Board Task (t = 1.31, p = 0.21).

2.3.1 Reliability

The ICC with 95% CI for each variable is presented in Table IV. The ICC's ranged from 0.65-0.92 for all tasks. Figure 2 shows Bland-Altman plots displaying limits of agreement between the testing sessions. One sample t-test suggested that there was no significant difference from 0 in the mean difference between the two testing sessions in Spot & Click Task, choice reaction time (5.24±89.91; p = 0.825), the total number of responses in category naming (-0.467±5.34; p = 0.740), Word List Generation (-0.133±3.88; p = 0.896), Letter Number Sequencing (-0.200±1.820; p = 0.677) along with the total time completion for Unveil the Star Task (4.49±10.21; p = 0.110), Color Naming task: incongruent slide (-0.467±5.34; p = 0.740), Peg Board Task (11.29±19.44; p =0.04), and finally total number of errors in the Peg Board Task(6.19±18.28; p = 0.211).

2.3.2 Validation

Correlation Coefficients are presented in Table V. Good correlations were found for the tests measuring the domains of working memory and information processing speed i.e. the verbal fluency test and the Visual Stroop test respectively. A moderate correlation was found for Tower of Hanoi test, which measured individuals problem solving and planning abilities on comparing the computerized cognitive and conventional paper-pencil tests.

2.4 Discussion

Computerized cognitive tests may provide very reliable indications of cognitive function in longitudinal investigations (Lowe & Rabbitt, 1998). However, the reliability of computerized cognitive testing administered via DirectRT, Empirisoft had not been determined. Overall results from this study indicate that CCT's administered using DirectRT™ Empirisoft provides a measurement of cognitive function that is highly reliable between sessions in young healthy adults.

Out of the computerized cognitive tests administered, some tests had have higher test/retest correlation compared to others. This can be due to the different cognitive domains (i.e. visuomotor function, working memory, executive function, discriminant decision making or verbal fluency) tapped during the testing session. The simple and choice reaction time tests had a high reliability co-efficient (i.e. ICC = 0.84 and 0.89 respectively) and compare favorably with the reaction time reliability co-efficients previously reported in existing computerized cognitive assessment tools ranging from 0.55 to 0.90 (Collie et al., 2003; Gualtieri & Johnson, 2006; Lowe & Rabbitt, 1998). As the stimuli in both the events were presented within a fixed time interval unknown to the participant being tested, it can be inferred that the high test-retest correlation observed in this study was not biased depending on any practice effects. A similar rationale has been reported in a study by Lowe and Rabbitt (Lowe & Rabbitt, 1998), who mentioned that reaction time is a non-strategic driven task thereby limiting practice effects and resulting in high test/retest correlation.

Tests measuring processing speed and response inhibition (Color Naming task), discriminant decision making (Peg Board game), spatial working memory (Unveil the Star task) and working memory/attentional switching (Letter Number Sequencing, Triangle and Letter

Tracking task) reported a high to moderate intraclass correlation range. Total time required to complete congruent and incongruent conditions of the computerized Stroop task were highly correlated between the two sessions. Total time to complete the incongruent condition was almost twice the time taken to complete the congruent slide, and is a common finding due to the complexity imposed by the multiple stimulus-response conditions (Gruber, Rogowska, Holcomb, Soraci, & Yurgelun-Todd, 2002; Lowe & Rabbitt, 1998).

The correlation for the three tests i.e., Letter Number Sequencing test measuring working memory along with cognitive flexibility and switching capability and the Triangle Tracking task and Letter Tracking task that measured working memory were moderate. A possible explanation for this can be that the test of working memory tests are usually 'strategy driven tasks' and hence provide accurate results only when they are novel because performance on them can improve as soon as the participant discovers an optimal strategy, but will improve less or not at all if no strategy is found. This learning effect can also be markedly different between each participant, which can result in greater variance and hence lower the ICC. These postulations probably account for the moderate reliability for the working memory tasks compared to higher reliability seen with the reaction time task and have been previously validated (Lowe & Rabbitt, 1998). Collie et al (Collie et al., 2003) had published findings supporting the above explanation, by suggesting that healthy people respond quickly and make fewer mistakes on tests of psychomotor functions in contrast to tests of decision making and working memory where they tend to be slow and make more errors. For Unveil the Star task, in which participants' are required to retain and manipulate visuospatial information in order to complete a complex the task, a high test-retest correlation for the total number of errors, and a moderate test-retest correlation for the total time required to complete the task were found. The variance in the test/retest correlation could be because the number of errors made by each participant across the two testing sessions remained constant, but the speed of completing the task during the second session increased slightly compared to the first. The change in speed could have occurred also due to this being a strategy driven task, as mentioned earlier.

Validity was tested for only three of the seven custom-designed tasks against the conventional paper-pencil testing methods (D-KEFS). Concurrent validity, estimated by correlation of the verbal fluency and processing speed/response between the computerized testing and D-KEFS was good, 0.79 and 0.72 respectively indicating that both tests correlate well with performance on conventional testing methods. No variance was observed between the responses recorded for accuracy for the Visual Stroop test administered via D-KEFS as compared to responses recorded on the Color Naming task administered via the DirectRT. The Peg board task validated against the Tower of Hanoi test showed moderate correlation i.e. total time completion was 0.565 and a total number of errors 0.752.These results indicated that computerized cognition testing methods are reliable, despite the differences in the method of stimulus presentation (physical, e.g. peg, versus virtual) (Howe, Arnell, Klein, Joanisse, & Tannock, 2006) and mode of administration (computer versus in person) have good concurrent validity and hence could be used to model the conventional Tower of Hanoi test (Gualtieri & Johnson, 2006).

The results of this study could be confounded by its small sample size. However, to address this a post-hoc sample size calculation was performed for each of the outcome variables using Pearson's correlation co-efficient (r), with the power being set at 0.84 and a significance level of 0.05. The resulting sample size from this analysis was 15, horizontal black line, shown in Figure 3 (Shoukri, Asyali, & Donner, 2004). Besides this results could also be confounded due to the practice effect as tasks measuring accuracy percent, total number of errors or total time completion are strategy driven and yield best results when novel after which an individual might be able to develop a strategy which could contribute to high or moderate correlation in order to avoid this practice effect the average number of days between the two testing sessions can be increased in future studies.

2.5 Conclusion

To conclude, the results of the current study indicate that the custom designed computerized cognitive tests administered using DirectRT is reliable. The Category Naming task, Word List Generation task, Color Naming task and of Hanoi Peg Board task showed to be valid measures when compared to the gold standard tests administered via D-KEFS. Future studies should establish psychometric properties for this computerized test battery for other populations including older adults with and without cognitive deficits and people with neurological disorders. CCT's can further be employed to measure the effect of cognitive-motor rehabilitation interventions in neurological conditions such as stroke, traumatic brain injury, Alzheimer's or in sports medicine i.e. concussions in contact sports by measuring their baseline and post intervention findings. Lastly, the ubiquity of computers and the, ease with which this battery can be administered, it could be easily translated to clinical and community-settings and could also be feasibly used to build self-confidence and promote behavior modifications amongst different population with an multidisciplinary approach involving care managers, general practitioners, occupational, physical and speech therapists, and clinical neuropsychologists (Ciccone et al., 2010).

Table I

Computerized cognition tests assessed for test-retest reliability and outcome variables

Test Name	Cognitive function assessed	Outcome Variables
Spot and click	Visuo-motor function	Reaction time
Category Naming & Word List Generation	Verbal Fluency	Number of responses
L-N Sequencing	Cognitive Flexibility/Switching	Number of correct responses
Triangle Tracking & Letter Tracking	Working memory	Number of correct responses
Color Naming	Processing Speed/Response Inhibition	Total Time of Completion
Unveil the Star	Spatial Working Memory	Total time of completion Total number of errors
Peg Board Game	Discriminant Decision Making	Total time of completion Total number of errors

Table II

Computerized cognitive test used to assess validity and outcome variable

D-KEFS	DirectRT	Cognitive function assessed	Outcome Variables
Verbal Fluency	Category Naming Word List Generation	Verbal Fluency	Number of responses
Visual Stroop	Color Naming (Visual Stroop)	Processing Speed/Response Inhibition	Total Time of Completion Accuracy %
Tower of Hanoi	Peg Board game	Discriminant Decision Making	Total time of completion Total number of errors

Table III

Presents mean and standard deviation on test session 1 and test session 2, Pearson's product moment correlation, r, and the co-efficient of determination, r2

		Test session 1		Test session 2			
Test Names	Outcome Variables	Mean	SD	Mean	SD	r	r^2
Spot & Click	Simple reaction time (ms)	337.32	77.29	337.187	108.56	0.77	0.59
	Choice reaction time (ms)	694.267	150.06	689.02	135.09	0.81	0.65
Category Naming	Number of responses	22.20	5.82	22.66	6.75	0.65	0.42
Word List Generation	Number of responses	17.87	5.50	18	3.38	0.74	0.51
Letter Number Sequencing	Number of responses	6.93	1.83	7.13	1.72	0.48	0.23
Color Naming	Congruent (total time, s)	17.71	3.92	16.38	3.95	0.64	0.41
	Incongruent (total time, s)	33.608	7.87	32.57	6.01	0.88	0.77
Unveil the Star	Total time of completion (s)	48.32	12.56	43.82	11.19	0.63	0.40
	Error (%)	1475.83	25.75	1477.08	26.05	0.91	0.84
Triangle Tracking	2-back Accuracy (%)	70.83	15.43	78.33	13.64	0.52	0.26
Letter Tracking	2-back Accuracy (%)	74.31	18.04	72.37	19.82	0.56	0.32
Peg Board Game	Total time of completion (s)	91.18	38.12	79.88	39.62	0.87	0.76
	Error (%)	37.14	29.35	31.90	29.31	0.82	0.66

