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Does the Type of Dual Cognitive Task Impact
Gait Variability Using the Quantitative Timed Up and Go (QTUG)
in Community-Dwelling Adults?

by

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A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

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We hereby certify that this dissertation, submitted by Laurie Hiatt, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirement for the degree of Doctor of Philosophy in Physical Therapy.

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ABSTRACT

Background and Purpose: The purpose of this study was to determine how different cognitive dual-tasks impact gait variability in community-dwelling adults using the Quantitative Timed Up and Go (QTUG).

Methods: Participants aged 65 and older were recruited. Inclusion criteria: ability to ambulate without assistive devices, independent community living, adequate vision, hearing, able to read and follow directions. Demographics included BMI, gender, fall history, medications, education, and age. The Activities-specific Balance Confidence Scale (ABC) and Screening Assessment for Falls Evaluation (SAFE) tests were administered.

QTUG body-worn sensors were applied on participant's shins and recorded temporal and spatial gait parameters. Participants performed 10 TUG tests, two were used as a control. The dual-cognitive tasks of serial subtraction (Subtract), reading (Read), auditory response naming questions (Audible), and visual confrontation naming pictures (Visual) conditions were randomized and recorded twice.

Results: Forty-four participants (30 female, 14 male) with mean age 73.11 years were included. The dual-task costs of Subtract was significantly different (*p* <.0001) from standard TUG. Read condition was also significantly different from standard TUG (*p* <.006) for TUG recording time. Subtract conditions consistently demonstrated greater dual-task cost than the other conditions and Post hoc pairwise comparisons showed Subtract was also significantly different from the other conditions. Significant differences were also found between fallers and non-fallers in all conditions for mean pre-turn time.

There was a significant $p < .01$ moderate negative correlation between SAFE and TUG pre-turn times. SAFE scores were moderately positively correlated to stride length at $p < 0.01$ level. ABC had a significant $p < .01$ moderate negative correlation to TUG and pre-turn times. There were no significant gait variability differences in the conditions or in participants with a history of falls.

Conclusion: Of the four dual-task conditions, the cognitive task of Subtract significantly impacts dual task costs for many TUG gait parameters. The four cognitive conditions (reading, answering a question, identifying pictures by name, and serial subtraction) impact gait differently as measured by the QTUG. The QTUG was able to distinguish fallers from non-fallers under all cognitive conditions for TUG pre-turn time.

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CHAPTER I

1.0 Introduction

This dissertation was developed to examine how common distractions such as talking, reading, naming pictures, and counting impact walking in older adults. This was accomplished under dual-task conditions using the Quantitative Timed Up & Go Test (QTUG) on community dwelling older adults. The research investigated if there was a relationship between gait variability and the Activity-specific Balance Confidence (ABC) Scale in the same population. This research was intended to address a gap in current knowledge regarding the understanding of how balance confidence and different cognitive-motor tasks impact gait variability. No study to date has compared the same variety of cognitive tasks that includes auditory and visual confrontation naming, reading, and counting backwards while performing a QTUG test. The various cognitive tests are specifically designed to challenge distinct neural pathways and measure the dual-task cost on gait variability.

The first chapter contains the introduction to the constructs that are at the foundation of this research. The complex nature of attention, dual-task demands, methodology, and gait variability are presented to assist in the description of the statement of the problem. This chapter also includes an introduction to the Timed Up-and-Go test and the influence of balance confidence on gait. Research questions for this dissertation are included. The end of the chapter contains a list of definitions.

Background for the Problem

1.1 Attention and Dual-Tasking

Attention is defined as the mental process of concentrating effort on a stimulus or mental event.[1] Attention capacity in every individual is limited, and performing any task requires a portion of this capacity.[2] Two tasks that are performed at the same time and exceed an individual's processing capacity will result in a decline in the performance of one or both tasks.[3] Attention has proven to be a difficult concept to measure, but despite this, it has entered the mainstream of research in dual-task methodology. McDowd (2007) provided physical therapists with an overview of attention to help explain the different task contexts of attention.[4] McDowd proposes that attention consists of four different types: selective attention, divided attention, sustained attention, and attention switching.[4] Divided attention is the concept of interest in this study and involves the ability to respond to more than one task at a time or to multiple elements within a task.[5] The ability to perform two tasks at one time can be described as dual-tasking and is taken for granted in daily living activities. Examples include walking in the grocery store isle while scanning for an item on the shelf. Another example is taking a walk while having a conversation with a friend in person or on the phone. Physical therapists need to have a functional understanding of attentional behavior because patients must dual-task in activities of daily living. McIsaac and colleagues define dual-tasking as the "concurrent performance of two tasks that can be performed independently, measured separately, and have distinct goals."[6]

Interpretation of dual-task research findings is complicated due to variations in task difficulty, varying populations, and lack of clear definitions.[6] There have also been significant limitations in dual-task literature due to a lack of consistency in testing protocols.[7] Despite this, dual-task testing is clinically meaningful to evaluate the impact of attention on gait and postural stability.[7]

1.2 Gait Variability

Gait variability is the fluctuation in gait parameters from one step to the next.[8] Studies of gait variability typically consist of measurement of stride-to-stride fluctuations in walking.[9] While this measurement can be done in several ways, the method that was used in this study placed kinematic sensors on the individual while walking. Advanced technology in these devices allows the gait cycle to be broken down into spatial (distance) and temporal (time) increments. Quantitative measurement of locomotion in healthy adults shows a relatively small coefficient of variation in many gait parameters.[10] The small coefficient of variation in healthy subjects is a testament to the reliability of the systems that regulate gait.

Increased gait variability can be seen in individuals afflicted with weakness, frailty, and neuro-degenerative diseases.[11-15] Higher variability is associated with decreased functional status in both self-reported and performance-based measurements.[9] The magnitude of the variability in gait parameters has become an important outcome measure in older adults because it is associated with deficits in mobility, advancing age, fall risk, and cognitive impairments.[8,13,16-18] Numerous studies have identified variability in spatiotemporal gait as a contributing factor in older people falling.[19-21]

1.3 Dual-Task Methodology

Lundin-Olson (1997) observed in her seminal paper that frail elderly patients stopped walking when talking.[22] This finding is consistent with McDowd who suggested when individuals are paying attention to one task, it means they are not processing other things.[4] Elderly individuals that had to stop walking in order to carry on a conversation sparked investigations to understand the impact of dividing attention during walking. Divided attention markedly impaired the ability of patients with Alzheimer's to regulate stride-to-stride timing.[23] In normal adults, gait control declines and variability increases with the addition of cognitive demands. Research focused on this type of dual-task methodology has enlightened clinicians on the relationship between attention, attention capacity, dual-task skill, and falls.[24-27]

1.4 Gait Variability and Dual-Tasking

Walking was once thought to be an automated motor task.[28] The implications were that walking could take place without attention. Research has shown the involvement of attentional resources in gait by using dual-task methodology.[29] If gait were automatic, performance of attention demanding tasks during walking would not cause any changes.[14] Studies have shown normal control of gait places measurable demands on attentional processes.[24,30-33] Walking is now recognized as a complex motor task with demands on both the sensory and cognitive systems.[34] Dual-task research from the past two decades has provided valuable insight helping clinicians understand normal and abnormal variability across the aging process. Research indicates that performance of a secondary or dual-task while walking negatively impacts gait across the age spectrum,[8,21,35,36] especially to those at risk of falling. The dual-task of walking and performing a verbal fluency task in healthy subjects results in a decrease in the stride or step to step velocity.[35] Measurement of dual-task variability is sensitive and reliable enough to detect change over time. Clinicians are measuring baseline performance and observing longitudinal changes in healthy individuals for the purpose of detecting declining attention or potential risk of falling.[19,21,37-41] Physical therapists are using dual-task outcome measures to detect declining gait patterns, that can put elderly adults at a higher risk for falls. Instrumentation can accurately measure variations that occur when walking under different conditions. Detecting those at risk for falling and initiating interventions before a fall occurs is the gold standard of fall prevention screening.

1.5 The Timed Up & Go Test

The Timed Up & Go Test (TUG)[42] is a quick and simple measure of functional mobility. It has been studied extensively in the literature and has excellent measurement reliability in various populations.[43-51] The TUG test requires individuals to get up from a chair, walk three meters, turn around, walk back to the chair, and return to sitting. The time taken to complete the test is recorded. Adding a cognitive dual-task to the TUG test, known as the TUG-cognitive, TUG-c, or CogTUG, provides valuable insight and detection of declining function in the elderly due to the additional attention load.[31,52,53]

1.6 Quantitative Timed Up & Go (QTUG)

Quantitative gait assessment has been performed in many ways, including gait analysis using pressure plates, treadmills, video analysis, and stopwatches. The latest technology includes the use of small, body-worn kinematic sensors that can measure more than 40 different parameters of gait. Body-worn kinematic sensors can add an objective and quantifiable analysis of every segment of the TUG test.[20] Greene et al. developed the Quantitative Timed Up and Go (QTUG) tool.[20,54,55] The QTUG is a highly reliable and valid tool that quantifies spatial and temporal gait parameters for assessment of healthy older people at risk for falls under both single and dual-task conditions.[56] Greene placed inertial sensors on the shins of his subjects to obtain gait parameters during walking.[55] The Kinematic sensors measure several spatiotemporal parameters of gait during walking. This type of quantitative analysis can provide an additional resource for clinical assessment of healthy and older adults at risk for falls. The TUG test is a motor task that requires motor planning, orientation in space, and organization.[47] The QTUG has the capability of recording the time to complete the test, number of gait cycles, number of steps taken, cadence, time to complete the turn and walk-turn time ratio. Also, the QTUG is capable of measuring stride time, swing time, stance time, double support, and single support percentages.[20,57] This allows for in depth analysis of the relationship between the performance of the TUG with dual-task cognitive demands. Studies have indicated that some sensor derived gait parameters are reliable.[56] The QTUG tablet contains software with a Screening Assessment for Falls Evaluation (SAFE) consisting of eight questions regarding medical status and fall history. The screening tool data was included in the research as an independent variable.

1.7 Self-Confidence

Many factors can account for declining gait speed with aging including self-confidence, sarcopenia, and sensory-motor changes.[58] Self-efficacy refers to an individual's perception of his/her capabilities to organize and execute the course of action required to perform a given skill.[59] The Activity-specific Balance Confidence (ABC) Scale is a measure of confidence.[60] The ABC scale is designed to measure falls-related self-efficacy and is considered a measure of balance confidence. It is a 16-item questionnaire with each item representing activities of daily living rated from 0% (no confidence) to 100% (complete confidence). Research has demonstrated falls-related self-efficacy was independently associated with gait speed.[61] Myers (1998) et al.

demonstrated that the ABC scale was able to discriminate between high, low, and poor mobility groups.[62] Adults that move slower because they are cautious will have a lower ABC score. Individuals that have reduced performance but have higher ABC scores are more likely to have physical limitations without perceived diminished confidence. Examples may include older individuals compensating in goal oriented performance based on the perceived difficulty of the cognitive-motor task,[63] and prioritizing safety by walking slower as a compensation strategy.[64] In summary, use of the ABC scale was used to assist in interpreting reduced performance for reasons of physical inability and self-efficacy.[60]

1.8 Statement of the Problem

Although prior research has studied the cost of dual-task conditions on functional mobility,[65-67] it is unclear if the different type of secondary cognitive task impacts a response in gait parameters. It is also unclear if self-confidence, as measured by the ABC scale, is related to functional mobility across dual-task conditions. Prior research has focused on cognitive demands such as mathematical skills (counting backward by 3's), verbal fluency skills (naming animals),[68] or saying days of the week backward.[52] These types of cognitive demands were created with the assumption that more challenging cognitive demands will result in greater dual-task effect and degradation of gait.

This current research investigated the impact of common but distinct cognitive tasks that occur in daily life on gait variability. The specific cognitive dual-task processes performed during the QTUG included the following: a) visual confrontation naming task, b) auditory response naming task consisting of listening to a question and then providing the one-word answer, c) reading a sign out loud, and d) counting backwards by three’s. Counting backwards by three’s was added to the list of dual-tasks because of a frequency of use in research. The comparison of serial subtraction and different cognitive tasks provided a unique comparison of the dual-task costs on gait. The convenience of the QTUG allowed for quantitative analysis of gait during real world cognitive demands.

The ABC scale has been studied with dual-task demands of walking and talking but not with a dual-task TUG or QTUG testing. The current research also investigated the correlation between the ABC scale and SAFE score with selected QTUG gait parameters.

1.9 Research Questions:

There are five research questions related to this study.