Table IV

ICC values for all the variables

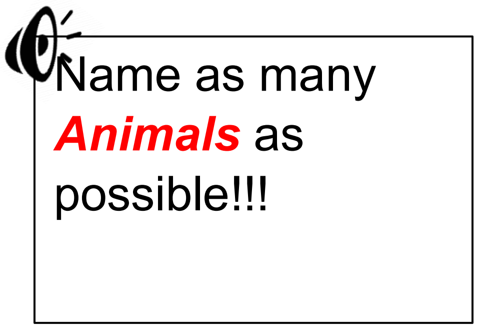
Test Names	Outcome Variables	ICC	P-Value
Spot & Click	Simple reaction time (ms)	0.84	0.00
	Choice reaction time (ms)	0.89	0.00
Category Naming	Number of responses	0.78	0.04
Word List Generation	Number of responses	0.78	0.04
Letter Number Sequencing	Number of responses	0.65	0.03
Color Naming	Congruent (total time, s)	0.78	0.004
	Incongruent (total time, s)	0.92	0.00
Unveil the Star	Total time of completion (s)	0.77	0.004
	Error (%)	0.95	0.00
Triangle Tracking	2-back Accuracy (%)	0.71	0.017
Letter Tracking	2-back Accuracy (%)	0.72	0.012
Peg Board Game	Total time of completion (s)	0.91	0.00
	Error (%)	0.89	0.00

Table V

Correlation coefficients for the validation of the computerized cognitive test battery

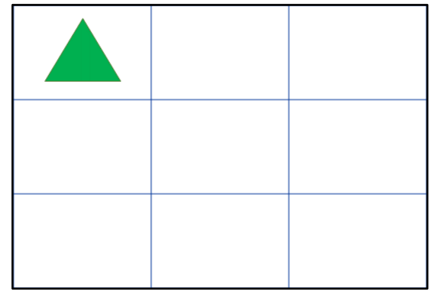
Test Names	Outcome variables	D-KEFS		DirectRT		R	r^2
		Mean	SD	Mean	SD		
Verbal Fluency (Cat N)	Number of responses	21.625	4.801	22.18	5.04	0.762	0.581
Verbal Fluency (WLG)	Number of responses	16.5	3.59	18.5	5.04	0.72	0.518
Visual Stroop Test (CN)	Congruent (total time, s)	26.31	4.46	26.47	6.25	0.798	0.637
	Incongruent (total time, s)	47.44	8.9	45.24	7.05	0.731	0.467
	Accuracy % (congruent)	44.55	0.72	45	0	*	*
	Accuracy % (Incongruent)	44.44	0.72	44.88	0.33	*	*
Tower of Hanoi Test	Total time (s)	92.64	51.29	89.22	39.52	0.565	0.319
(PG)	Total number of errors	22.98	14.41	18.11	14.85	0.752	0.565

* No variance was observed between the means for accuracy % for Visual Stroop test administered via D-KEFS and Color Naming test administered via DirectRT.

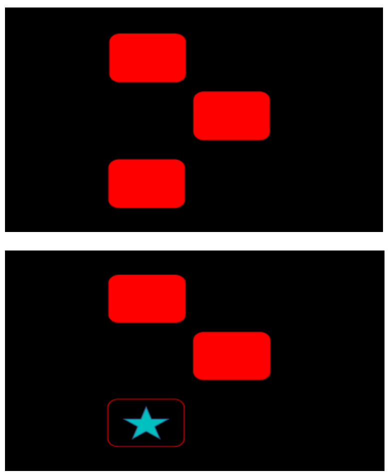


1-a) Category Naming

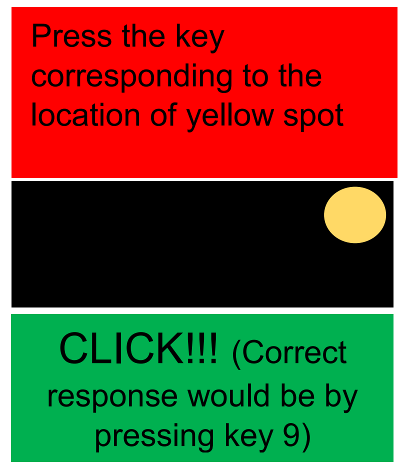
1-b) Color Naming Test



1-c) Triangle Tracking



1-d) Unveil the Star



1-e) Spot & Click

Figure 1. Screenshot for different cognitive tasks used for assessment. Image 1-a represents the incongruent slide for the Color Naming task wherein the participant has to name the ink color in which the word is printed. Image 1-b and 1-f represents the instructions given prior to the onset of the task. Image 1-c represents the triangle in the grid that the participant tracks and responses when he observes the triangle in the same location n-trials back. Image 1-d represents the Number & Position task (i.e. 1- upper left) response recorded by the participant. Image 1-e represents Unveil the Star task.

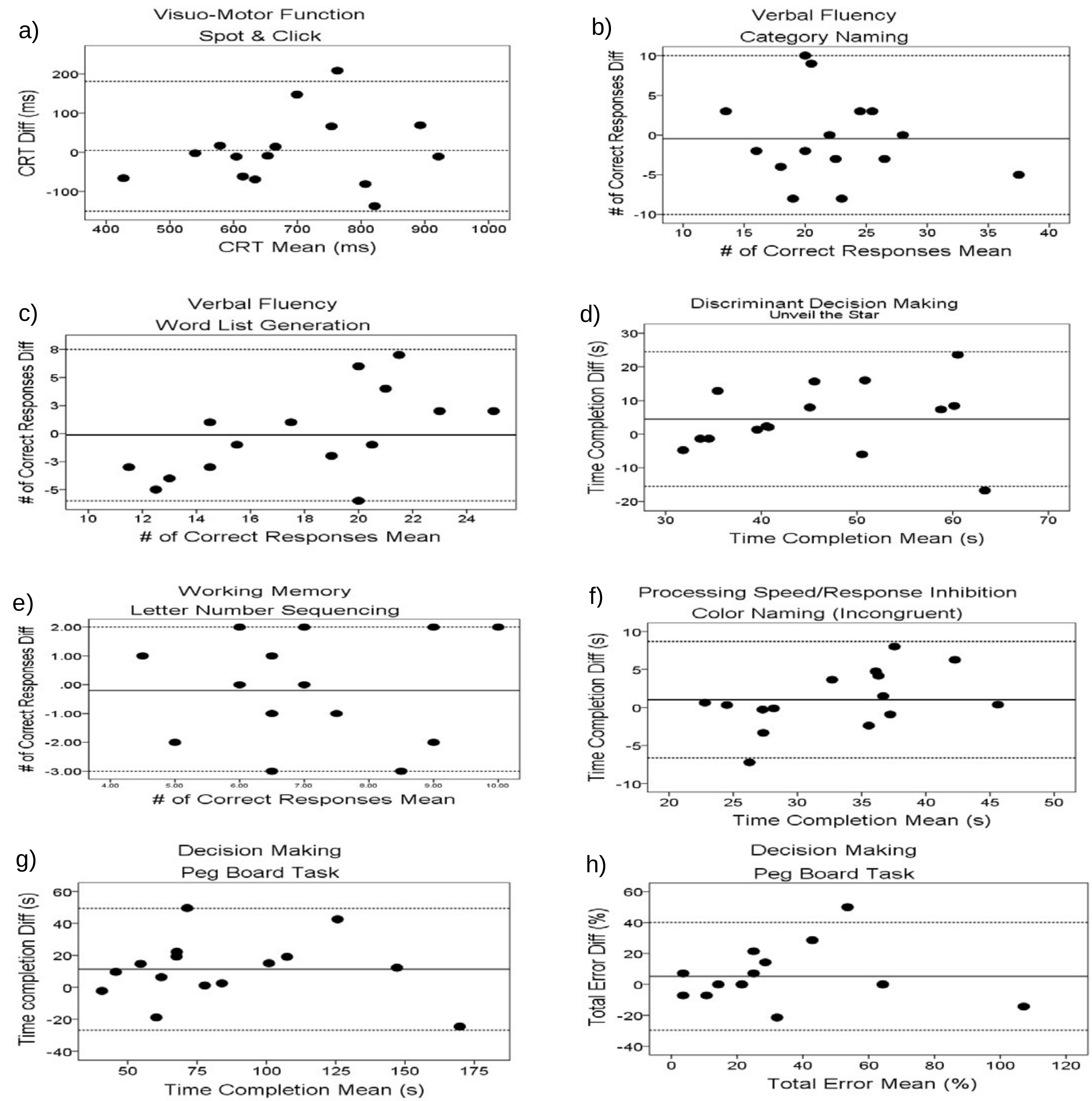


Figure 2. Bland-Altman plots displaying limits of agreement: mean (solid line) ±1.96 SD (dotted line) of the difference between test session 1 and test session 2 values for the variables: (a) choice reaction time (CRT); (b, c & e) number of correct responses ;(d, f &g) total time completion; and (h) total error.