1. Is there a difference in the dual-task cost for the TUGvisual, TUGaudible, TUGreading, TUGsubtract in community dwelling adults? Dual-task cost is measured as TUGcontrol mean time – TUG condition mean time.

   Ho: There is no difference in the dual task cost of the four conditions.

   H1: There is a difference in the dual-task cost.

2. Is there a significant difference in gait parameter variability between the TUGcontrol and the four distinct cognitive conditions: TUGvisual, TUGaudible, TUGreading, TUGsubtract? The specific parameters of interest are swing time variability, single support variability, cadence, and the number of gait cycles.

   Ho: There is no difference in gait parameter variability between each of the four measures compared to the TUGcontrol.

H1: There is a difference in gait parameter variability between each of the four measures compared to the TUGcontrol.

3. Groups were dichotomized into fallers and non-fallers (based on a history of falls in the past 12 months.) Are the ABC, SAFE scores, and mean TUG time associated with fallers for each of the cognitive conditions?

   Ho: There is no association between the ABC and SAFE scores with fallers.

   H1: There is an association between the ABC and SAFE scores with fallers.

4. Is there a linear correlation between the ABC and SAFE scores and the QTUG parameters?

   Ho: There is no correlation between the ABC and SAFE scores and the QTUG parameters.

   H1: There is a correlation between the ABC and SAFE scores and the QTUG parameters.

5. Is the change in swing time variability associated with fallers? Calculations were performed for single support variability, cadence, and the number of gait cycles.

   Ho: There is no association in variability parameters in fallers

   H1: There is an association in variability parameters in fallers

1.10 Relevance and Significance

Gait variability has been identified as a predictor of falls.[9,18,38] There is ongoing geriatric and rehabilitation research focusing on identifying markers that could help to identify those at the greatest risk of falling. Adding a cognitive dual-task during the TUG has improved the ability to discriminate subtle changes in gait variability.[50,69] Gait variability with dual-task cognitive loading is one of those markers.[7,70,71] Research shows that the decline in performance during a dual-task TUG can help to differentiate individuals at risk for falls from those that are at lower risk of falls.[22,31,72] Despite the abundance of research that has been done over the past two decades, there is no clear methodology for choosing the type of cognitive task to perform with a TUG test. It is not known what impact the type of cognitive task has on gait variability under these test conditions. This study provides new insight into that question.

Task difficulty is critically important when investigating dual-task performance.[29] Walking at a self-selected speed can leave older adults with a reserve capacity.[73] Completing a secondary task while walking at a self-selected speed becomes somewhat easier when gait slows down. This can be seen in the research findings of Cardon-Verbecq et al., who found the CogTUG score was not associated with a history of falls in a population of frail older adults.[74] The methodology allowed subjects to walk with or without assistive devices at a self-selected pace.[74] In contrast, the methodology used in this research required subjects to perform the demanding TUG test with instructions to perform both tasks as quickly and as safely as possible. This study incorporated the commonly used cognitive demand of counting backwards by three's in order to compare the results to existing literature.

This investigation also extended previous research performed using the QTUG and addresses a gap in the current body of knowledge regarding how different cognitive tasks affect gait variability. A review of the literature reveals that there are differences in methodology in assessing the effect of dual-task cost that could confound the results. Differences include the type of cognitive tasks and how gait is measured (gait speed, walking path, etc.). The variations in methodology make it difficult to discern whether the observed gait changes are from the complexity of the dual-task requiring more processing[75] or the methodology itself.[68,70]

Furthermore, not all cognitive tasks draw upon the same neural pathways. If the motor control and cognitive pathways function independently, then the dual-task cost is minimized, and gait variability remains normal. If the motor and cognitive pathways are competing for the same attention processes, such as is true with walking and talking, then the effect would be greater, resulting in increased gait variability. Hall et al. studied nine different cognitive tasks with self-selected pace walking and found that most were significantly correlated to walking while performing a cognitive task except spatial ability and recall memory.[24] Spatial ability was measured using various patterns on cubes and asking subjects to identify the correct pattern from multiple choices. Recall memory was tested using digit span sequencing. The subject listened to a sequence of letters and recalled the letters back in the order given. It should be noted that these tasks were performed with the Walk While Talk Task at self-selected speeds. Research to date strongly suggests that not all cognitive demands employed during dual-task testing are going to have the same gait decrement. This is exactly what Belghali and colleagues suggest.[76] The type of secondary cognitive task will influence the dual-task related gait variability. This assumption is further supported as Bloem et al. suggests that gait is affected in the same manner regardless of the type of walking associated cognitive task under dual-task conditions.[77] Cognitive tasks such as verbal fluency and mental tracking are interlinked with those of gait control and demands of the tasks may increase interference and disturb gait.[70] In contrast, research has shown that cognitive tasks involving external interfering factors such as reaction time share some lower networks with gait control and results in less interference.[70]

There is a paucity of research comparing the dual-task cost of cognitive demands that use different neural pathways. Recent advances in technology are allowing investigations of the neural correlates involved in performance changes between single and dual-task gait research.[78] Mobile EEG and fMRI studies are providing insight into ecologically valid cognitive dual-tasks. fMRI research has identified the neural pathways including the neuroanatomy activated with during cognitive functions that include math, reading, picture naming and response naming.[78-85] Understanding how specific cognitive demands affect gait will help to interpret research findings with greater clarity.[6] Numerous studies suggest future research needs to be directed toward finding secondary cognitive tasks that interfere with gait and challenge underlying neuropathological processes. Research is also needed to investigate how to improve the ecological validity of those cognitive demands because serial subtraction and word generation tasks lack real-life demands.[70]

This study thus addresses several important issues relevant to balance and mobility in older adults. First, what is the impact of the type of cognitive load on gait variability? Researchers are currently exploring the benefits of using dual-task interventions to treat gait and balance disorders in individuals with a history of falling.[7,70,71] Researchers have compared single-task and dual-task balance exercise programs and found that the dual-task exercise group which included counting backward, naming objects and days of the week did better than their counterparts who did balance only activity.[86] Researching, understanding, and developing the most effective type of cognitive dual-task is a vital part of the advancement of physical therapy tools for intervention, and this study provides information that addresses this area.

Defining and contrasting different dual-task conditions may have implications for designing fall risk assessments.[87] There are floor effects for a number of the cognitive tests such as reciting alternate letters of the alphabet or counting backward by 7's. If an individual has a mild cognitive impairment, they may not be able to perform this task due to limited short-term memory. They may, however, be able to visually recognize and verbalize a picture, listen to and then answer a question or read a sign. The results of this study may assist clinicians with alternative modes of dual cognitive task testing that are appropriate for older adults with a range of cognitive abilities.

1.11 Practical Application of Findings

Objective assessment of dual-task gait variability during common activities of daily living provides real life balance and mobility data that can be used to evaluate fall risk as well as potential areas for intervention/training. Analysis of that data may provide a new gait marker. Earlier detection of increased gait variability with one or more of the cognitive tasks in this study could be used in screening methods. Early and effective screening for falls has the potential to improve the quality of life for community-dwelling elderly adults. Exploratory research in this area is needed to compare the impact of specific cognitive interference with the known gait changes expected in this population.

1.12 Summary

In summary, there is an abundance of research that has investigated the effects of cognitive dual-tasks on gait variability. Many of the types of cognitive tasks are selected because they have been used previously and are known to interfere with gait.

Unfortunately, these are not cognitive tasks that occur in normal daily activities. There is a paucity of knowledge regarding the impact of reading, listening, and recognizing symbols under a dual-task TUG condition. Exploration of real-life distractions can provide ecologically valid insight to improve clinicians' and researchers' understanding of attention processing. This results from this study may assist in the understanding of the relationships of cognitive tasks and mobility.

1.13 Definition of Terms

Attention- The mental process of concentrating effort on a stimulus or mental event.

Cognition- The collection of mental processes and activities used in perceiving, remembering, thinking, problem-solving, and understanding, as well as the act of using those processes.

Dual-Task- The concurrent performance of two tasks that can be performed independently, measured separately, and have distinct goals

Self-Efficacy- The belief in one's capabilities to organize and execute the course of action required to produce given attainment.

Divided Attention- The ability to focus on several relevant stimuli simultaneously.

Motor Control- The ability to regulate or direct the mechanisms essential to movement.

Degrees of Freedom- The number of axes that movements can be performed about a single joint.

Synergy- The functional coupling of groups of muscles that are constrained to act together as a unit.

Stride- The distance between successive contacts of the same foot.

Stride Time- Time for one stride to occur as in the time between successive heel strikes.

Stance- The period of time the foot is in contact with the floor.

Stance Time- The time between a heel-strike and toe-off point on the same foot.

Swing- The period of time the foot is not in contact with the floor.

Swing Time- The time between toe-off point and the heel strike point of the same foot.

Spatial- Measurements related to distance

Temporal- Measurements related to time.

Gait Variability- Changes in gait parameters from one stride to the next.

Balance- The ability to maintain a position and the center of mass within the limits of stability or base of support.

Balance confidence- The confidence in one's ability to maintain balance and remain steady

CHAPTER II

Review of the Literature

2.0 Introduction

The purpose of this chapter is to review the literature regarding attention, including definitions and the impact that divided attention has on gait and balance. This chapter discusses the historical overview of the various concepts regarding dual-task methodology, gait measurement, and variability. This chapter will also synthesize background information regarding the TUG, ABC scale, instrumentation, and development of the protocols for each test.

2.1 Attention

Attention is one of the most complicated topics in cognitive psychology.[1] To better understand the challenges of defining attention, one needs to look into the various fields in which it has been studied. The earliest discussions of attention came from the field of philosophy in the 16th century. Philosophers developed the first concept of attention laying the groundwork for the 19th century when William James published "The Principles of Psychology".[88] James dedicated an entire chapter to attention, providing an exhaustive discussion of philosophical and psychological perceptions on the subject. James's work can still be found referenced in research today and is a testament to his contributions to the subject. The evolution of understanding and defining attention continues through the eyes of experimental psychology, cognitive psychology, and cognitive neuroscience.

The constructs and meanings of attention are not without controversy. It is important to understand some of the fundamental theories and meanings of attention when undertaking research that investigates the mental process. James's definition of attention has been widely quoted,

> "It is the taking possession by the mind, in clear, vivid form, of one of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness, are of its essence. It implies withdrawal from some things in order to deal effectively with others and is a condition which has a real opposite in the confused, dazed, scatterbrained state in which the French call distraction." pages 403-404

There are multiple definitions and assumptions regarding attention. Shumway-Cook defined attention as the ability to focus on a specific stimulus without being distracted.[2] A broader definition is that attention can be thought of as the mental process of concentrating effort on a stimulus or mental event. This mental process occurs within cognition.[1] This latter definition emphasizes the importance of understanding the relationship between attention and cognition.

Cognition is the collection of mental processes and activities used in perceiving, remembering, thinking, problem-solving, and understanding, as well as the act of using those processes.[1,89] Cognition can be viewed as an umbrella term for all higher mental processes and can be broken down into functional divisions.[1,90] Lezak (2012) defined the divisions as: 1) receptive functions involve the ability to select, acquire, classify, and integrate information; 2) memory and learning refer to information storage and retrieval; 3) thinking concerns the mental organization and reorganization of information, and 4) expressive functions are the means through which information is communicated or acted upon.[90] Lezak acknowledges that it is important to realize the functional divisions of cognition are, to some extent, conceptual constructs to help clinicians understand the complexities of normal and impaired brains.[90]

Kahneman (1973) is credited with developing a model for the capacity of attention.[2,91] He assumed that attention has a single reservoir of finite processing capacity.[2] This capacity has the flexibility to be divided between two concurrent tasks.[2] The assumption that attention has finite capacity is not controversial and can be found readily in psychology and physical therapy literature.[1,2,4,90] Abernethy gives Kahneman credit for coining the term “structural interference,” considered to occur when two concurrent tasks compete for the same specific processes.[29] The model of attention described by Kahneman as structural interference is the essence of the dual-task decrement.[29] Dual-task methodology is discussed later in this chapter.