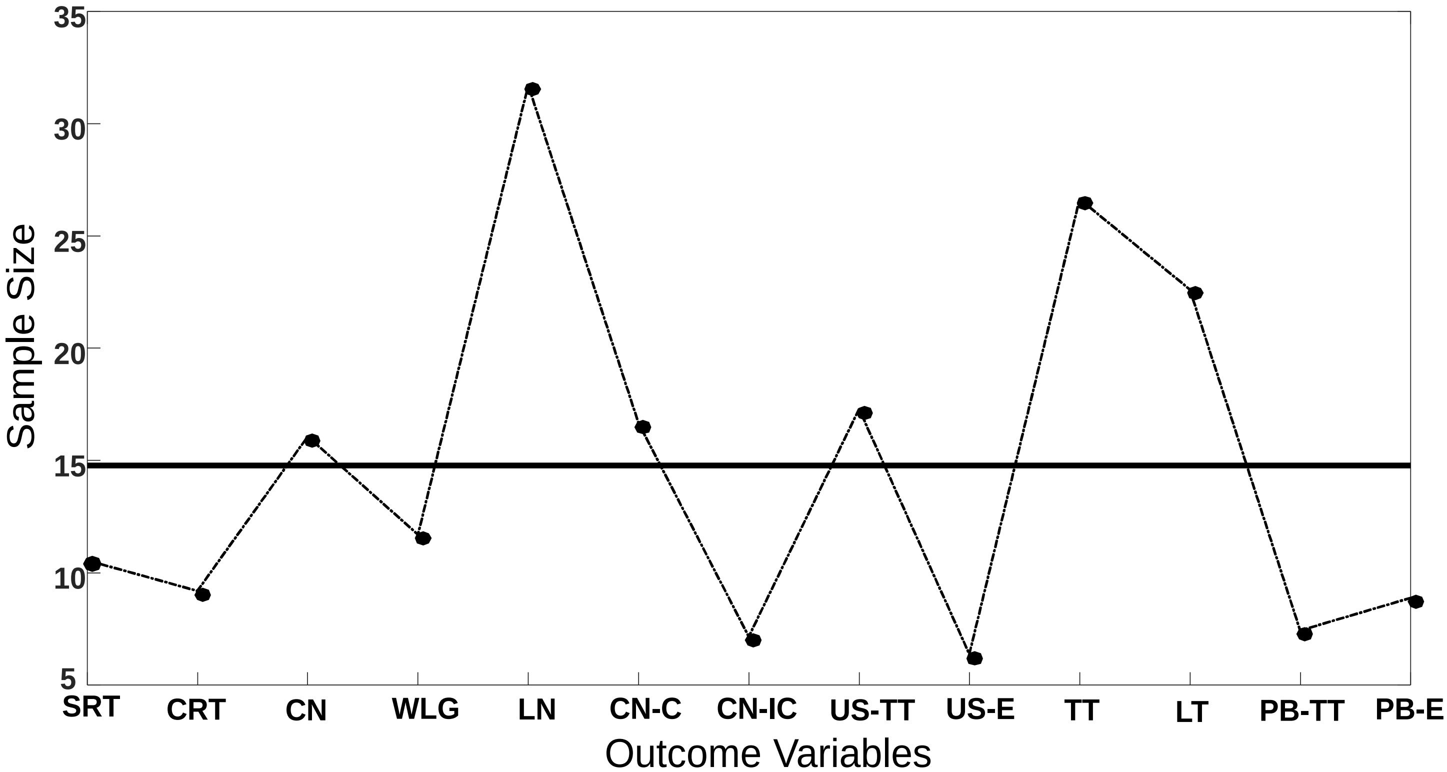


Figure 3. Post-hoc sample size analysis plot displaying number of required subjects (black solid line) for the variables of interest: Simple Reaction Time (SRT), Choice Reaction Time (CRT), Category Naming (CN), Word List Generation (WLG), Letter Number Sequencing (LN), Color naming: Congruent slide (CN-C) and incongruent slide (CN-IC), Unveil the Star task: Total time of completion (US-TT), number of errors (US-E) and Peg Board task: Total time of completion (PB-TT), number of errors (PB-E). The plot was obtained using a custom written Matlab Algorithm (Shoukri, Asyali, & Donner, 2004).

CHAPTER III

AIM 2: TEST-RETEST RELIABILITY OF A COMPUTERIZED NEUROPSYCHOLOGICAL TEST BATTERY: A CROSS-SECTIONAL STUDY ASSESSING COGNITION IN HEALTHY YOUNG AND OLD ADULTS, AND STROKE SURVIVORS.

The data presented in this chapter is currently under review as:

Vora J, Varghese R, Patron V, Weisenbach S, Bhatt T. Test-retest reliability of a computerized neuropsychological test battery: A cross-sectional study assessing cognition in healthy young and old adults, and stroke survivors (2016).

3.1 Introduction

Neurocognitive decline is a growing healthcare concern that can result in loss of functional independence in healthy aging baby boomers and individuals with neurological diagnoses (Deary et al., 2009). More than 5.1 million individuals in the United States are estimated to be living with cognitive impairment (Hebert, Scherr, Bienias, Bennett, & Evans, 2003). The medical costs for older adults with mild cognitive impairment (MCI) are 44% higher than those for non-impaired older adults (Zhu et al., 2013). Due to structural changes in the prefrontal cortex parietal and medial temporal regions including hippocampus, cognitive functions most commonly affected in healthy older adults include executive function, information processing, and working and associative memory (Simons & Spiers, 2003). In addition to age-related cognitive changes, individuals with long-standing neurologic disorders, such as stroke, may retain permanent damage to brain areas affecting cognitive, sensory, and motor functions (Ku et al., 2009).

Cross-sectional studies show that 64% of stroke survivors have cognitive impairments unrelated to dementia (Jin et al., 2006). Furthermore, among individuals presenting with MCI post-stroke, the chances of reversibility of cognitive impairment decline with the chronicity of the condition (Rasquin, Lodder, & Verhey, 2005; Schaapsmeerders et al., 2013).

Recent findings suggest that higher cortical centers may contribute to poor motor control during performance of daily functional motor activities like walking, grocery shopping, and driving by sharing the same attentional resources with cognitive functions, such as working memory, spatial decision making, and information-processing (Owsley et al., 1991; P. Patel & Bhatt, 2014). This has been observed through dual-task paradigms focusing on simultaneous performance of a motor and a cognitive task. Studies have shown that dual-tasking results in deterioration of performance in either motor and/or cognitive tasks, which is described as cognitive motor inference (CMI) (Abenethy, 1988). There are various potential patterns of interference described by Plummer et al. (Plummer et al., 2013) namely, 1) no interference, where the performance on either task does not change relative to single-task performance; 2) cognitive-related motor performance, where cognitive performance remains stable while motor performance deteriorates; 3) motor-related cognitive interference, where motor performance remains stable and the cognitive performance deteriorates; and 4) mutual interference, where performance on both tasks deteriorates (Lundin-Olsson et al., 1998; Plummer et al., 2013). CMI results from competing demands of both motor and cognitive tasks for accessing the limited and probably shared processing resources within the brain (Al-Yahya et al., 2011).

In older adults it has been observed that motor performance is significantly altered with concurrent performance of a secondary cognitive task (dual-task) such as increased postural sway and decreased gait speed and step lengths (Brauer, Woollacott, & Shumway-Cook, 2002; Snijders, Verstappen, Munneke, & Bloem, 2007). Such findings of deteriorations in gait and balance performance are evident in stroke survivors, as well. Dual task assessments could thus provide a platform to understand the interaction between cognitive and motor systems in healthy and neurologically-affected individuals (Plummer et al., 2013).

Although there is evidence suggesting a critical role of cognition in facilitating motor performance, cognitive testing and interventions have not been routinely utilized in clinical rehabilitation settings. Studies indicate that neural plasticity endures across the lifespan, and continuous cognitive stimulation is important for enhancement and maintenance of cognitive functioning (Park, Polk, Mikels, Taylor, & Marshuetz, 2001). However, prior to providing cognitive or cognitive-motor interventions, an accurate and comprehensive neuropsychological assessment is fundamental to identify specific cognitive domains most severely impacted by aging and/or neurologic processes.

Conventional paper-and-pencil measures used to assess cognitive function tend to be lengthy, require specialized training, and are prone to manual error. They are also not feasible for use in cognitive-motor dual task paradigms. Computerized cognition testing (CCT) is gaining popularity and offers an alternative to some of the traditional paper-and-pencil testing measures. CCT has potential advantages over conventional testing methods as it renders precise stimulus control, consistency in administration and scoring, visually appealing interfaces, cost efficiency, ability to develop large and accurate databases, and ease of administration of cognitive-motor testing paradigms (Gualtieri & Johnson, 2006). Computerized cognitive testing also helps to assess and monitor cognition in large sample size (Tornatore, Hill, Laboff, & McGann, 2005).

However most of the commercially available neuropsychological test batteries are generally lengthy and require several sessions of testing as they assess multiple domains of cognition thoroughly, without understanding the mental fatigue, the patients undergo which may eventually affect the test outcome measures (Hommel, Miguel, Naegele, Gonnet, & Jaillard, 2009; Sachdev et al., 2003; Särkämö et al., 2008). Keeping this in mind after extensive research, we developed a customized computerized cognitive test battery consisting of six task assessing the six main domain of cognition namely, visuo-motor function, verbal fluency, executive function, discriminant decision making memory, working memory and associative memory and the average total time to complete this battery was 40 minutes. We choose to evaluate the test battery administered via the DirectRT Empirisoft™ over other commercially available tests as it is affordable, user friendly, allows the development of customized test stimuli and easy to modulate tests with increasing difficult levels and allow subsequent interpretation of a variety of cognitive tests without the need for specialized training.

Nonetheless, there can be certain challenges associated with use of computers to assess cognitive function in an older or post-stroke population. Hence a good interface design and simple cognitive tests were created that could improve the usability of computerized testing in the above mentioned population, and in turn increase the reliability and validity of the cognitive data (Acevedo & Loewenstein, 2007; Van Gerven, Paas, & Tabbers, 2006)

In a previous study we examined the reliability and concurrent validity of a computerized cognitive test battery administered using DirectRT™ Empirisoft among healthy young adults (Vora, Varghese, Weisenbach, & Bhatt, 2016). While the results of the study established the reliability and concurrent validity in young adults (Vora et al., 2016) the battery's reliability and concurrent validity needs to be examined in other populations prone to cognitive decline.

The primary aim of this study was to establish the test-retest reliability and concurrent validity of a custom-designed, computerized cognitive test battery (CCT) in post-stroke patients and healthy older adults, compared to the reliability and validity among healthy young adults using the commercially available Direct RT™ Empirisoft, to determine its potential for use in clinical or research settings. The secondary aim was to understand the effect of aging and neurologic disorder due to stroke on cognitive functioning amongst healthy older individuals and stroke survivors. For this aim, we hypothesized that cognition would be significantly impaired in the participants with stroke as compared to healthy older adults and young adults.

3.2 Methods

3.2.1 Participants

Fifteen adults with chronic hemiparetic motor stroke as confirmed by the physician (age: 58.9± 6.9, years of education: 14.2± 2.7), fifteen healthy older adults (age: 64.4± 5.1, years of education: 16.2± 2.3), and fifteen healthy young adults (age: 23.86 ± 1.35, years of education: 16.8 ± 1.47) participated in this study. Participants were recruited via informational flyers posted across the University of Illinois at Chicago Medical campus. Exclusion criteria for participants with chronic stroke was severe receptive or expressive dysphasia, which would limit their participation in the assessment as determined via the scores obtained on Mississippi Aphasia Screening Test (Nakase-Thompson et al., 2005). Individuals taking medications impacting cognition or having comorbid psychiatric and medical conditions were also excluded. Healthy older and young adults were included if they had no self-reported neurological disorder or injury that could affect sensory, motor, or cognitive functioning. The study was approved by the Institutional Review Board of the University of Illinois at Chicago, and informed consent was obtained from all participants.

Prior to testing, individuals' premorbid IQ score was assessed using the WRAT-4 reading test (total score out of 70) after which participants completed the computerized neurocognitive test battery administered using DirectRT™, Empirisoft (Jarvis, 2014).