McDowd[4] attempted to reign in the unwieldly and thorny concepts of attention by creating a taxonomy to aid in categorizing the different types. (Figure 2.0) Physical therapists and other clinicians have benefitted from the effort and integrated this into clinical practice, research, and professional journals. Different task contexts have been proposed, including selective attention, divided attention, sustained attention, and switching attention.[4]

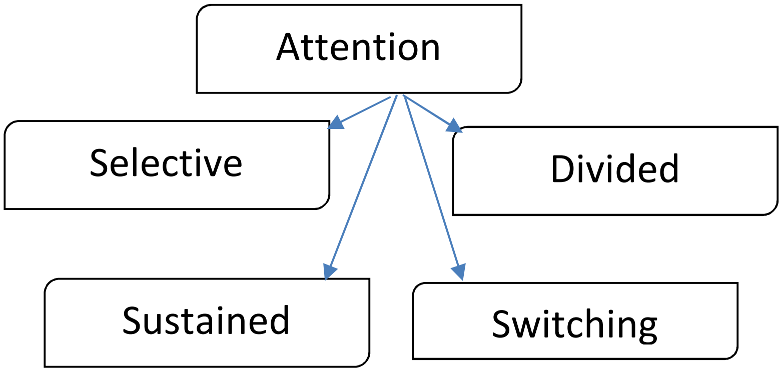


Figure 2.0 Different types of attention as described by McDowd[4].

Selective attention in a research context involves presenting tasks to subjects with multiple stimuli, some are relevant, and other stimuli should be ignored.[4] Divided attention requires individuals to process more than one source at a time or perform more than one task at a time.[4] There are many tasks in daily living that can be performed at the same time with ease. Some examples include driving a car and listening to the radio and walking while talking on a cell phone. When the difficulty of the task approaches the limit of capacity, the result is a decline in performance of one or both tasks.[29] Sustained attention is maintaining attention over a long period without distraction.[4] In contrast, attention switching is used in a task that requires a person to alternate their focus from one task to another. For example, when driving a car, attention can switch from left to right while monitoring traffic in nearby lanes. It is thus similar to divided attention, but the focus of attention must switch from one or multiple sources of information to another.[4] The remainder of this discussion on attention focuses on the interaction of attention, the central nervous system (CNS), and production of purposeful movement.

2.2 Motor Control and Attention

Motor control research has been defined as an area of natural science, exploring how the central nervous system produces purposeful, coordinated movements in its interaction with the body, the task, and with the environment.[92] Motor control is the ability to regulate or direct the mechanisms essential to movement.[2] The production of movement in an individual requires multiple systems to interact.[2] Cognitive processes are essential for motor control, and among those processes are attention, motivation, and emotion.[2] The exact mechanism of the physical and physiological processes to achieve movement has been elusive. The absence of understanding this process requires theories to be formulated and tested to prove or disprove the accuracy. These theories are dynamic and have evolved as science, technology, and knowledge of anatomy have advanced. In 2010, Latash described the body as a very complex system, maybe too complex to be studied with currently available physical tools; suggesting many crucial variables are not directly measurable or even identifiable.[92] This statement acknowledges that no one theory can explain the complexities of the CNS and purposeful movement.

Among the important principles in systems theory of motor control is variability. Human movement variability is described as the normal variations that occur in motor performance across multiple repetitions of a task over time.[93] Harbourne and Stergiou emphasize that variability reflects multiple options for movement, improving flexibility and adaptations that accommodate to changing conditions.[94] It is important to recognize that too little or too much variability can lead to injury or impaired motor performance.[2] It is equally important to consider that some variability is natural and not necessarily the result of an error.

2.3 Attention and Dual Tasks

Up until 1988, most dual-task research existed in the field of cognitive psychology. Published works on dual-task methodology extended into motor behavior and skilled performance for athletes.[29] This research used the dual-task paradigm and linked it to theories of attention. Specifically, the divided attention discussed earlier and defined by McDowd. Dual-task methodology requires subjects to perform two tasks simultaneously. There is a basic task, termed the primary task for which performance is measured.[29] Then a secondary task is performed together with the primary task and performance is measured again.[29] Inferences are made regarding the changes that occur with the addition of the secondary task.[29] Abernethy recognized the laboratory struggles to produce real life conditions, and researchers challenged to control variables in field conditions, but it is possible for confounding variables to exist in both settings.[29]

Five key issues should be considered when using dual-task techniques in research.[29] First, the primary task should be a task that individuals perform in a "real world" activity. The selection of the secondary task should be based on two things: whether the secondary task is continuous or discrete, and intentionally creates, or avoids effects of structural interference, i.e., dual-task effect.[29] The second issue to consider is the problem of temporal uncertainty in the presentation and timing of the secondary task. The third consideration is the problem of attention switching between the primary and the secondary tasks.[29] This problem may be resolved with instructions to have subjects perform both tasks to the best of their ability. The fourth issue to consider is achieving appropriate secondary task controls. The researcher should define what conditions need to be satisfied with the secondary task. The fifth and final problem is determining the actual locus of attentional demands.[29] Abernethy notes in some situations there are limits in the interpretation of data as to the precision with fluctuations in attentional demand.[29]

2.4 Gait Measurement and Variability

Human movement in the form of walking has been the subject of interest to researchers for decades. Interest has varied from the simplest measurement of distance and speed to the complex study of a biomechanical and neuro-cognitive model of motor control.

The basic description for walking consists of a step, which is the advancement of one foot in front of the other. The length of a step is the distance between successive contact points on opposite feet.[95] A stride is the distance between successive contacts of the same foot.[95] There are additional phases of the step cycle called stance and swing phases.[2] The stance phase is the time when the foot is in contact with the floor. The swing phase is when the foot is not in contact with the floor, defined from just after toe off to just before heel strike.[96] Spatial gait parameters include step and stride length and step width. Temporal gait measures include step and stride time, double and single support time, and swing and stance time. Gait speed is typically measured in feet/sec or meters/sec.

Yogev-Seligman et al. (2008) noted that until recently, gait was considered to be mainly an automated motor task, requiring minimal higher-level cognitive input.[28] This position became untenable due to the increasing volume of research demonstrating a relationship between executive function and walking speed.[97-99] Current literature identifies gait as an extraordinarily complex behavior.[2,100]

The landmark study related to gait and gait variability included the observation that some frail elderly patients stop walking when carrying on a conversation.[22] The authors theorized that because walking demands attention, the activity stopped to free up the attention needed for talking.[22] The authors found individuals that stopped to talk had slower overall mobility, were more dependent on assistance for activities of daily living, less safe with gait, and had an increase in the number of falls after a six month observation period.[22]

Walking speed is a simple assessment that provides insight into underlying physiological and psychometric processes.[101-105] Walking speed: The Sixth Vital Sign, published in 2009, demonstrated that gait speed has validity for predicting falls, frailty, disability, and hospitalization.[101,102]

Gait is regulated through the CNS by the interaction of input from the motor cortex, cerebellum, and the basil ganglia.[106] It is also dependent on feedback from visual, vestibular, and proprioceptive sensors to produce repetitive coordinated movement.[106,107] Hausdorf noted that when the systems regulating gait are disturbed by either disease processes or attention, impairment of movement control leads to increased stride to stride fluctuations.[9] The fluctuations are also known as gait variability. In healthy young adults, stride-to-stride fluctuations demonstrate a relatively small coefficient of variation for many gait parameters.[10,108,109] Before 2005, gait variability was considered to represent instrumentation or physiological noise.[110] Research investigations of gait variability analyzed stride intervals or step-to-step variations in healthy subjects under constant conditions and found that even though the stride interval is fairly constant about the mean, it fluctuates in an apparently unpredictable manner.[111] The literature review of gait variability reflected a very limited theoretical framework to guide researchers studying gait variability parameters.[110]

In the last decade, considerable effort has been spent to understand the implications of gait variability. Impairments of sensory, motor, or cognitive processes result in gait instability. The term gait instability, gait variability, gait disturbances, and gait disorders are known to be interchangeable in the relevant literature.[112] Brach discouraged the use of the generic term of variable gait and encouraged researchers and clinicians to identify the specific gait variable.[113] Balasubramanian defined gait variability in spatiotemporal characteristics between steps.[16] Variability has been reported in at least eleven different spatiotemporal parameters, but the questions remain which are the most relevant in mobility.[16,113]

Research overwhelmingly demonstrates the presence of age-related spatiotemporal gait variability. Gait variability has been extensively researched in an aging population of community dwelling elderly.[8,9,16,18,19,37,38,40,110,114] Assessment of gait variability is a useful tool and provides quantifiable measurements that are altered in the presence of aging, disease, and frailty.[9] Variability measurements are also sensitive to neuromotor function and can provide fall risk predictions.[9,115,116]

2.5 Development of the Timed Up and Go

A number of screening tests have been developed over the years to identify persons with gait and or balance deficits. Constraints of laboratory testing prompted clinicians to develop mobility tests that could easily be used in clinical settings. The Get up and Go test was developed by Mathias et al. to provide clinicians with a quick screening tool for balance for an elderly population.[117] The test required subjects to stand up from a chair, walked 3 meters, turned around, and returned to the chair and sit down. The test was subjectively scored with a 1-normal to 5-severely abnormal, on an ordinal scale. Scores three and above were considered at an increased risk for falls. Some may consider the study as a simple subjective test, but that couldn't be farther from the truth. This very early study measured sway path, gait speed, and gait parameters such as stride width, step length, stance time, and stepping frequency during the up and go. Those parameters were then correlated to the subjective 1-5 scoring. The subjectivity limited the interrater reliability in the middle scores 2-4 because the scoring system lacked guidelines and was less precise.[42]

The Get up and Go test assesses multiple components of balance and mobility. Getting up from a chair to a standing position is one of the most commonly performed transfers. This movement requires both strength and technique. The Get up and Go test consists of basic everyday movements, but the components are very complex.

Podsiadlo and Richardson removed the subjective components of the test and added a timed component and resulted in significantly improved reliability between raters.[42] The name changed to the "Timed Up and Go" (TUG) and is well known to rehabilitation professionals. The TUG test is also referred to as the Timed Get Up and Go (TGUG).[118] The score of the test is the time it takes to complete the task in seconds. The TUG as a screening tool includes both transitional movements (standing up and sitting down) and gait assessment (walking and turning). It is also a quick, easy test and can be performed in any setting. Initial research studies demonstrated that the TUG test has the ability to distinguish between elderly who have balance problems from those who do not. Research has also concluded the TUG test was objective, practical, and a reliable measure of physical mobility.[42]

2.6 Timed Up-and-Go with a Motor Demand Added

During the 1990s, researchers continued to investigate the impact of attention on balance, posture, walking, and the effects of concurrent attention demanding tasks.[119-121] Lundin-Olsen et al. investigated the effect of a second task on balance and gait while performing the TUG.[31] They were the first researchers to add a manual task of carrying a glass of water concurrently with the TUG.[31] This test became known as the TUG(man). They surmised that the TUG was suitable for the modification because it is simple, quick, and consists of routine movements used every day.[31] The second task, carrying a tumbler with water, was selected for several reasons.[31] The upper limb would alter the postural system and interaction between posture and manipulation of the object creates additional challenges. The posture adjustment would occur first, and then the movement would occur.[31] They chose a glass with water only 5cm from the top of the cup to ensure subjects had to pay attention so the water would not spill.[31] The assumption was that this would require increased attention demands while performing the TUG. Statistical analyses were performed by measuring the TUGmanual then subtracting the TUG and determining the TUGdiff. It was determined that a time difference of 4.5 seconds or longer between the TUGman and the TUG had a higher risk of falling than those with a shorter time difference.

2.7 Timed Up-and-Go with a Cognitive Demand Added

Shumway-Cook and Woolacott were the first to add a cognitive demand to the TUG test.[3] They had previously investigated the effects of single and dual-task cognitive demands on attention and the effect on postural stability in standing.[72] Recent research suggested that investigating balance under dual-task conditions resulted in a more sensitive indicator of balance problems than testing under a single-task.[22,72,119] Subjects performed three different TUG tests, including TUGcog, TUGman, and a standard TUG test. The TUGcog was performed by counting backwards by 3's, starting at a random number between 20 and 200. The TUGman was performed with a full glass of water. Researchers hypothesized that the TUGcog would be more specific and the most sensitive. The results did not demonstrate significant differences between the three separate tests.

Since 2000 there have been numerous versions of the TUG. The original TUG instructed the subject to walk at a comfortable and safe pace. Some of the methodology changes include walking as fast as possible,[122] measuring the time it takes to complete each component,[118] and adding cognitive and motor tasks.[31,51]

Several studies have investigated different types of cognitive demands with the TUG on older adults with and without Parkinson's disease.[52] Walking while talking was not shown to be a good predictor of falls in patients with Parkinson's disease.[123] Campbell et al. set out to determine the impact of talking while performing the TUG test.[124] The study investigated nine individuals with Parkinson's disease and ten adults without Parkinson's. All subjects performed all three conditions. The single task TUG and the TUGlow – a low cognitive demanding task was repeating "Where is the child?" over and over during the performance of the TUG task. The last condition was a TUGhigh- Repeating the days of the week in reverse order during the performance of the TUG task.[52] The order of the tasks was randomized to avoid the influence of fatigue.

The results indicated a significant effect of the two cognitive tasks for subjects with Parkinson's disease. However, for healthy adults, the additional cognitive tasks revealed no significant effect on TUG performance measured by time and number of steps. The authors noted both groups had errors in saying the days of the week backwards while performing the test. The results of this study conflicted previous research that demonstrated a sixteen percent increase in time to perform a serial subtraction cognitive task. The authors indicated that the differences found in the studies could be the result of the different secondary task used.

2.8 Timed Up-and-Go Limitations

The TUG test is an important mobility test used by physical therapists, but it does have limitations. Numerous studies that have demonstrated that the use of time measurement only is not sensitive to falls risk across populations.[69,125-127] One study investigated gait speed with frail elderly subjects and discovered that some of the subjects walked faster than was considered safe.[128] The study included subjects from both geriatric care settings and psychiatric wards. The study included subjects with dementia, Alzheimer's disease, vascular dementia, fronto-temporal dementia, and Lewy-body dementia. Gait velocity was measured on a Gaitrite walkway and allowed subjects to use walking aids. The dual-task consisted of counting backwards by one's from forty-five. The counting rate and errors were not recorded. The study concluded that some patients with dementia might lack insight, and frontal lobe disinhibition resulted in walking at a faster speed and increased the risk of falling.[128] Walking faster than is safe would lower the TUG time. Other studies have shown the association to slower walking speeds, which increases the TUG time, in frail elderly with a history of falls.[51]

The TUG test poses four different subtasks: walking, turning, sit-to-stand, and stand-to-sit.[129] Performance of the subtasks can vary due to different movement strategies. The 180-degree turn could be performed in several ways. A subject could pivot on the mark on the floor or take multiple steps in a curve-like turn, and some researchers placed a square mark on the floor at the end of the walk, so subjects knew to turn around within the square.[118] Movement strategy may vary slightly from one trial to another.

Medley and Thompson investigated the influence of the use of assistive devices on the TUG test.[130,131] The use of a cane increased the amount of time by two seconds for men and four seconds for women when compared to the same test without a cane. The authors reasoned that adding a cane increased the complexity of the task. Increased time is likely needed to perform an accurate motor sequence, and subjects may have slowed down to maintain their accuracy with the use of an assistive device and gait pattern.[130] For this reason, assistive devices were not used in the present study.

The use of the TUG test has limitations when only the time to complete the task is considered as the quality of movement, gait variability, and dynamic performance are completely ignored. An example would be when a subject makes multiple attempts to get up or may require additional cues to continue. Performance goes unnoticed, and the focus tends to be on whether there has been a significant change to the time.[132]

Multiple researchers have suggested that the distance of three meters is too limited for data collection.[118,132,133] The early phase of gait is acceleration followed by only a short distance of steady state gait, then deceleration occurs before the turn. Researchers interested in the middle gait parameters can record more data when the distance of the walk is lengthened. Longer distances are beneficial when working with subjects with Parkinson's disease. The Expanded Timed Get Up and Go (ETGUG) was proposed to extend the walking path from 3 to 10 meters, but left the remaining TUG task components unchanged.[118] The longer walkway was used to allow for better delineation of the component phases of the test.[118] Tape was placed on the floor at two and eight meters. A stopwatch was used to record this time, in addition, to stand up time, turn time and turn and sit time. The results of the longer test (expanded timed up and go or ETUG) yielded similar findings to the Timed Get Up and Go test when comparing young, healthy subjects to elderly groups.[118] For this reason, the standard three meter distance was used in this study.

The type of chair used can introduce variability in the results. The chair type and height have been shown to influence the score of the TUG test.[134,135] A low chair may require subjects to scoot forward and push themselves up, requiring more time. Some studies have intentionally chosen lower height chairs (41cm) and no arms to increase the difficulty of the task. This can make it difficult to compare the times of those studies to ones that follow a standard methodology. A chair without arm rests may make it more difficult for some subjects to stand up. Siggeirsdottir et al. investigated the effect of four different chairs on TUG scores. The recommendations are to use a chair with armrests and a seating height between 44-47 cm.[134] It is also important to avoid using a chair with a backrest that leans backwards.[134] Utilizing the same chair for the study can limit the introduction of another variable.

Many TUG studies have selected their subjects from different patient populations that included senior living, community dwelling, and mixed samples.[51] Researchers have suggested that measurement scales and thresholds might demonstrate validity in one population, but may not be directly transferrable to other populations of elderly adults.[46]

Footwear can affect the outcome measures for walking tests. Researchers studied the effects of footwear on the measurement of the TUG.[136] Footwear was not standardized in original work as instructions stated "regular footwear" should be worn.[42] The research concluded that the type of footwear does affect measurements of the TUG.[136] Gait speeds were slower when subjects wore dress shoes than when wearing walking shoes.[136] Several considerations should be made regarding footwear. Shoes should be worn during test performance. The recommendations for this study included that shoes should not be new or have heels and should be comfortable.

2.9 Timed Up-and-Go Methodology Variations

The importance of examining the predictive ability of assessment tools to identify fallers continues to motivate research involving the TUG test. Falling poses serious health risks to the elderly, and the detection of increased risk for falling is needed to implement preventative measures. Systematic reviews of the TUG began to uncover inconsistent findings. At least four studies have reported the prognostic ability of the standard TUG test to predict falls was limited.[45,46,50,137] Reviewers cited numerous statistical and methodological inconsistencies that should be considered when designing research trials.[46]

The methodology of the TUG is important to control for validity and reliability. The following are some of the methodological variations seen in past research: population, use of an assistive device or not,[51,138] location in which the study is performed,[139] chair height and whether or not the chair has arms,[140] walking around a cone instead of a piece of tape on the floor, and the use of longer distances.[141] One investigation reported that linoleum was the best surface to perform the TUG test.[136]

In 2000, researchers investigated the TUG for predicting the probability of falls in elderly community dwelling adults.[51] They recorded whether or not individuals used an assistive device and the type of assistive device. They did not exclude the individuals using assistive devices from the study. The category of fallers had three individuals that did not use an assistive device, seven that used a cane, and five that used a walker. The physical characteristics of the individuals are too different to be grouped together and make conclusions about the test unreliable. The amount of attention required to use the different assistive devices with ambulation should be taken into consideration. The demands of using the device with sequencing placement and turning would add time and possibly confound the results. The current investigation used community dwelling adults not dependent on assistive devices to eliminate the confounding variables that have an impact on the measurement. Other research has indicated that quiet settings, comfortable footwear, and the type of floor should be considered.

The speed with which the TUG is performed appears to have several critical influences, and the choice of walking speed directions may be influenced by the population or disability. The initial instructions for the TUG were to "walk at a comfortable and safe pace."[42,117] There have been numerous studies that are using a fast pace TUG instruction.[122,142-146] The instructions for the faster pace are to "move as quickly and safely as possible."[142-144] McGough et al. in 2011 studied executive function, gait speed, and the TUG test. The subjects underwent neuropsychological tests of executive function that included a Trail-making test and Stroop test. Subjects also performed a standard TUG and a fast pace TUG. Only the fast pace TUG results were addressed in the discussion.[144] The results of the testing indicate that physical performance speed was associated with executive function after adjusting for age, sex, and age related factors in sedentary adults with mild cognitive impairment.[144] Other researchers investigated more than 2000 community dwelling older adults. Subjects were recruited through multistage random sampling.[147] A longitudinal study in Malaysia performed from 2012 and concluded in 2015 used a standard speed TUG, but had subjects walk around a cone for the turnaround point. The results demonstrated that the TUG performance was moderated by MCI (Mild Cognitive Impairment) x gender and MCI x age. In the discussion for future studies, they suggested a TUG with a fast pace speed is warranted as speed further challenges cognitive ability.[147]

The TUG has been shown to be able to discriminate between faller and non-faller groups.[51,148] Researchers suggest a need for a better test to predict falls in a healthy, higher functioning elderly population.[137] The TUG, TUGcog with serial subtraction by three's, and a manual task TUGman with water in a glass 1cm from the top were investigated. The objective was to determine if any of these tasks demonstrated prediction of fall risk in community dwelling elderly.[137] The findings revealed that the TUGcog was a better predictor for recognizing a higher fall risk in older community dwelling individuals.[137] The researchers concluded further investigations are needed in different patient populations and examining different types of dual-tasks. Investigating dual-tasks with varying difficulties could influence the prognostic ability of the TUG dual-task. This research project focused on investigating this area of interest.

2.10 Difference of Single and Dual-Task TUG

Research has increasingly demonstrated that the time difference in performing the TUG in single and dual-task conditions is a valid predictor of frailty and falls.[27,31,149] Research investigating the factors contributing to dual-task performance demonstrated interesting correlations in the performance of TUG, TUGman, TUGcog (serial subtraction of 3's).[53] Results suggested that the performance of the TUGcog relied primarily on the cognitive abilities of the participants. Univariate correlation analysis revealed that the Mini Mental State Exam (MMSE) score and Stroop word score were the primary independent factors correlating to TUGcog performance.[53] The findings suggest that focused attention is uniquely influencing TUGcog performance. The authors noted limitations and small sample sizes but supported the increasingly accepted concept that the time to perform a TUGcog uniquely measures interference between mobility and attention. Researchers use the dual-task paradigm to assess the interaction between gait and cognition.[28,150,151]

2.11 Development of Body-Worn Sensors

Gait analysis research can be divided into three main stages reflecting the type of instrumentation: photoelectric video recording devices, force plates, and wearable sensors.[152]

Veltink et al. (1996) envisioned that rehabilitation would be enhanced if activities of daily living could be evaluated in the home environment based on kinematic measurements using sensors mounted on the body.[153] His team successfully mounted small uniaxial accelerometers to the sternum and upper thigh to detect basic movement in healthy subjects.[153] They were able to identify dynamic and static activities and appears to be the earliest investigation of functional movement assessment using accelerometers. An accelerometer measures acceleration in meters/second^2.

Sensors have been used to measure spatiotemporal parameters of gait.[154] Equipment consisted of a powerful microcontroller, miniature sensors, high capacity memory, small batteries, and three piezoelectric gyroscopes.[154] A gyroscope measures angular velocity in degrees/second and is placed on each tibia and another on the right thigh. The sensors provided stride to stride parameters and concluded that results were similar to laboratory research findings using force plate measurements.[154]

The earliest work using sensors related to components of the TUG test started with investigations of sit to stand and stand to sit transitions.[155,156] One study investigated the use of kinematic sensors with sit to stand tasks improving previous sampling rates from 100 samples per second to 1000 samples per second.[156] These early wearable devices were validated with optoelectric systems for motion analysis.[156]

Body-worn sensors have also been used to quantify movement phases of the TUG.[157] The measurement system consisted of two sensor units and could each measure three axes of acceleration.[157] Various phases of the TUG were identified and included total time, standing up, walking forward, turn one, return walk, turn two, and sitting down.[157]

2.12 Instrumented Timed Up and Go (iTUG)

Narayanan et al. investigated the feasibility of using waist-mounted triaxial accelerometers to measure parameters of a set of controlled movements.[158] The set of movements included the TUG test, an alternate step test, and sit to stand with five repetitions. This work used an accelerometer capable of streaming the data using a

Bluetooth signal to a laptop nearby.[158] A model for falls risk was then developed to compare each of the three sets of movements. The unique feature of this study allowed subjects to participate in the research in their homes unsupervised.[158] The use of only one accelerometer limited the certainty of some of the extracted parameters, and the final fall risk model calculation did not include information from the TUG. The early use of body-worn sensors only utilized timed measurements of the different components of the TUG.[158] Measurements included start to stand, stand to three meters, turn time, time to chair, and time when seated.[158] The value of the timed sub-components of the TUG appeared to have more value in the model than a single recording time. The added value suggests the need for spatial gait parameters to be added to data collection and considered in fall risk.

One of the first research studies using an instrumented TUG selected subjects with early stages of Parkinson's disease (PD) and compared them to age-matched control of healthy adults.[133] Subjects were fitted with five inertial sensors. Two sensors were attached to the tibia, two were attached to the dorsum of the wrist, and one was attached to the chest on the sternum. Subjects were asked to perform three trials of the standard TUG and three trials of a modified seven-meter iTUG. The reasoning given for extending the distance from three meters to seven was to be able to record more total steps.