All testing was conducted in a silent room in order to avoid any external disturbances. For computerized testing, a screen was placed in front of the participant and a headset with microphone was used to record the responses. Each test was preceded by an instruction slide and instructions were also repeated by the examiner, after which the participant was asked to press a key when he or she was ready to start the test. Each participant underwent two testing sessions separated by 10-

12 days interval. During each session all the tests from the computerized cognitive test battery were administered in a randomized order i.e. with respect to the order of the tests administered.

3.2.2 Neuropsychological Test Battery

Six domains of cognition (visuo-motor function, verbal fluency, executive function, discriminant decision making memory, working memory, and associative memory) were included in the testing protocol. Visuo-motor function was assessed by measuring the response latencies after the stimulus is presented to the examinee i.e. the Spot & Click task. Both, Simple reaction time (SRT) and Choice reaction time (CRT) were assessed. The participant was presented with a stimulus (yellow circle) and asked to respond by pressing the corresponding key on the number pad depending on the position of the stimulus. Measurement of executive function consisted of the classic stroop paradigm, which measures processing speed and response inhibition. The computerized version of the test (Color Naming) consisted of two conditions. In the first condition the participant was asked to read the words that were printed in the same color ink (congruent condition). Condition 2 required the participant to name the ink (color) in which the color word was printed. The actual word frequently differed from the ink in which it was printed (incongruent condition). The total time taken to complete the task was recorded. Unveil the Star task assessed the manipulation and retention of visuo-spatial information and discriminant decision making. In this task, the participant was required to search for a blue star in multiple red boxes without clicking on the same box twice where the star was previously found. There were three increasing levels-of-difficulty as the task progressed. The total time taken to complete the task, along with the total number of errors was recorded. Test of verbal fluency included the Category Naming task in which participants' semantic fluency was assessed. Participants were provided a category cue (i.e. animals, boys' names, or countries) and were given one minute to provide as many words as possible relating to that category. They were instructed to avoid repeating the same responses. The voice responses were recorded by the computer via the microphones. Working memory was also assessed using the Triangle Tracking task in which the participant was presented with a sequence of stimuli and asked to indicate when the current stimulus matches the one from n-steps earlier in the sequence. We used 1 and 2 steps earlier for the current protocol. Lastly, the Number & Position task was administered to assess associative memory, where the participant was presented with a slide displaying numbers in a grid and the participant was asked to memorize the position of the number (i.e. 7- center, 3- Upper left, 1- lower right) after which a slide with the single number in the center was presented and the participant was asked to recall the position of the number from the previously presented slide. The outcome variables for each of the computerized neurocognitive test battery are presented in Table VI.

3.2.3 Statistical Analyses

Descriptive statistics (mean ± SD) were performed for all cognitive test variables. Intra-class correlation coefficients (ICC) were used to determine the reliability of each of the computerized tests in the cognitive battery. Test-retest reliability was characterized as excellent (ICC > 0.8), good (ICC 0.6-0.79), moderate (ICC 0.4-0.59), fair (ICC 0.2-0.39), and poor (ICC < 0.2) (Guo et al., 2012). The level of agreement between the two testing sessions is represented using Bland Altman plots. One-sample t-test was used to analyze whether the bias (difference) between the mean score of the two sessions was significantly different from zero. ANCOVA was performed to analyze the significant differences between the groups in cognitive test variables using the premorbid IQ score and years of education as covariates among the three groups followed by post-hoc Tukey's test. The statistical significance was set at $p < 0.05$. All statistical analyses were performed using Statistical Package for Social Sciences (SPSS), version 22.0 (Chicago, IL version 22).

3.3 Results

3.3.1 Demographic data

Demographic comparisons between the three groups (i.e., stroke, healthy older adults, and healthy young adults) are shown in Table VII together with the neurological data.

3.3.2 Reliability

Paired t-tests showed no significant difference between the two testing sessions among the different variables for the groups when analyzed separately as shown in Figure 4. Test-retest reliability data revealed significant intra-class correlation (ICC) with 95% CI for each of the computer-generated tasks, which is presented in the Table VIII. The ICCs ranged from 0.72-0.98 for all tasks. There was no significant difference from 0 in the mean difference between the two testing sessions for the three groups together and this is further represented in the Bland-Altman's Plots which displays the level of agreement between the testing sessions in Figure 5.

3.3.3 Group Effects

The results of the ANCOVA on the computerized cognitive test (CCT) battery showed that the difference in the cognitive test between the stroke group, the healthy older adults group, and the healthy young adults group were statistically significant ($p < 0.05$), as presented in Table IX. Premorbid IQ scores and years of education were significant covariates for the Reaction Time test variables. Tukey's HSD test revealed significant differences in the CCTs between the three groups. The stroke group showed a significantly longer reaction time on Spot & Click task and a longer time for completion for Color Naming task than the healthy older group ($p < 0.05$) and healthy young group ($p < 0.05$). The stroke group presented significantly more errors for Unveil the Star task as compared to the healthy young group ($p < 0.05$). The stroke group presented a significantly lower number of correct responses and decreased accuracy for the Triangle Tracking task and Number & Position task as compared to the healthy older adult group ($p < 0.05$) and healthy young group ($p < 0.05$). The healthy older adult group showed a significantly longer reaction time for the Spot and Click task and an increased time for completion for the Unveil the Star task, as compared to the healthy young adult group ($p < 0.05$) as presented in Table X and Figure 4.

3.4 Discussion

Overall, the findings from our study indicate that the computerized cognitive tests (CCTs) administered via DirectRT™ Empirisoft are a moderately reliable measure of cognitive functioning across two testing sessions in chronic stroke survivors, healthy older adults, and young adults. Further, the secondary finding of our study was that the CCTs were able to detect a difference in cognition between a small sample of stroke survivors, healthy older adults and young adults.

3.4.1 Test-retest reliability

The test-retest reliability correlations measured with intraclass correlation coefficient (ICC) for all of the computerized cognitive tasks assessed across two testing sessions ranged from 0.75- 0.98 for all of the groups together. On further analyzing the reliability coefficient for individual groups, a high test-retest reliability coefficient was obtained for the young and older adults as compared to chronic stroke survivors for both simple and choice reaction task. The range of the reliability coefficients in this study across all the groups for reaction time was consistent with the previously reported ranges i.e. ICC = 0.60 - 0.98 (Collie et al., 2003; Lowe & Rabbitt, 1998; Register-Mihalik et al., 2012).

Furthermore, the high test-retest coefficients reported in the study were not biased depending on the practice effects because the stimuli across both testing sessions were unpredictable for the participants being tested as the stimuli presented were random. It has been proposed by Lowe and Rabbitt (Lowe & Rabbitt, 1998) that reaction time is a non-strategic task and therefore might not result in forming a memory as to when the stimuli will appear. This task can thus yield high test-retest correlation, suggesting that the likelihood of practice effects was reduced as a result of unexpected stimuli.

For the Category Naming task (verbal fluency), a high test-retest reliability coefficient for all groups together i.e. ICC = 0.89 and for individual groups was attained. The Unveil the Star task (Discriminant Decision Making) and Color Naming task (processing speed/response inhibition) demonstrated high ICCs for the groups together. Moderate test-retest correlation for total time taken to complete Unveil the Star task was observed for individual groups. Examination of the data suggests that participants required less time to complete the task during the second session as compared to the first session possibly due to familiarity with the test. Similar results were obtained for the Triangle Tracking task (i.e., working memory) and the Number & Position task (i.e., associative memory), wherein moderate test-retest reliability was observed for all three groups together. The moderate results obtained could be due to a practice effect seen on the working memory task due to this being a strategy-driven task, wherein learning can occur when the stimuli presented is not novel and the participant could have potentially discovered an optimal strategy/test sequence (e. 1-back vs 2-back). (Lowe & Rabbitt, 1998).

3.4.2 Group Differences in cognitive abilities

Our secondary findings focused on understanding mean group differences and interpreting which cognitive domain is primarily impaired post-stroke. The reaction time recorded for the choice reaction time task and the time difference calculated between simple and choice reaction time tasks (CRT-SRT) demonstrated higher means for stroke survivors compared to healthy older and young adults. A significant difference in the reaction time was observed between the older adults and young adults. Reaction time has been extensively studied in the literature and is found to increase with age (Clarkson, 1978; Gottsdanker, 1982). It has also been suggested by Birren et al., that reaction time is one of the most sensitive markers of structural and functional deterioration in the aging central nervous system which is further hampered if there is underlying neurological insult such as stroke (Birren, Woods, & Williams, 1980).

The stroke group demonstrated decreased accuracy on the Triangle Tracking task (working memory) and the Number & Position task (associative memory) as compared to older adults and young adults. For Unveil the Star task, the older adults and stroke groups required more time to complete the task as compared to young adults. One explanation for this result can be related to the increased complexity inherent in the task, as the individual is required to follow a strategic sequence in which they successfully avoid the boxes on which they have already clicked. Further, we may suggest that stroke affecting prefrontal regions could have impacted processing within the working memory system, thereby requiring more time and have less accuracy in completing the task but more information with respect to the site of the lesion and affected lobe is warranted.

Studies have suggested that executive function tasks could be as equally complex as the working memory tasks, demanding greater attentional resources for information processing and response inhibition by suppressing task-irrelevant information (Long & Prat, 2002; P. Patel &

Bhatt, 2014) resulting in increased time of completion for the incongruent slide of the Color Naming task as compared to the congruent slide. For the Category Naming task, in which the participants were asked to recall words belonging to a particular semantic category (e.g. animal), a significant difference for the number of correct responses was observed between chronic stroke survivors and healthy older and young adults. The stroke group demonstrated a decreased number of correct responses for the Category Naming task (semantic fluency) as compared to the other two groups. This suggests that that verbal fluency is a frontally mediated cognitive function and hemiparetic stroke can result in poor performance on this task (Brady, Spiro, McGlinchey-Berroth, Milberg, & Gaziano, 2001).

Notwithstanding these results, the study had certain limitations. The overall sample size was small, and reliability measurements should be repeated in a larger sample and also try to limit practice effects due to familiarity to the paradigm. Furthermore, for future implication we would like to incorporate not only the type but also the site of lesion for a better understanding of which cognitive function is affected more by comparing the sites of the cerebral lesion. Also, the CCTs can be further explored in people suffering from MCI, dementia or any other cognitive impairments.