The iTUG was able to measure arm swing symmetry and velocity, temporal and spatial gait parameters, stride length, and velocity variability. It was also able to provide postural transition parameters such as peak and average turning velocities, as well as, peak and average sit to stand velocities. A total of twenty-two parameters were measured, and the results showed that ten of the parameters were significantly different between the PD group and control subjects. The standard TUG was not sensitive to the specific gait and turning deficits seen in subjects with early PD.

Subsequent researchers investigated the test-retest reliability of the iTUG measures.[132] The test also used the modified seven-meter TUG distance. The results demonstrated spatial and temporal measurements were reliable when taken an hour apart. The iTUG was able to measure significant differences between the early PD subject and the control. The authors also noted that they introduced a new mathematical model for quantifying turning during gait with their research. Quantifying the forces during a turn has been problematic in the past because of noise, the variability of speed, trunk angle, and the axis of rotation. The authors note the iTUG provides a new subset of gait measurement and has the potential applications to be a sensitive test for detecting early stages of mobility disability.[132]

Subsequent researchers have used the QTUG test to investigate a cohort of community dwelling elderly.[20] Of the 349 community-dwelling adult subjects, there were 207 self-reported fallers and 147 non-fallers. SHIMMER Kinematic sensors were placed on the mid-point of each tibia. Each sensor contained a triaxial accelerometer and an addon gyroscope board. The sensors provided wireless streaming data. Each was programmed to sample at 102.4 Hz with custom firmware. Subjects were video-taped simultaneously with kinematic data collection while performing the standard TUG to ensure the validity of the TUG tests.

This investigation focused on standard temporal gait parameters and then calculated the coefficient of variation for each to provide a measure of gait variability.[20]

The mean, minimum, and maximum angular velocity measurements during the swing and turn were derived from the data and considered novel at the time.[20] They used logistical regression to test the predictive properties of each parameter derived from the QTUG and a Berg Balance Scale (BBS) to provide a comparison for a different standard measure of fall risk. The results revealed that only temporal gait parameters showed a significant difference between fallers and non-fallers with variability in the right vs. left lower extremity stance time in fallers. There were 44 spatial parameters measured, and 29 were shown to provide significant discrimination between fallers and non-fallers.[20] These findings are consistent with other research suggesting that spatial parameters of gait variability are strongly linked to future falls.[20,113,114,159] A stated weakness of the study is that retrospective evaluation of fall risk analysis tends to overestimate the ability of the TUG to predict falls risk.[127] Based on this research, the QTUG tool developed by Greene and Kinesis Technology was used in the study.

Greene and Kinesis Technology built into the software a Screening Assessment for Falls Evaluation (SAFE). It is a fall screening tool consisting of 8 questions with a 0-8 scoring. There is a paucity of research using this tool, but it screens physical and medical conditions that can influence fall history such as foot and vision problems, history of falls, and if the answer is yes, records how many falls. The SAFE score was used, and comparisons were made with gait parameters and balance confidence.

2.13 Summary of the Instrumented Timed Up and Go (iTUG)

The limitations of the standard TUG include the focus on time while ignoring any deficiencies of movement, and only measuring total time to perform the complex set of movements without separating the performance of each part.[132] The use of accelerometers in measuring performance provides insight into the complex tasks of the TUG and physiological variations that researchers are seeking. These studies show the benefit of the technological evolution of the iTUG and its ability to increase the sensitivity of the TUG to identify pathological variability.

2.14 Balance

Balance is a multidimensional concept, referring to the ability of a person not to fall as well as the ability to maintain a position within the limits of stability or base of support.[160,161] Postural control is the act of maintaining, achieving, or restoring a state of balance during any posture or activity.[162] Shumway-Cook and Woollcott note that postural control for stability and orientation require complex interactions between the musculoskeletal system and neural systems.[2]

2.15 Falls

Falls are often defined as inadvertently coming to rest on the ground, floor, or other lower level, excluding intentional change in position to rest in furniture, wall, or other objects.[163] In 2013, one out of every seven Americans were 65 or older, and falls were the leading cause of fatal and non-fatal injuries in that age group.[164,165] In 2012, more than 24,000 adults age 65 and over died from falls with an average cost of $25,487 for health care.[166] During the same year, there were 3.2 million non-fatal falls from the same age group costing our healthcare systems 30.3 billion dollars.[166] The impact goes far beyond costs for the elderly. A fall can result in loss of independence, reduction in quality of life, and restricted activity.[167] Falls have been found to be associated with psychological difficulties that can impact the quality of life.[168] Falls also can create a loss of confidence in older adults' mobility.[169] Fear-induced activity avoidance can lead to physical decline resulting in decreased muscle strength and postural control.[170] Restrictions on physical and social activities can lead to further decline, increasing the risk of falling, social isolations, and depression.[171,172]

Fear of falling was initially thought to be a consequence of experiencing a fall and then suffering from a psychological "post-fall syndrome."[173] Later research revealed that fear of falling could be found among the elderly who had not experienced a fall.[174]

The simplest approach to measuring fear of falling is just to ask someone. Single-item falls-related psychological measures are often used for screening purposes. The most common used single-item question is, "Are you afraid of falling?"[175] Howland et al. researched "How afraid are you that you will fall in the coming year?" and Lachman et al. "How afraid are you that you will fall and hurt yourself in the next year?"[176,177] Single-item measures are widely used but because the fear of falling is a multidimensional construct made up of partially independent components, operationalizing it into a single item can result in underestimating the incidence of fear of falling.[169,176,177]

The most common and best-studied falls-related psychological issues are fear of falling, falls-related self-efficacy, and balance confidence. Tinetti et al. argued that fear of falling could be conceptualized as low perceived self-efficacy about balance.[175,178] Tinetti developed the Falls Efficacy Scale (FES) to assess the perceived efficacy or confidence of avoiding a fall during activities of daily living (ADL's).[175] The scale includes ten activities that are rated on a ten point scale. The FES has been extensively studied and found to be sensitive to change,[179] and scores can predict falls and decline in functional ability.[171,180] Several authors believe the fear of falling and self-efficacy (considered balance confidence) are correlated but are distinct dimensions or constructs.[170,181] The argument summarizes that self-efficacy refers to beliefs about one's ability, and low self-efficacy can, but does not always lead to fear.

Investigations of self-efficacy, balance confidence, and fear of falling found that correlations of falls efficacy with fear of falling measures were considerably lower than balance confidence and falls efficacy.[182] Research recommends that the FES should be used to measure specific confidence in the ability to perform activities without falling.[181] Criticisms of the FES include the simple non-specific daily activities, use of a ten-point numerical response scale, and failure to accurately measure falls-related concerns in active, higher functioning older adults.[60,177,183]

The main function of fear is to provide a signal of danger, motivation, and to trigger appropriate adaptive responses.[184] Researchers have postulated that the physiological reaction consists of the flight or fight response of the autonomic system.[170,185] In response, a person may slow gait speed in order to prevent a fall or feel safer. Hughes et al. investigated the term "falls related psychological concerns" (FrPC)[186], which includes the following four distinct constructs, fear of falling, falls-related self-efficacy, balance confidence, and outcome expectancy. The relationships between the constructs are complex and psychological factors such as anxiety, depression, quality of life, activity avoidance or restriction, activity levels, and coping are also associated with the constructs.[186]

2.16 Activity-specific Balance Confidence (ABC) Scale

Balance confidence is the confidence in one's ability to maintain balance and remain steady.[60] Powell and Meyers created the Activity-specific Balance Confidence

Scale (ABC) scale to improve upon the weaknesses found in the FES scale.[60] The development of the tool included input from physical and occupational therapists as well as patients receiving therapy.[60] The ABC scale created situation-specific questionnaire items of self-rated difficulty and confidence. The ABC scale increased the 0-10 rating of the FES scale with 0% being no confidence and 100% being full confidence in being able to perform the activity without losing balance.[60]

There are 16 items developed along a spectrum of difficulty. Examples include standing on toes or standing on a chair to reach item high up, walking inside and outside the home, and walking on icy surfaces.[60] The broader range of activities makes it more sensitive to a loss of confidence in higher functioning adults.[187] The ABC scale was found to have strong test-retest reliability (r=.92).[60] The ABC has been used in studies as an outcome measure[62] and to assess the association between balance confidence and fall risk.[188,189] The ABC has also been validated in numerous patient populations.[62,190,191]

Researchers studied the association between fear of falling and functional decline using a sample size of 1560 elderly women in Korea. Researchers concluded that fear of falling itself has a significant role in functional decline even after adjusting for risk factors of activity avoidance, decreased social interaction, and symptoms of depression.[192]

Several factors make the ABC test helpful in this research study. It is sensitive to mobility levels and variations of activity level within the study population. Because of the relationship between balance confidence and fear of falling, this research used the ABC scale to determine if there is a relationship to gait speed, changes in speed, and variability of gait.

2.17 Selected Cognitive Tasks

The selected cognitive tasks for this study include auditory response naming, visual confrontation naming, reading, and serial subtraction. There are surprisingly few neuropsychological battery tests for learned skills such as reading, writing, spelling, and arithmetic.[90]

The use of serial subtraction is prevalent in studies involving dual-task methodology. Serial subtraction is the mental task of counting backwards from a given number and subtracting the same number each time. The sequential subtracting tasks of serial 3's and 7's are used to assess attention and working memory and were first used in 1942.[193] The findings suggest that school age populations had a linear correlation between SST errors and mental age.[193] Researchers have studied SST with adults and found that only 42% could make all correct calculations by subtracting seven from one hundred with no time limit.[194] The mini-mental status examination uses the serial subtract test, as does the mental status exam (MSE). Over the years, there has been a lack of consensus as to what SST measures. Some research postulates that SST is a general measure of concentration; however, significant concerns have been raised about construct validity.[195]

Functional Magnetic Resonance Imaging (fMRI) has been used to create detailed images of blood flow to detect the neuroanatomical processes and structures involved during SST.[196] Subsequent research demonstrated a large degree of individual variation with neural activation outside of the areas mentioned.[197] All subjects demonstrated bilateral premotor, posterior parietal, and prefrontal cortex activation during SST. The studies demonstrate that brain areas involved with basic numerical computation also engage some cognitive processes not directly associated with arithmetic.[198] The researchers concluded that the exact cognitive demands taxed with SST remain unclear and can vary from one individual to another. SST is less than an ideal choice for a cognitive demand, but because of the extent that it has been used in the past, the results were used for comparisons to the new cognitive tasks introduced in this research.

Researchers have recommended that SST no longer be used in standard mental status examinations.[199] In a study of the serial seven procedures with subjects of varying ages and diagnoses, researchers found that performance was heavily influenced by basic arithmetic skills.[200] The variables impacting performance on the SST include emotional, attentional factors, gender, and social expectations for math achievement.[196] The results suggest that for some subjects who excel in math skills, the cognitive demands of the test would be lower. For subjects that struggle or dislike math, the cognitive task would be more difficult. Another problematic issue of serial 7's requires regrouping (borrowing) calculations.[201] For 100-7, it is simple subtraction, but for 93-7, it requires borrowing. Thus the basic math subtraction is easier than the multi-digit arithmetic.[201] This could confound the gait variability results as there would no way to separate the cause of resultant changes.

2.18 Naming

Naming is the process of providing a verbal label to an object or concept and is a fundamental aspect of language.[202-204] The two pathways identified are auditory and visual based naming. Auditory Response Naming approach (ARN), also called definition naming, can be used as a test to determine word finding difficulties.[205] A descriptive clue is given, such as "a device used for taking pictures," and individuals should respond with an answer, "camera."[206] Visual Confrontation Naming (VCN) involves looking at a picture and asking individuals to identify and verbalize the name.[205] Visual based word retrieval involves multiple processing stages.[203] A visual process must encode the shape and details of the object. Then the encoded information must be matched to memory. The stored memory may be searched in regards to functional and associative properties (semantic description) and name (phonological description).[203] Figure 2.1 illustrates the different lobes of the brain and their function. Despite this complexity, the brain is efficient in the task of putting a name to an object.[203]

The current research used both ARN and VCN to reproduce the cognitive dual-task components of activities of daily living. Evidence has demonstrated the two tasks follow distinct neural networks. Cortical stimulation studies suggest that VCN tends to be more localized in the posterior temporal cortex and ARN is more localized in the anterior temporal lobe with a greater overall distribution of sites.[207,208] In a study of 144 people with memory complaints, researchers found that ARN but not VCN correlated to three measures of executive functioning involving working memory or cognitive flexibility.[205] The authors also believed that ARN places greater demands on self-initiated search strategies within the semantic system because there was no visual cue.[205] This dissociation between ARN and VCN has been confirmed by fMRI.[209] Importantly, they appear to rely on different neural networks to successfully retrieve names.