3.5 Conclusion

To conclude, the results from the study suggest that the customized computerized cognitive test battery is a reliable tool to assess cognitive function. The custom developed CCT'S may be a good tool to capture more subtle changes in cognitive functioning, relative to paper-and-pencil tests or clinical global cognition tests such as the Montreal Cognitive Assessment which can be useful as screening tool (McDonnell et al., 2011). Computerized measures also require less training for administration without undue burden on staff.

Computerized batteries can be used as either screening instruments to identify patients requiring further evaluation by a neuropsychologist, or as part of a standard neuropsychological assessment. Lastly, CCT's can be employed as dual-task paradigms for cognitive-motor rehabilitation in clinical settings. Future studies should establish sensitivity and specificity of this CCT for identifying Mild cognitive impairment and dementia among patients with stroke and other neurological problems.

Table VI

Computerized cognition tests assesses for test-retest reliability and outcome variables

Test Name (task)	Cognitive function assessed	Outcome variable
Spot & Click	Visuo-motor	Reaction Time
Category Naming	Semantic verbal Fluency	Number of correct responses
Color Naming	Response inhibition/processing Speed	Total time of completion
Unveil the Star	Discriminant Decision Making	Total time of completion
		Total number of errors.
Triangle Tracking	Working Memory	Number of correct responses
Number & Position	Associative Memory	Accuracy (%)

Table VII

Demographics and Disease characteristics of chronic stroke patients, older adults and young adults.

	Stroke patients mean(SD)/ % *N*= 15	Healthy Older adults mean(SD)/ % *N*=15	Healthy Young mean(SD)/ % *N*=15
Age (years)	58.9(6.9)	64.4(5.1)	23.86(1.3)
Gender (M/F)	7/8	8/7	6/9
Premorbid IQ (%ile)	55.8/70 (79.8%)	64.8/70 (92.6%)*	64.6/70 (92.3%) #
Years of Education	14.2(2.7)	16.2(1.7)	16.8(1.5)#
Time since stroke (years)	10.29(5.99)		
Stroke type (% I/H)	58.82/41.18		

I-ischemic, H- Hemorrhagic

Significant difference in means for Premorbid IQ and Years of Education ($p \leq 0.05$).

* Difference in means between stroke and Healthy older adults statistically significant ($p < 0.05$).

Difference in means between stroke and Healthy young statistically significant ($p < 0.05$).

Table VIII

Intra-Class Correlation Coefficient assessing test-retest reliability for different test variables across two sessions.

Test Variables	Stroke Survivors (*N*= 15)		Healthy older adults (*N*= 15)		Healthy Young (*N*= 15)		All Groups (*N*= 45)
	ICC	*P*-Value	ICC	*P*-Value	ICC	*P*-Value	ICC#
Spot & Click							
Simple reaction time(ms)	0.75	0.007	0.76	0.01	0.84	0.00	0.84
Choice reaction time(ms)	0.68	0.01	0.73	0.01	0.89	0.00	0.87
Number & position							
Accuracy (%)	0.85	0.00	0.83	0.001	*		0.77&
Category Naming							
Number of responses	0.91	0.00	0.83	0.001	0.78	0.04	0.89
Color Naming							
Incongruent (total time, s)	0.98	0.00	0.88	0.00	0.92	0.00	0.98
Unveil the Star							
Total time of completion(sec)	0.66	0.02	0.73	0.01	0.77	0.00	0.85
Error (%)	0.78	0.003	0.76	0.01	0.95	0.00	0.86
Triangle Tracking							
1-back Accuracy (%)	0.65	0.02	0.81	0.002	*		0.72&
2-back Accuracy (%)	0.80	0.002	0.62	0.03	0.71	0.02	0.77

ICC: Intra-Class Correlation Coefficient

ICC's for all the test variables are statistically significant ($p < 0.05$).

* No variance observed between the testing sessions. Mean (SD) for Number & Position task: 98.33(4.39) and 99.16(3.22). For the Triangle Tracking (1-back accuracy): 97.50 (5.17) and 97.50 (5.17).

& No variance was observed between the testing sessions resulting into moderate ICC.

Significance level for ICC of all groups (*p*- value < 0.001)

Table IX

Computer generated test scores for Stroke patients, Healthy Older adults, and Healthy Young adults

Computerized test	Test Variables	Stroke patients mean(SD) (*N*=15)	Healthy Older adults mean(SD) (*N*=15)	Healthy Young mean(SD) (*N*= 15)	F value	*P*
Spot & Click	CRT (ms)*	1347.1 ± 333.7	994.4 ±192.1	694.2 ± 150	17.6	<0.001
	CRT-SRT (ms)*	858. ± 299.1	565.8 ± 146.7	356.9 ± 116.9	14.9	<0.001
Category Naming	# of responses	16.8 ± 5.8	23.6 ± 6.1	22.20 ± 5.8	5.5	<0.001
Color Naming	Incongruent(total time, s)	63.9 ± 24.1	44.5 ± 6.5	33.6 ± 7.8	15.4	<0.001
Unveil the Star	Total time of completion(s)	98.3 ± 34.1	73.9 ± 26.1	48.32 ± 12.56	14.1	<0.001
	Error (%)	-1451.6 ± 28.2	-1464.5 ± 22.2	-1475.8 ± 25.7	3.3	0.04
Triangle Tracking	2-back Accuracy (%)	45 ± 22.5	73.3 ± 17.5	78.33 ± 17.3	12.9	<0.001
Number & Position	# of correct responses	84 ± 19.2	96.66 ± 7.4	98.33 ± 4.4	6.1	<0.001

*Premorbid IQ Score and years of education were significant covariates ($p < 0.05$).

Table X

Computer generated test scores for Stroke patients, Healthy Older adults, and Healthy Young adults reporting mean differences with 95% Confidence Interval.

Computerized test	Test Variables	Stroke vs. Older adults mean diff (95%CI)	Stroke vs. Healthy young mean diff (95%CI)	Healthy young vs. Older adults mean diff (95%CI)	Stroke vs. Older adults	Stroke vs. Healthy young	Healthy young vs. Older adults
Spot & Click	CRT (ms)	352.72 (141.1 – 564.4)	652.85 (441.1 – 864.5)	300.13 (88.4 – 511.9)	$p = 0.01$	$p < 0.001$	$p = 0.04$
	CRT-SRT (ms)	292.22 (111.3 – 473.1)	50.1.10 (320.2 – 681.9)	208.88 (28.0 – 386.7)	$p < 0.001$	$p < 0.001$	$p = 0.02$
Category Naming	# of responses	-6.80 (-12.1– -1.5)	-5.40 (-10.2 – -1.2)	-1.40 (-6.7 – 3.9)	$p < 0.001$	$p = 0.04$	$p = 0.79$
Color Naming	Incongruent(total time, s)	19.44 (5.9 – 32.9)	30.36 (16.9 – 43.82)	-10.91 (-24.4 – 2.5)	$p < 0.001$	$p < 0.001$	$p = 0.13$
Unveil the Star	Total time of completion(s)	24.42 (1.5 – 47.6)	50.05 (27.1 – 73.0)	-25.62 (-48.6 – -2.7)	$p = 0.03$	$p < 0.001$	$p = 0.02$
	Error (%)	12.91 (-9.7 – 35.5)	24.2 (1.5 – 46.8)	-11.25 (-33.9 – 11.4)	$p = 0.35$	$p = 0.03$	$p = 0.45$
Triangle Tracking	2-back Accuracy (%)	-28.33 (-45.5 – -11.2)	-33.33 (-50.5 – -16.2)	5.00 (-12.1 – 22.1)	$p < 0.001$	$p < 0.001$	$p = 0.76$
Number & Position	# of correct responses	-12.50 (-23.5 – -1.7)	-14.2 (-24.9 – -3.4)	1.66 (-9.1 – 12.4)	$p = 0.02$	$p < 0.001$	$p = 0.92$

CI= Confidence Interval.

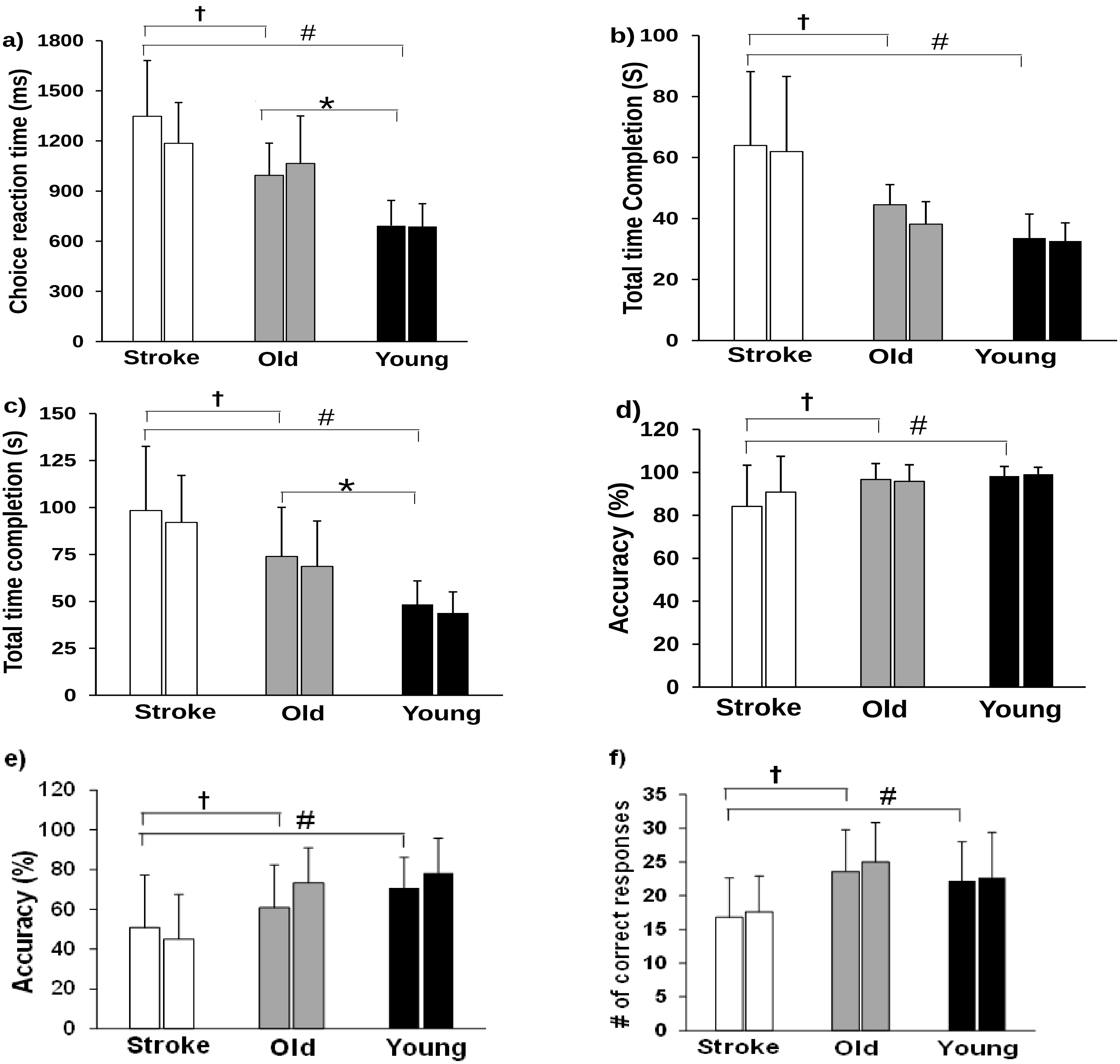


Figure 4. Plots displaying means of each outcome variables for test session 1 and 2 which are not significantly different from each other ($p > 0.05$)**.** a) Choice reaction time b) Total time completion for Color Naming task-incongruent slide c) Unveil the Star task respectively. d) Accuracy (%) for Number & Position task e) Accuracy (%) for Triangle Tracking (2- back) f) number of correct responses for the category naming task.

Difference in means with significance level ($p \leq 0.05$)

† = Difference in means between stroke and healthy older adults.

= Difference in means between stroke and healthy young adults.

* = Difference in means between healthy older adults and healthy young adults.

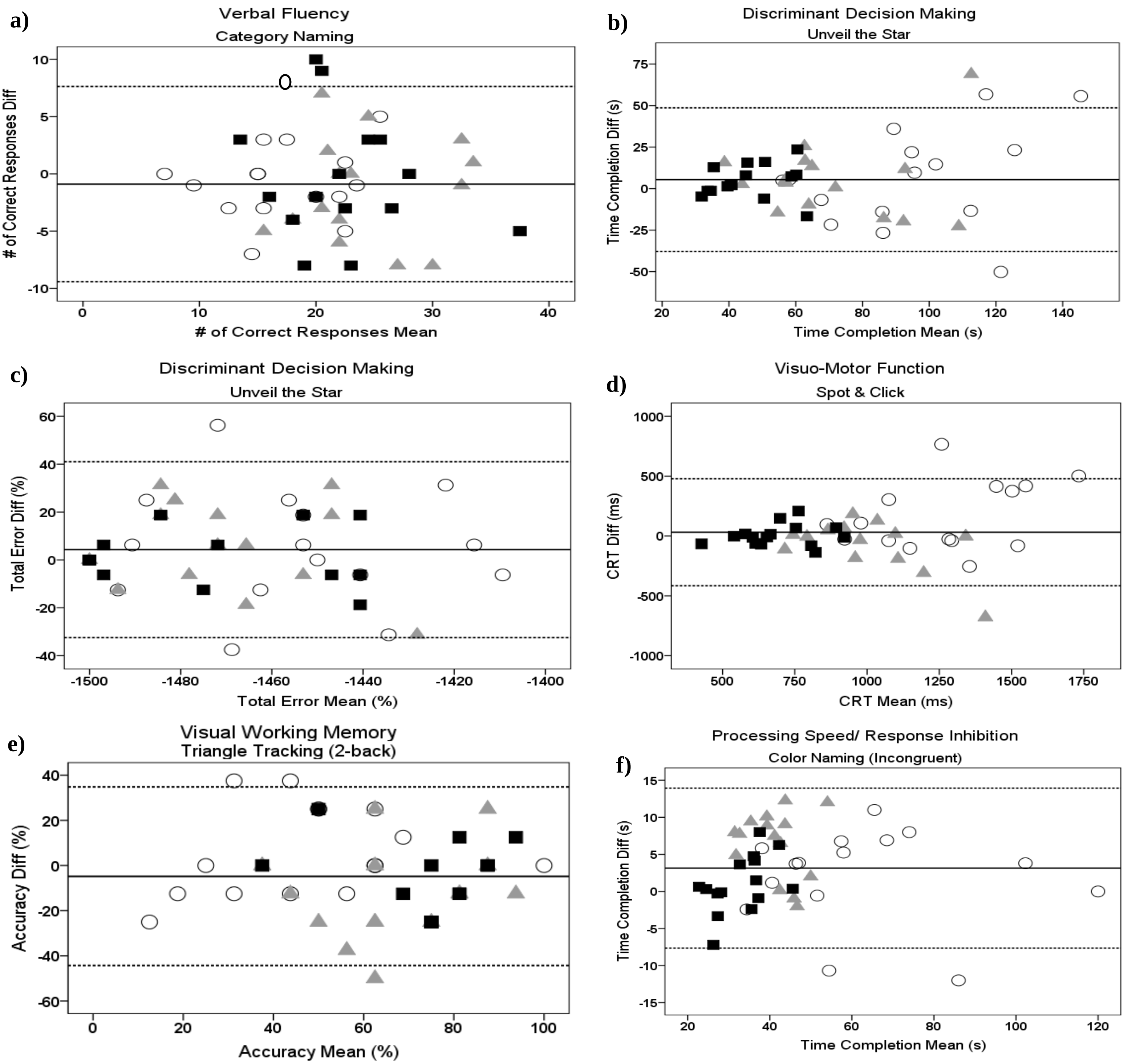


Figure 5. Bland-Altman plots displaying limits of agreement: mean (solid line) ±1.96 SD (dotted line) of the difference between test session 1 and test session 2 values for the variables: (a) number of correct responses ;(b & f) total time completion; (c) total errors (d) choice reaction time (CRT); and (e) accuracy (%). (The ○ represents the stroke group, ▲ represents healthy-older adults & ■ represents the healthy young group).

CHAPTER IV

AIM 3: EFFECTIVENESS OF NOVEL COGNITIVE-BALANCE CONTROL TRAINING PARADIGM FOR IMPROVING COGNITION IN STROKE SURVIVORS: A PILOT STUDY.

4.1 Introduction

There is an increasing incidence of falls during aging, with one-third of =community dwellers over the age of 65 incurring in falls annually (Ageing & Unit, 2008; Blake et al., 1988; fall, 2016; Stevens et al., 2012; M. E. Tinetti, Speechley, & Ginter, 1988; Mary E Tinetti & Williams, 1997). This incidence is doubled in older adults who have neurological insult such as CVA or stroke. With the advances in medical care the number of ambulatory elderly stroke survivors living in the community are increasing. Although most individuals undergo an intensive rehabilitation program these individuals' are involved in little to no therapy or exercise upon discharge to their home settings (Vincent et al., 2007). Furthermore, these individuals experience an apparent physical impairment (hemiparesis) concurrent with subclinical cognitive impairments that are not apparent, however, do influence everyday functioning.

Cognition is a broad term that cannot be solely defined as an individuals' awareness of his surrounding or environment but also incorporates attention span, recall, registration, calculation, decision making and planning skills which are frequently reported to be impaired post-stroke (Tatemichi et al., 1994). Moreover, several studies show that approximately 64% of stroke survivors have cognitive impairment unrelated to dementia (Jin et al., 2006). Cognitive functioning is an important precursor to predict and determine rehabilitation goals especially focusing on motor skills, functional independence and community integration after stroke. Recent literature report positive cognitive-motor rehabilitation relationships post-stroke, known to be beneficial among stroke survivors (Kong, Chua, & Tow, 1998; Mysiw, Beegan, & Gatens, 1989; Sisson, 1995).

Cognition plays an important role in understanding, self-evaluating and overcoming limitations that are commonly observed post-stroke. Cognitive domains that are primarily affected post-stroke are executive function, information processing, decision making skills, visuo-motor functions, and working and associative memory which a stroke survivor requires to understand and learn new skills in order to regain the lost functions and progress successfully in their rehabilitation program (Ozdemir, Birtane, Tabatabaei, Ekuklu, & Kokino, 2001). Evidence suggests a critical role of cognition in facilitating motor performance, and this interaction can be effectively examined and rehabilitated by employing the novel dual-task assessment and intervention paradigms (Lauenroth et al., 2016). Although dual-task paradigms often examine intervention- induced changes in dual-task cost, the motor cost has been more frequently examined than cognitive cost. Further, functional outcome measures also target motor performance –with change in cognitive performance or function rarely being examined.

In this study we aimed to examine the efficacy of a novel dual-task intervention paradigm that combined virtual reality for balance training, which provides increased number of repetitions via its engaging and motivational aspects in conjunction with cognitive training, however we will be focusing on improvement observed in cognition, measured using the computerized cognition test battery.

4.2 Methods

This study included thirteen community dwelling individuals with chronic hemiparetic stroke (60.63± 4.24 years of age, > 6 months of stroke). After obtaining an informed consent, the participants were screened for the exclusion criteria. Individuals with cognitive impairment (< 26 on Montreal Cognitive Assessment screening tool (Toglia, Parfene, Taub, O'Dell, & Mastrogiovanni, 2016) or severe dysphasia assessed using the Mississippi Aphasia Screening Test (Nakase-Thompson et al., 2005)were excluded from the study. Individuals with self-reported history of any musculoskeletal, cardiac or neurological impairment and inability to stand for 5 minutes without support were excluded from the study. In order to document the changes in cognition, testing of outcome measures was performed prior to and after the intervention as shown in Table XI. The cognitive outcome measures selected primarily focused on reaction time, processing speed/response inhibition, and different sub-domains of working memory.