Several clinical tools can be used to assess naming tasks. The Boston Naming Test (BNT)[210] and Visual Naming subtest of the Boston Diagnostic Aphasia Examination (BDAE)[211] are two of the more common assessment tools. Naming questions were selected from the BDAE test because of standard questions using common everyday words.

In contrast, VCN in the form of picture naming is widely used in the assessment of perceptual and cognitive processing. Researchers developed and published a standardized set of 260 pictures.[212] They developed characteristics of pictorial representations of concrete nouns. It was developed to help with the different drawings of similar objects that could confound the process under investigation.[212] The authors standardized their stimuli in four variables relevant to cognitive processing: familiarity, image agreement, name agreement, and visual complexity. These are factors that can result in participants' ability to name the items.[213] Concerns about the ecological validity of the line drawings have led to new and improved images. Subsequent researchers developed 360 high quality color images that provide a more realistic representation of real-life objects. Many of the original drawings were matched with photographic quality images. It is important to select images that have been previously used in research to reduce the chance of introducing a confounding variable. All the images should be consistent with the ease or difficulty of identifying. Images for the VCN were selected based on item descriptions and ease of naming for discrimination.

2.19 Reading

Clinical research that involved reading as part of an experiment needs to take into consideration how individuals read print. Reading print is something that is learned in school and is common to most languages. The relationship between spoken and written language has been written as follows: “Writing is not a language, but merely a way of recording language by visible marks.”[214] Written language is acquired and must be taught. Similarly, reading has been described as difficult, but speaking has been described as easy.[215] The task of reading and word recognition in mature readers for a long time was believed to be automated.[216] Subsequent studies began to disagree with the concept of automaticity, suggesting that attention is a critical, overlooked component, integral for translating print into speech, necessary for achieving fluent reading.[217] Reading verbally out loud from print is currently recognized as a very complex task, and an in-depth literature review is beyond the scope of this current study. The general concept and accepted theory for reading are as follows: an experienced reader converts print to speech by taking what they are reading and referencing it to a mental dictionary and then the words are read aloud by accessing the word's lexical entry from the printed form and retrieving from that entry the word's pronounciation.[218]

The neural systems for reading have been identified using fMRI and encompass three anatomical structures.[215] Looking at the surface of the left hemisphere, Broca's area is included in the anterior system in the region of the inferior frontal gyrus. This area is believed to serve articulation and word analysis. There are two posterior systems. One is in the parietotemporal regions, which is believed to serve word analysis. The second is in the occipitotemporal region, which is believed to serve for the rapid, automatic, fluent identification of words.[215] Figure 2.1 provides an illustration of the brain anatomy corresponding to reading and articulation.

Another very important component in reading not yet discussed is the influence of cognitive control of the eyes during print reading. This study required subjects to read while they are walking. There is very limited research to date that has focused on the impact of reading while walking. It is important to understand how reading while moving will likely create a greater challenge than reading while stationary. In reading, eye movements are influenced by a variety of linguistic factors.[219]

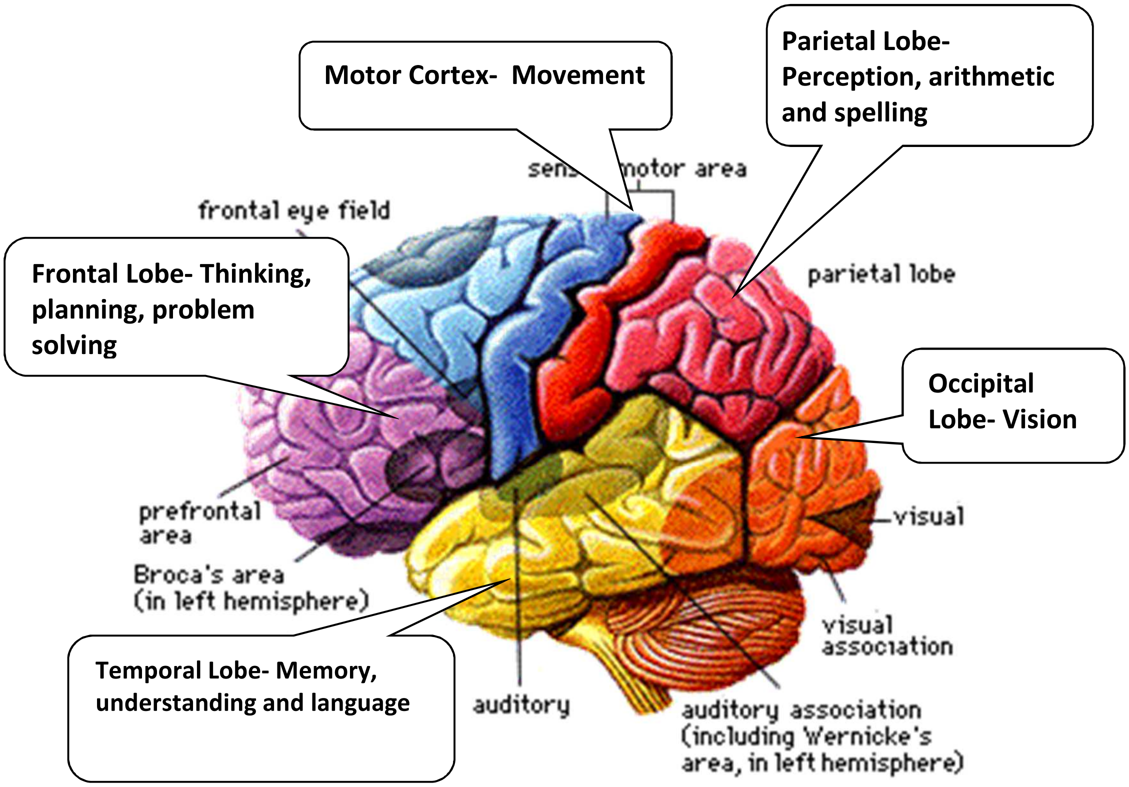


Figure 2.1- Illustration of different lobes of the brain and their function.[220] Modified with text box labels and reprinted with permission. Licensed by “CC by 2.0”.

When reading aloud, the eyes tend to fixate slightly longer than when reading silently, and the eyes are capable of reading faster than the voice.[221] Research has shown that with reading out loud, the eyes appear to hold in space to prevent getting too far ahead of the voice.[222] Eye movements and information processing are critical in several of the tasks in this study. The eyes are continually adjusting when reading or looking at an object. Between the eye movements, called saccades, the eyes remain still but very briefly for about 200-300ms.[221] The eyes move about four times a second when reading.[219] Researchers have found that information is suppressed when the saccades occur.[223] Even though vision still occurs during the saccade, information is not processed.[224] If the brain did not suppress the information, it would result in blurring input. Eye movements during reading indicate that there is evidence of on-line processing.[221] If there is a word or phrase that was not understood, the saccades will move the eyes back, sometimes referred to as first and second-pass reading.[221] Therefore, the current study sought common and easy to read material in an attempt to reduce the need for second pass reading by participants in this study.

Eyesight needs to be normal or corrected for participants to identify objects and read a sign. Participants were able to read at their own pace but needed to complete the tasks before reaching the turnaround point of the TUG.

Research utilizing fMRI studies of skilled adult readers in four different languages discovered a common brain signature of neural pathways for reading.[225] It has been suggested that reading is not just a mere recognition of orthographic forms but a function of the linguistic system, including an interaction between hemispheres.[226,227] The findings show that bilateral striate and extrastriate regions of the brain were significantly active only for print, and anterior aspects of the superior gyrus (STG) were active only for speech.[225] There was an extensive convergence of printed and spoken language processing in many areas, including both cortical (bilateral inferior frontal gyrus (IFG), bilateral middle temporal gyrus (MTG) to STG, left inferior parietal lobule (IPL) and subcortical regions associated with both phonological and semantic processing.[225]

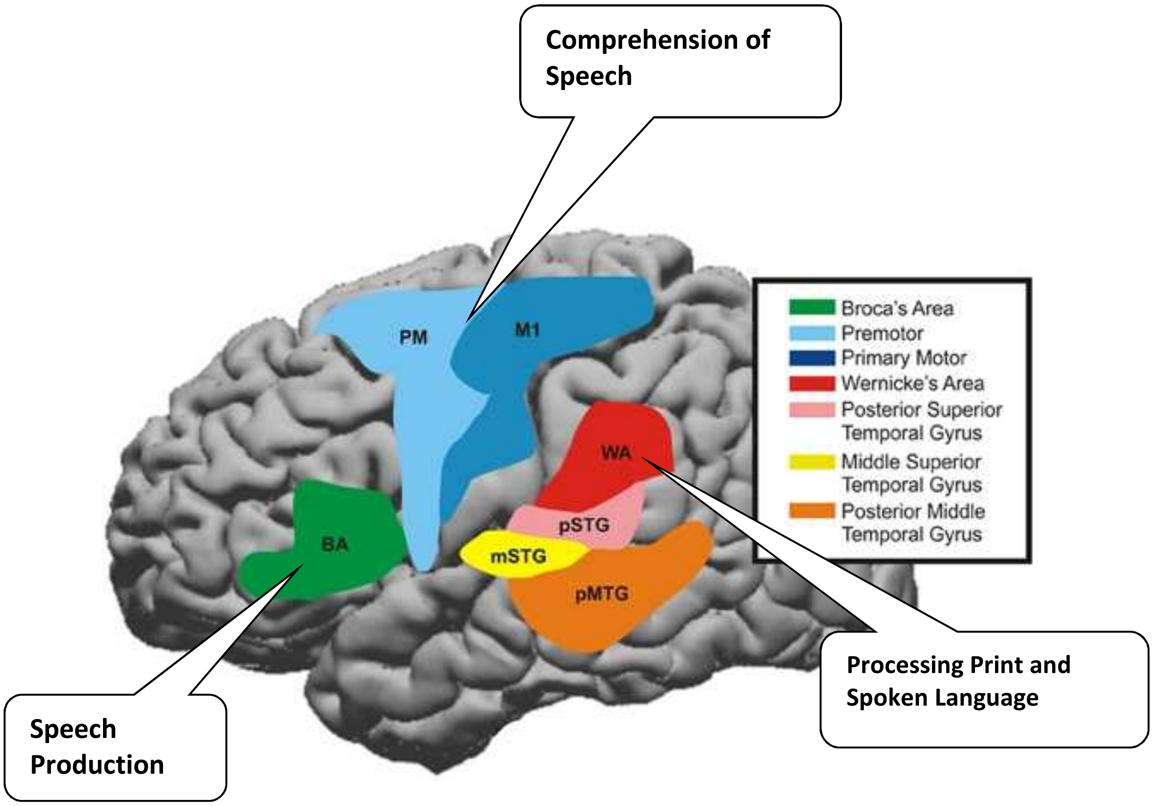


Figure 2.2- Illustration of brain areas involved in speech processing.[228] Modified with text box labels and reprinted with permission. Licensed by "CC by 2.0".

2.20 Summary of Cognitive Test Selection

The complexities and descriptions of the neural pathways of each of the cognitive tasks selected in this study are different. Understanding the underlying neural processing involved may help to understand measurable changes under dual-task conditions. The changes in gait variability when performing a dual-task activity have been extensively researched, but many questions remain unanswered. Does the interference or dual-task cost of different neural pathways cause the same changes in gait variability? My current study examines this question by comparing the dual-task influence on gait parameters for each of the cognitive conditions.