4.2.1 Intervention

The novel cognitive-motor training paradigm was designed to improve strength, balance, weight bearing, and endurance along with emphasis on improving higher level cognition simultaneously. The cognitive motor intervention consisted of the participants playing on 6 different Nintendo Wii fit games while simultaneously performing higher level cognitive tasks. The intervention was initiated 5 days after baseline testing. Depending on performance on the Berg Balance Scale (Tyson & DeSouza, 2004), subjects were divided into 3 groups i.e. Low (28-36), Moderate (37-44), and High (44-52). The training consisted of 6 Balance board games performed in a randomized order: *Table tilt (TT), Tight Rope Walking (TRW), Soccer Heading (SH), Bubble Balance (BB), Basic Step (BS) and Light Run (LR)* which were played in conjunction with any of the cognitive games namely *Category Fluency (CF), Word List Generation (WLG), Digit Recall (DR), Mental Arithmetic (MA)* and *Analogies (AN).*

4.2.2 Wii Games

The protocol for the low performing group consisted of 4 balance board games played in the randomized order: Table tilt, Tight Rope Walking, Soccer Heading, and Bubble Balance throughout 20 sessions under therapist supervision in a research setting. Likewise, the Moderate performing groups consisted of the same games but in order to increase the difficulty level, two challenging games namely Light run and Basic step were added from session 11 which focused on stepping and endurance. Finally the high performing group was similar to the moderate group i.e. two challenging games namely Light run and Basic step were added at an earlier stage at session 5 as compared to the moderate group in order to increase their endurance and stepping strategy.

During the initial session, the participants were made to play the games for familiarization, verbal feedback from the therapist and visual feedback from the gaming system enhanced their understanding and helped them to come up with a strategy to achieve their goal. Subjects were given a brief orientation regarding the objective of each game.

1) *TRW*: The subject was asked to step on the board that helps them to cross the rope. The distance or the total time required to reach the end point was recorded.

2) *SH*: The aim was to hit the balls and dodge the other flying objects by continuously shifting weight from side to side, thereby initiating the weight shifting. The total numbers of soccer balls hit were recorded.

3) *TT*: The goal was to guide the ball to the hole by shifting weight forward, backward and sides in a fixed amount of time. The points corresponding to the level completed were recorded.

4) *BB*: The subject was asked to reach the other end of the river without popping the bubble by shifting the weight forward and stir their body left to right to avoid the sharp edges of the stone. The distance or the total time required to reach the end was recorded.

5) *LR*: The subject was made to run or jog for a fixed distance. The amount of calorie burned was calculated.

6) *BS*: The subject was asked to follow the directions and foot print projected on the screen to step up-down and to the sides. The total number of perfect moves, okay moves and the missed moves were recorded.

Cognitive Games: The games to be played while performing the Wii games, included:

1) *CF*: The Subject was asked to name the things belonging to a particular category like animals, furniture, and name of the Streets. Different categories were given after 30 seconds. The number of correct responses were recorded.

2) *WLG:* The subject was asked to generate different words from a letter (words from letter A, F) for a fixed time of 30 seconds after which another letter was given. The total number of correct responses were recorded.

3) *DR:* The subject was asked to repeat the numbers in forward or backward order. Initially we start with two digits and as the session progresses along with the increased number of correct responses they were are given 3-4 digits and a new component of arranging the numbers in the ascending number was added.

4) *MA:* The Subject was asked to perform addition, subtraction, multiplication, and division. The correct responses were recorded.

5) *RL:* The subject was given a buzzer and asked to press the buzzer when he hears a particular letter. (Press the buzzer when you hear the letter A and we start saying a series of letters).The number of times buzzer pressed correctly and errors were recorded.

6) *AN:* The subject was asked to complete the sentence with an appropriate abstraction. (Banana is yellow then strawberries are… and their expected response would be Red).

Dual Task Training Combinations: Each Wii game was performed in a block for 5 minutes with 3 cognitive games (approximately 90 seconds each). The order of the 4 Wii games as well as the combination of 3 out of 6 cognitive games to be played within the 5-minute block was randomized. These randomly generated order and combination were then paired and presented randomly as well.

4.2.3 Statistical Analysis

All the statistical analysis were performed using Statistical Package for the Social (SPSS) (version 22) for windows. Descriptive statistics (Mean ± SD) were performed to characterize demographics and for performance on the cognitive test both pre- and post-intervention. The differences for pre-post intervention were compared using paired sample t-test.

4.3 Results

Thirteen community dwelling stroke participants completed the 6-weeks training program. The demographic characteristics of the participants are presented in Table XII.

4.3.1 Cognitive outcome measures

Stroke survivors did show a trend to favor the intervention with respect to change in cognitive scores post-intervention. Global cognitive assessment done using the Montreal Cognitive assessment measured at pre-intervention (26.84 ± 1.21) and post-intervention (27.53 ± 1.51) showed a statistically significant improvement (p<0.01). For the Spot & click measuring reaction time, Simple reaction time measured at pre-intervention (473.2 ± 88.4) and post-intervention (413.7 ± 106.5) showed improvement but was not statistically significant. Whereas for the Choice reaction time an improvement was observed from pre- (1426.5 ± 441.4) to post-intervention (1181.9 ± 242.7) which was statistically significant. For the Color Naming test a reduction in total time completion was observed for the congruent slide from pre- (23.7 ± 6.1) to post-intervention 20.7 ± 4.2) without statistical significance, whereas reduction in total time completion for the incongruent slide from pre- (55.6 ± 11.3) to post-intervention (46.4 ± 10.1) was statistically significant ($p = 0.01$). For Unveil the Star test assessing the spatial working memory, a significant reduction is total time of completion in the task was observed pre- (97.6 ± 26) to post-intervention (75.8 ± 11.5) without a significant change in the number of errors even though the error (%) did reduce pre- (-1451.9 ± 24.7) to post-intervention (-1461.1 ± 12.2). Lastly, for the Number & Position task assessing the associative memory an increase in the accuracy % is observed from pre- (89.4 ± 18.3) to post-intervention (90.3 ± 10.4) although it is not significant. The change in the cognitive outcome variables from baseline to post-intervention have been shown in Figure 6.

4.4 Discussion

Rehabilitation is an important objective as it enables the patient to perform the activities of daily living and functional ambulation independently. In order to predict future outcomes and evaluate the efficacy of the intervention which the participants undergo, we must consider independent variables such as demographics, disease-related parameters, motor loss and cognitive disorders prior to the start of training (Shah, Vanclay, & Cooper, 1991). As suggested cognitive impairments are frequent after stroke as it stresses the importance of cognitive assessment at the baseline (Paolucci et al., 1996). Computerized cognitive testing is gaining popularity and numerous studies have used commercially available tests for testing cognition in different populations (Asken, Clugston, Snyder, & Bauer, 2017; Fredrickson et al., 2010; Gualtieri & Johnson, 2006; Moore et al., 2017; S. K. Patel et al., 2017). In this study we have used a custom designed computerized cognitive test battery which was administered using DirectRT™ Empirisoft and whose reliability and validity has been previously established (Vora et al., 2016). Furthermore, this paper aimed to understand the efficacy of computerized cognitive tests (CCT) to assess change in cognitive scores pre-post intervention.

In the case of chronic stroke survivors, the novel dual task cognitive-motor paradigm influenced and improved their cognitive function. A significant improvement or a positive trend was also observed in the computerized cognitive test battery scores post-intervention indicating that the novel dual task intervention paradigm helped the participants to improve their attention, memory and decision making skills.

For the tests measuring the simple reaction time and choice reaction time, an improvement was observed from pre-post intervention. Reaction time is a non-strategic task as the individual is unaware when the stimulus would appear but Wii fit games such as soccer heading where the participant continues to hit the ball coming from different directions or dodges one's self from other objects trains the participant to make swift movement, react faster and also increase their attention span post-intervention (Bisson, Contant, Sveistrup, & Lajoie, 2007). Similarly, due to repetitive and engaging training provided in this novel dual task paradigm an increase in attention span, decision making skills, association and recall were observed which are reflected in the cognitive testing done post-intervention. The cognitive tasks played along in the conjunction with the Wii-games also influenced and improved the cognitive scores. Tasks such repeated letter in which the subjects were asked to respond or press a buzzer as soon as they heard a particular letter helped to increase subjects' attention span and concentration and also increased their speed to respond to a particular cue. This change in seen on assessing the reaction time using the Spot & Click task which showed significant improvement pre-post intervention. Similarly cognitive tasks such as Digit Recall, Mental Arithmetic, and Analogies primarily focused on attention span, information processing speed, response inhibition, and cognitive flexibility which assisted in improving the cognitive score for the Number & Position task, Color Naming task and unveil the Star task assessed post-intervention.

The accuracy for the Number & position task increased pre-post intervention even though there was no significant change observed. For the color naming task which assesses the processing speed and response inhibition, the time required to complete the congruent slide reduced by 3 seconds whereas the total time required to complete the incongruent slide reduced by 9 seconds which was statistically significant. Finally, for Unveil the Star test assessing the spatial working memory there was a significant reduction in amount of time required to complete the three levels similar to the Table Tilt game where the participant developed an strategy to guide the ball in the whole in the least amount of time even though the total numbers of errors did not reduce significantly. Apart from changes in the neuropsychological computerized cognitive test battery, significant improvement was observed in the clinical global cognitive assessment employed using the Montreal Cognitive assessment (MoCA). Similar findings were observed by Pompeu et al, 2012 wherein they assessed the effects of Nintendo Wii-based motor cognitive training versus balance exercise therapy in patients with Parkinson's observing an increase in the MOCA scores without significant group mean difference (Pompeu et al., 2012). For the tests administered using the Delis-Kaplan Executive Function System a similar trend was observed with regards to change in the cognitive scores pre-post intervention for Visual Stroop test, Verbal Fluency test and Digit Recall test where in the a significant improvement was observed in total number of correct responses and reduction in total time completion of condition 3 (incongruent) for the Visual Stroop test presented in Table XIII.

It is suggested that methods such as ‘feedback' and ‘repetitive training’ plays an integral role in improving cognitive and motor recovery post-stroke. The knowledge of feedback and knowledge of performance from the therapist with regards to the cognitive games played in conjunction with the Wii Fit games could have encouraged the participants to improve their cognitive performance and minimize the deficiency in their motor movements. Additionally, the high intensity tapering dual-task protocol provided training for 6 weeks, having a total of 20 sessions, each session being 90 minutes long, in the present study might have offered an effective dosage for improving the cognitive performance post-intervention.

The findings of this preliminary study should be interpreted with caution given the limited sample size. Further, studies with larger sample sizes are required to assess the effectiveness of this intervention and efficacy of the computerized cognitive test for potential translation into clinical rehabilitation program. Furthermore, this study did not account for the inter-individual variation in cognitive deficits hence subsequent intervention-related improvements that could result due to differences in lesion sites within the cortex.

4.5 Conclusion

To conclude, the results from the study suggest that the novel dual-task intervention paradigm that combined virtual reality for balance training with cognitive training was fairly effective in improving cognition which was assessed using the computerized cognitive test battery. Thereby suggesting, that CCT’s, may be a sensitive tool to record the subtle changes pre-post intervention. The CCT's can be effectively used as both an assessment tool and a training tool for cognitive-motor rehabilitation in clinical settings.

Table XI

Computerized cognition tests assessed for pre and post intervention.

Test Name(task)	Cognitive function assessed	Outcome Variables
Spot and click	Visuo-motor function	Reaction time
Color Naming	Processing Speed/Response Inhibition	Total Time of Completion
Unveil the Star	Spatial Working Memory	Total time of completion Total number of errors
Number & Position	Associative Memory	Accuracy (%)

Table XII

Demographics and Disease characteristics of chronic stroke patients

	Stroke patients mean(SD)/ % N= 13
Age (years)	58.76(6.58)
Premorbid IQ (%)	79.65%
Years of Education	14.02(2.58)
Time since stroke (years)	10.29(5.99)
Stroke type (% I/H)	58.82/41.18
CMSA- Leg impairment (/7)	5.07± 0.64

I- ischemic, H- Hemorrhagic

Table XIII

Cognitive scores pre-post intervention for tests administered using D-KEFS

Tests	Test Variables	Pre-intervention (Mean/SD)	Post-intervention (Mean/SD)	*t*- value	*P*- Value
Visual Stroop	Condition 3(incog) (total time, s)	72.70 ± 20.9	65.32 ± 20.4	2.15	0.05
Verbal Fluency	Number of correct responses	10.63 ± 4.1	13.25 ± 4.75	-2.91	0.01
Digit Recall	Number of correct responses % (out of 48)	47.04 ± 7.6	51.56 ± 8.5	-3.48	0.06

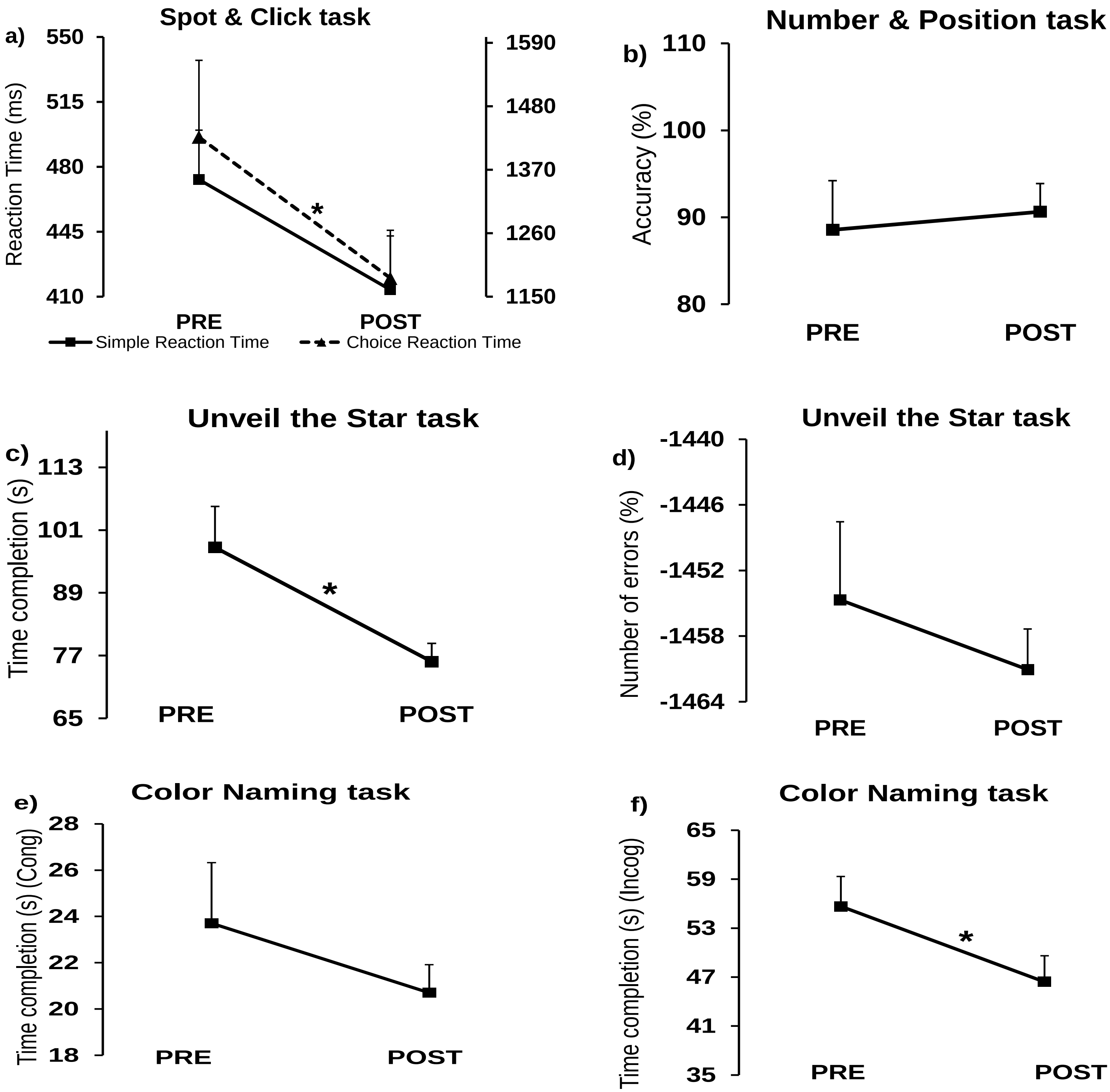


Figure 6. Change in pre-post intervention cognitive scores is observed for a) Simple and Choice Reaction Time b) Increase in accuracy (%) for Number & Position task c & d) Decrease in time of completion and number of errors (%) in Unveil the Star task, (e & f) Reduction in time of completion for congruent (e) and incongruent (f) slide for the Color Naming task. * denotes significance $p < 0.05$.

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VITA

JINAL PANKAJ VORA

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EDUCATION

Master of Science **May 2017**
Major: Rehabilitation Science
University of Illinois, Chicago
(GPA: 3.5/4.00)
(Expected Graduation Date: May 2017)

Bachelor of Physiotherapy **August 2009 – January 2014**
Sancheti College of physiotherapy, Pune
GPA: 3.9/4.00 (As evaluated by World Education Services)

LICENSURE:

- State of Oregon, Physical Therapist Licensing Board **Active (Lic. No. 61860)**

WORK EXPERIENCE

- Junior Physiotherapist-Physiotherapy Clinic and Kasturba Health Society – Mumbai, India **April 2014-Jul 2014**
  - Initial assessment and recommendation of investigations to aid the diagnosis of the ailments.
  - Adept at the use of electrotherapeutic modalities like the short wave diathermy, ultrasound, interferential therapy.
  - Extensive experience in patient treatment mainly focusing on out-patient rehabilitation.

RESEARCH EXPERIENCE

- **Research Assistant-UIC** **January 2015- May 2016**
- *Motor Behavior and Gait Analysis Laboratory, University of Illinois, Chicago*
  - Assistance in the core funded project
  - Lead research personnel for the project titled "Comparing alternative therapies in order to reduce fall-risk and improve balance control among chronic stroke survivors."
  - Data collection, analysis with Motion Analysis System and ActiveStep.
  - Patient screening, Balance training intervention.
  - Statistical data organization and analysis.

- **Current Projects:**
- "Test-retest reliability and validity of a computerized neuropsychological test battery: A cross-sectional study assessing cognition in healthy young and old adults, and stroke survivors'' (*Paper in review*)
- "A high intensity tapering conventional balance training for decreasing fall-risk in chronic stroke survivors: Measuring improvement across different domains of balance control."

- Effects of fatigue on dynamic balance control in football players using the Star excursion test. (Sancheti college of physiotherapy, 2014)

PEER-REVIEW PUBLICATIONS

Vora J, Varghese R, Weisenbach S, Bhatt T. Test-retest reliability and validity of a custom-designed computerized neuropsychological cognitive test battery in young healthy adults***. Journal of Psychology and Cognition*** 2016; 1:11-9.

POSTER PRESENTATIONS

1) Application of computerized neuropsychological cognitive test battery for dual-task paradigms: Test-retest reliability and validity in young, old and stroke survivors.
   Jinal P Vora1, Rini Varghese1, Victor G Patron2, Sara L Weisenbach 2, 3 and Tanvi Bhatt1. ***Combined Sections Meeting.*** Anaheim, CA. February 17-20, 2016.
2) High intensity tapering conventional balance training for decreasing fall-risk in chronic stroke survivors: Measuring improvement across different domains of balance control.
   Jinal Vora, Rini Varghese, Prakruti Patel, Tanvi Bhatt. ***Combined Sections Meeting****.* Anaheim, CA. February 17-20, 2016.
3) The test-retest reliability of a computerized neuropsychological cognitive test battery in chronic stroke survivors: Application for dual-task paradigms. Jinal P Vora, Rini Varghese, Tanvi Bhatt. ***Society of Neurosciences.*** Chicago, IL. October 17-20, 2015.
4) Can conventional balance training improve reactive balance responses to decrease fall-risk in chronic stroke survivors?
   Jinal Vora, Prakruti Patel, Tanvi Bhatt***. AHS Research Day.*** University of Illinois at Chicago. Chicago, IL. November 4, 2015.
5) Effects of a high intensity tapering conventional balance training for improving balance control among chronic stroke survivors.
   Jinal Vora, Lakshmi Kannan, Rini Varghese, Prakruti Patel, Tanvi Bhatt. ***American Congress of rehabilitation Medicine***. Chicago, IL. November 1-3, 2016.

CERTIFICATION

6) Basic life Support Training, AHA certified. **March 2015**
7) Follow-up workshop on Brian Mulligan's Concept Mobilizations with Movement, NAGs, SNAGs, etc. **March 2014**
8) Basic course of dry needling and acupuncture Prof. Prakkash Sharoff (M.P.T) **June 2013**
9) Hands-on workshop on integrated manual therapy of strain counter-strain technique **October 2013**

SKILL SET

- Strong interpersonal skills with a commitment to clinical excellence and ability to work in a multi- task environment.
- Microsoft Word, Excel and Access, SPSS