CHAPTER III

Methodology

3.0 Introduction

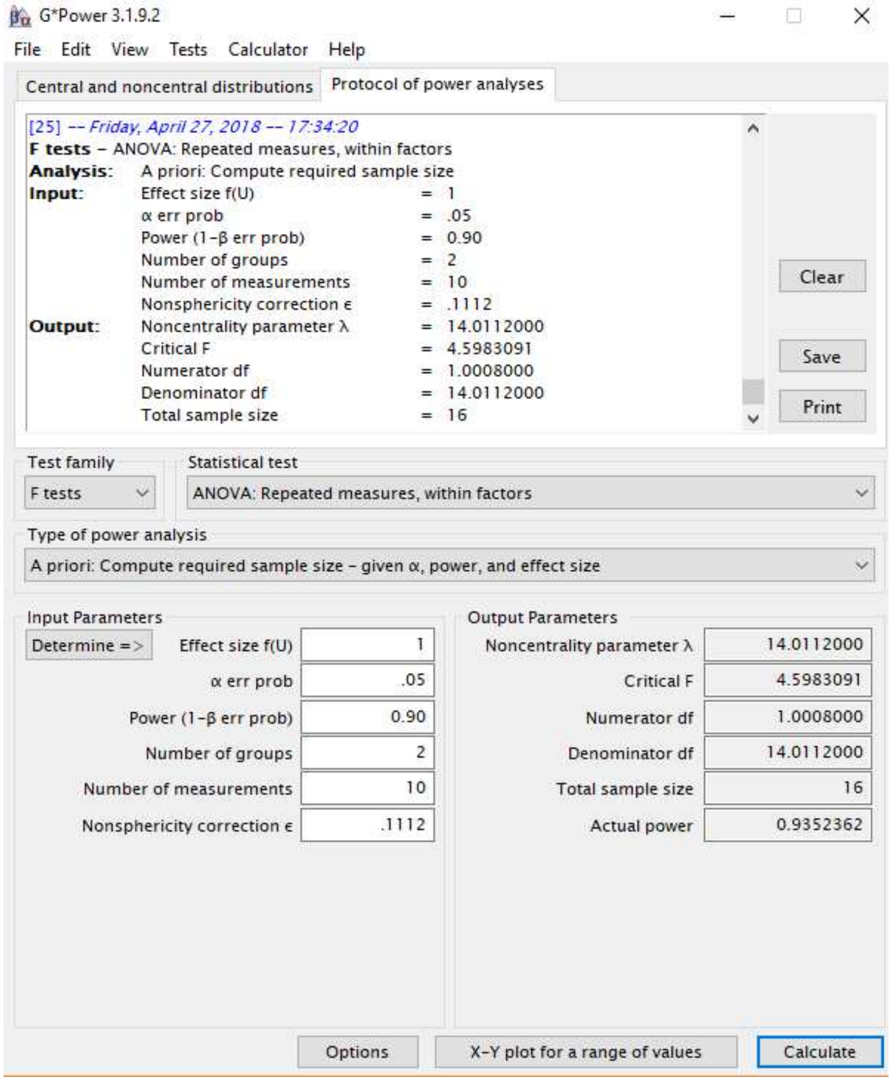
This chapter contains the methodology, including power analysis and recruitment strategy for participants. It lists and discusses the specific procedures that were used to obtain data and corresponding data analysis. Approval from the Nova Southeastern University Institutional Review Board was obtained on November 26th, 2018. Data collection began on December 10th and was completed on March 8th, 2019.

3.1 Power Analysis

The selection of the within-subject design is advantageous in helping reduce errors associated with individual differences. Each subject's performance of the standard TUG served as their own controls. Figure 3.2 is from http://www.gpower.hhu.de/ and is a free software program that was used to compute effect sizes, and graphically displays the results of power analyses. Permission was obtained to use the display information.

Power analysis was used for the research question, "Is there a difference between the four dual-task effects for the TUGvisual, TUGauditory, TUGreading, and TUGsubtract?" There were two trials of each condition and the mean ±S. D. was used for the calculations. Dual-task cost was measured as the TUG standard mean variable-TUG condition mean variable divided by the TUG standard mean variable times 100.[65,229]

Smith et al. recently reported that the pooled effect of dual-task on gait speed showed a mean decrement of 0.18m/s in walk speed between single and dual-taskconditions.[230] The pooled standard deviations were 0.13m/s for single-task and 0.16m/s for the dual-task condition. The effect size was calculated by taking the difference between the control and experimental group (in this case, a dual-task) and dividing it by the standard deviation. This provided for a large effect size of 1. A similar large effect size was anticipated here for power calculation for the primary question. The Linear mixed model test analysis with two planned comparisons was anticipated and performed. A post-hoc Dunnett's test with adjusted $\alpha = 0.05$ and $\beta = 0.10$ were chosen. Dunnett's adjusted critical value of $P < 0.025$ for pairwise comparisons.



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[25] -- Friday, April 27, 2018 -- 17:34:20
F tests - ANOVA: Repeated measures, within factors
Analysis:   A priori: Compute required sample size
Input:      Effect size f(U)                 =  1
            α err prob                       =  .05
            Power (1-β err prob)             =  0.90
            Number of groups                 =  2
            Number of measurements           =  10
            Nonsphericity correction ε       =  .1112
Output:     Noncentrality parameter λ        =  14.0112000
            Critical F                       =  4.5983091
            Numerator df                     =  1.0008000
            Denominator df                   =  14.0112000
            Total sample size                =  16
```

Test family: F tests

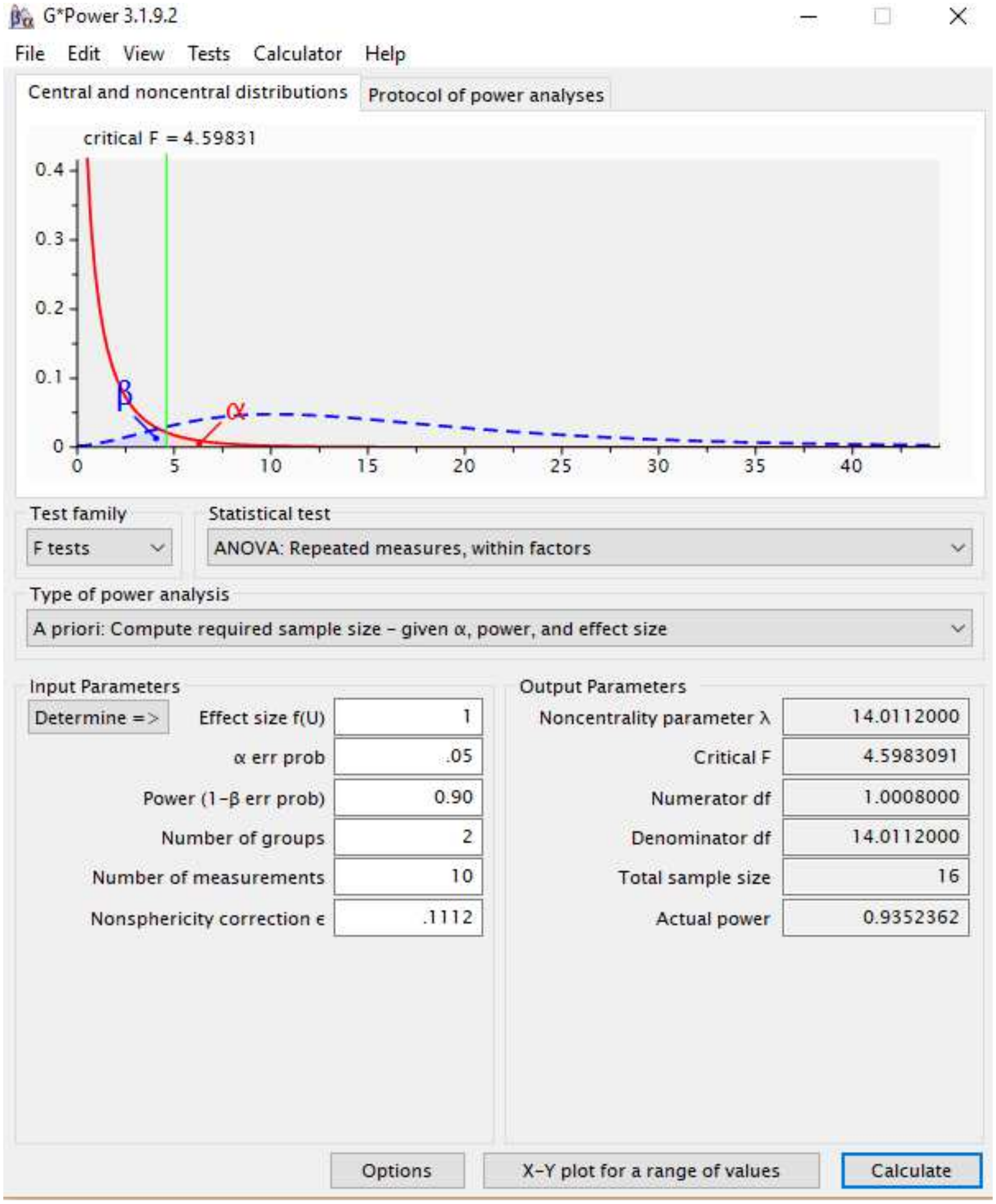
Statistical test: ANOVA: Repeated measures, within factors

Type of power analysis: A priori: Compute required sample size – given α, power, and effect size

Input Parameters		Output Parameters	
Effect size f(U)	1	Noncentrality parameter λ	14.0112000
α err prob	.05	Critical F	4.5983091
Power (1-β err prob)	0.90	Numerator df	1.0008000
Number of groups	2	Denominator df	14.0112000
Number of measurements	10	Total sample size	16
Nonsphericity correction ε	.1112	Actual power	0.9352362

Figure 3.0 Calculation of power analysis

df- p = degrees of freedom of the predictors divided by n= denomination of (observations) degrees of freedom. So, df = p/n. Number of parameters measured 20+ / number of observations (trials) 2. The number of groups = 2.



Test family: F tests

Statistical test: ANOVA: Repeated measures, within factors

Type of power analysis: A priori: Compute required sample size – given α, power, and effect size

Input Parameters

Effect size f(U)	1
α err prob	.05
Power (1–β err prob)	0.90
Number of groups	2
Number of measurements	10
Nonsphericity correction ϵ	.1112

Output Parameters

Noncentrality parameter λ	14.0112000
Critical F	4.5983091
Numerator df	1.0008000
Denominator df	14.0112000
Total sample size	16
Actual power	0.9352362

Figure 3.1 Central and Noncentral Distribution

Results indicated that a sample size of 16 would be sufficient to demonstrate if there is a difference in the pairwise comparison of the means of the effects between four conditions and the standard TUG. Data analysis planning assumed that there was a normal distribution of the data.

There are three covariates: BMI, number of medications, and highest education level achieved. A sample size of 40 allowed correlation of temporal and spatial mean changes and the participants who have reported a fall and ABC scale scores, assuming a normal distribution. Correlation test analysis to measure the strength of the association between changes in spatiotemporal gait means for several parameters was performed with an $\alpha = 0.05$ and $\beta = .10$. The goal was to recruit 44 participants to allow for any missing data.

3.2 Inclusion and Exclusion Criteria

Community-dwelling older adults were recruited for this study. Inclusion criteria included: 1) Able to stand and ambulate without an assistive device, 2) Having no orthopedic surgical procedure in previous six weeks, 3) Living independently in the community, 4) Demonstrate corrected vision and read words from a computer screen 3 meters away, 5) Demonstrate sufficient hearing to carry on a conversation and follow directions, 6) Able to provide informed consent, 7) Able to follow 3-step commands, 8) No history of falls in past 30 days. Falls were defined to include only those episodes of imbalance in the past 30 days that resulted in a fall to the ground. This definition did not include those who experienced some degree of instability and loss of balance during functional or recreational activities.

Exclusion criteria included: 1) History of a stroke with residual hemiplegia, 2) A neurological diagnosis such as Parkinson’s or Multiple Sclerosis 3) Any psychological or memory impairment that would interfere with following directions, 4) Asymmetrical gait due to hypertonicity or orthopedic impairment.

3.3 Participants

Forty-four healthy community dwelling adults age 65 or older were recruited for this research with the assistance of community hospitals, doctor's offices, adult fitness classes, and an integrated health center. Flyers were disseminated in the hospital and local physical therapy departments. Participants were recruited by a sample of convenience, and by word of mouth or snowball sampling in social retirement settings. Potential participants were provided with a summary of the purpose of the research, exclusion criteria, and what would be required to participate in this study. Participation was completely voluntary. Appointment times were scheduled after it was determined that the subject was appropriate to participate in the research. The research required only one visit and took about thirty-five minutes to complete the paperwork and data collection. Participants met with the principle investigator who explained and reviewed the protocols and consent forms. Each subject was asked to sign the General Informed Consent and the Nova Southeastern University Authorization for the use and disclosure of Protected Health Information in Research. Copies of the consent forms were provided to participants (Appendix H).

3.4 Research Design and Methods

This was a single cohort descriptive study with randomized testing designs of community dwelling adults age 65 and older. Data was collected using a screening form with eleven questions that included exclusion criteria, history of falls, and any medical conditions that could affect the ability to participate in the study. Demographic information obtained included age, height, weight, and number of prescription medications taken. Additional information collected included the highest level of education completed. Participants were asked eight specific questions in the Screening

Assessment for Falls Evaluation (Appendix E), and after instructions completed the Activities-specific Balance Confidence (ABC) Scale, (Appendix D). Participants were then oriented to the two QTUG shimmer kinematic sensors. Data collection utilized the QTUG software version 2.2.1, Samsung Galaxy Tablet Model SM-T230. The tablet contained a microSD card for data storage. Two SHIMMER kinematic sensors, Model Shimmer2R w/450mAH Battery. Each sensor contained a triaxial accelerometer and an addon triaxial gyroscope sampling at 102.4 Hz. The sensors were oriented to capture movement about the anatomical mediolateral axis. Data was streamed wirelessly to the Bluetooth handheld Samsung Galaxy Tablet. Bluetooth radio transmission in the sensors was at a 2.4Ghz and a frequency range of 2400MHz-2483.5MHz. Bluetooth radio receiver bandwidth was 75kHz with a frequency range of 2400MHz-2483.5MHz.

The Shimmer sensors are designated R in (Red) for the Right leg, L in (Blue) for the Left leg. They also have UP to designate the orientation when placing them on the participants. The sensors can be turned on and off using a restart button. Both sensors had rechargeable batteries and came with a charging dock. Procedures were to keep the sensors charged before use.

A triaxial sensor was placed in the middle of each tibia and held in place with Tubigrip. The sensors were paired using a Bluetooth signal with the Samsung Galaxy Tablet in the QTUG software. Participants were assigned a four-digit identifying number, and information such as height, weight, gender, and SAFE answers were entered into the tablet. Participants were given verbal instructions before each trial, as outlined in 3.7. Each subject was allowed a practice TUG test. The participants were asked if ready to begin, and upon receiving an affirmative, the data collection began. Two baseline TUG tests were performed first for each subject, followed by the randomized order of the four different cognitive dual-tasks conditions. (Figure 3.1)

3.5 Specific Procedures and Testing Set Up

TUG set up consisted of - a Staple's Esler Mesh Guest Chair with arms. The chair seat height measured 17.8 inches and 45.2 cm. A tape measure was used to determine the walking distance of three meters. Two short pieces of tape were placed on the floor in front of the legs of the chair, and a thirty-inch long piece of yellow tape was placed on the floor three meters to designate the place where the subject was to turnaround (Figure 3.1). This same procedure for set up was used for each testing session and at each location where testing was done. A twenty-five inch Sanyo television was placed on the top of a thrity-four inch tall plastic Quartet AV cart facing the subject. The cart was located four meters from the chair and measured one meter from the turn around point for each trial. A Dell computer containing the Powerpoint slide files was placed on the same cart, but facing away from the subject, and attached to the television via an HDMI cable. Microsoft Powerpoint programs were developed for each block presentation. Each block program had slides that provided on screen prompts for the sequence of steps task. The investigator operated a Logitech R400 Laser Presentation Remote to advance the slides. The PowerPoint slides ensured that the proper order of tests was followed, and the participant was aware of which test was coming up next. Additional slides included alternate questions, pictures, reading tasks, and another subtraction starting point in case of error or malfunction of the instruments.

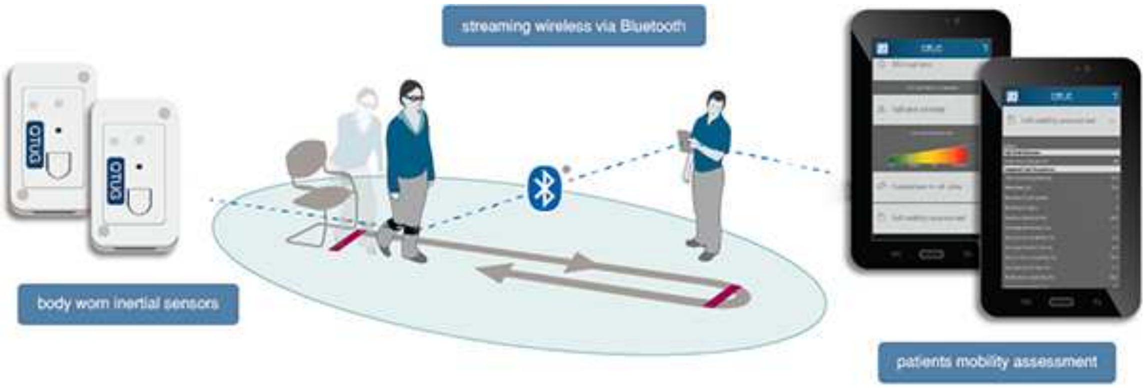


Figure 3.2 QTUG sensors, TUG walkway, and Bluetooth Tablet. Kinesis Technologies R

The timing was measured using the QTUG tablet. Timing started at the word "GO," and the start button on the tablet was pressed simultaneously. The stop button was pressed when the subject's buttocks came in contact with the chair.

Participants were allowed to perform a practice TUG. After the practice test, data recording commenced. Each subject was asked to perform 2 trials for each task. An error in recording prevented one subject's data from being recorded, and the principle investigator chose not to require the subject to perform a third trial. Participants were then given the other conditions in a randomized order to reduce the likelihood of fatigue impacting gait variability.

Definition of terms used for data collection labels.

TUGcontrol - Standard TUG test with no modification.

TUGvisual -TUG test performed with a dual-task of visual confrontation naming.

TUGaudible -TUG test performed with a dual-task of an auditory response naming.

TUGread - TUG test performed with reading a grocery sale sentence.

TUGsubtract - TUG test performed with serial subtraction of 3's

3.6 Visual Confrontation Naming Procedure- TUGvisual

The photographic quality picture stimuli for Visual Confrontation Naming (VCN) were used for the TUGvisual cognitive condition. The principle investigator stated ready, set, go to start the trial. The start button was pressed simultaneously with the word go. Shortly after the subject stood up, the investigator used the Logitech remote to advance the blank screen to show three pictures. The participants were asked to name the objects or animals in the pictures before they reached the turn-around point, and correct responses were recorded. See Appendix A for the sets of visual confrontation naming photos utilized.

3.7 Auditory Response Naming Procedure- TUGauditory

The auditory response naming questions were obtained from the Boston Naming Test. The naming test questions were designed to stimulate a one-word response. TUGaudible task asked participants to answer a question while performing the TUG. Participants were given the same ready, set, Go instructions, and shortly after standing, the principle investigator asked one of the questions listed in Appendix B. Participants were asked to respond before reaching the turnaround point.

3.8 Reading Cognitive Demand Procedure- TUGreading

The reading material represented real-life signage seen in a grocery store (Appendix C). Reading while walking recreates real-world dual-task activity, and each sentence contained 32-33 type characters. The sentence was displayed on the television screen shortly after they stood up to start the TUG test. Participants were asked to attempt to read the entire line before they reached the turn-around point. The advertising sentences for reading were displayed at 80-font size in the PowerPoint slide presentation on the computer.

3.9 Serial Subtraction by 3's- TUGsubtract

The TUGsubtract task asked participants to count backwards outloud while performing the TUG. Participants were given the same ready, set, Go instructions, and shortly after standing, they were instructed to begin counting backward from 100 by 3's. The second trial asked participants to count backwards by 3's starting at 70 and then 50 if a third trial was necessary.

3.10 Verbal Instructions for each Task

The following instructions were read to the subject prior to the first of the two trials for each task. After the first trial, each subject was instructed that the same task would be repeated and after a short rest was asked if ready to continue.

Tug Control	"My commands for this test are going to be ready-set-Go. Your starting position in the chair should include sitting with your back resting on the backrest of the chair. Hands should be resting on top of your legs. On the word "Go," I want you to stand up from the chair. You may use the arms of the chair to stand up or sit down. Once you are up, I want you to move as quickly as you feel safe and comfortable until you pass the mark on the floor with both feet. Turn around and walk back to the chair. I will stop the clock when your seat reaches the chair."
TUGvisual	"This test will require you to do a second task while you perform the same TUG. The starting position is the same. Your back should be against the chair and hands on your legs. I will say "ready, set, GO" You will stand up and shortly after standing the television in front of you will display three pictures. You will look at the pictures of three objects or animals and identify them by name outloud. You should attempt to do both tasks as quickly but safely as possible. Attempt to identify the pictures before you reach the turn. The test ends when you are back in the chair seated."
TUGaudible	"This test will require you to do a second task while you perform the same TUG. The starting position is the same. Your back should be against the chair and hands on your legs. I will say "ready, set, GO" You will stand up and shortly after standing, I will read a descriptive clue such as a device used for taking pictures, and you will verbally respond with an answer. You should attempt to do both tasks as quickly but safely as possible. Attempt to verbalize

	the answer before you reach the turn. The test ends when you are back in the chair seated.”
TUGreading	“This test will require you to do a second task while you perform the same TUG. The starting position is the same. Your back should be against the chair and hands on your legs. I will say “ready, set, GO” You will stand up and shortly after standing the television in front of you will display several words and a dollar amount. It will be similar to what you would see in a grocery store. You will read all the items out loud. You should attempt to do both tasks as quickly but safely as possible. Attempt to read the sign before you reach the turn. The test ends when you are back in the chair seated.”
TUGsubtract	“This test will require you to do a second task while you perform the same TUG. The starting position is the same. Your back should be against the chair and hands on your legs. I will say “ready, set, GO” You will stand up and shortly after standing, I would like you to begin counting backwards from 100 by 3’s. You should attempt to do both tasks as quickly but safely as possible. You only have to count backwards until you reach the turn. You do not have to count the entire way. The test ends when you are back in the chair seated.”

Table 3.0 Instructions given prior to performing the first trial of each condition.

Each test was performed two times due to the potential influence of fatigue. Participants were allowed to rest between tasks if needed. When an error in timing, asking a question or visualizing the computer screen occured, the test was repeated to ensure accuracy for all ten tasks.

3.11 Administration of the ABC Scale

The test was self-administered and was printed using 14-font size. Participants completed the questionnaire prior to performing the TUG testing.

Instructions to Participants: For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale from 0% to 100%. If you do not currently do the activity in question, try, and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as if you were using these supports. If you have any questions about answering any of these items, please ask the administrator. See appendix D for the ABC scale questionnaire.

3.12 Data Collection

Participants were allowed to perform one practice TUG test to become familiar with the process. Data was not collected for the first performance.

The QTUG software is capable of recording up to a 6-digit patient ID. Each participant was assigned an ID number at enrollment. This assigned number became the identifier for all the data intake. The QTUG software recorded the age, height, and weight as well as gender. TUG results were stored and retrieved from an SQLite database and exported in an Excel format for statistical analysis.

QTUG software contained a Screening Assessment for Falls Evaluation (SAFE) consisting of eight questions. The eight questions can be found in Appendix E and were answered with a yes or no response.

The triaxial sensors were placed on the anterior mid-shins of the participants. Bluetooth connections to the tablet were obtained. The tablet displayed the cyclic movement as the participant stood up and started to walk. The cyclic motion confirmed that data collection had occurred.

3.13 Randomized Block Design

The 44 participants were randomly assigned one of four Group blocks (Figure 3.1). The order of recriutment determined which of the four groups they were assigned. Each of the four groups was assigned a random order of the four cognitive TUG conditions and contained an equal number of participants. The two baseline TUG control tests were performed first for each subject to reduce any effect of fatigue. This block design was to control for fatigue or influence of repetition that could have occurred with ten trials (Table 3.1).

Table 3.1

Group Summary of Block Design

Order of Tasks	1	2	3	4	5
Group 1 (N=11)	TUG Control	TUG Read	TUG Audible	TUG Subtract	TUG Visual
Group 2 (N=11)	TUG Control	TUG Audible	TUG Read	TUG Visual	TUG Subtract
Group 3 (N=11)	TUG Control	TUG Visual	TUG Subtract	TUG Read	TUG Audible
Group 4 (N=11)	TUG Control	TUG Subtract	TUG Visual	TUG Audible	TUG Read

3.14 Dependent and Independent Variables

Dependent variables of interest included multiple temporal-spatial variables. Temporal gait parameters included time taken to stand (s), number of gait cycles, number of steps, cadence (steps/min), walk time (s), average swing time (s) and average stance time (s), Variable parameters included swing time variability percentage, stance time variability percentage, stride time variability percentage, step time variability percentage, single support variability percentage, double support variability percentage. Spatial gait parameters included average stride velocity (cm/s), stride velocity variability, average stride length (cm), stride length variability percentage. Turn parameters included pre-turn time (s), post-turn time (s), the ratio of pre-turn to post-turn, the time taken to actually turn (s), number of strides in the turn, turn steps to time ratio.

Definitions of Dependent Variables

- Time taken to stand (s) - Time from ‘Go’ to first heel strike or toe-off point
- Number of gait cycles - Number of gait cycles in total test
- Number of steps - Number of steps in the TUG test
- Cadence (steps/min) - Average number of steps taken per minute during the test
- Walk time (s) Time from first to last heel-strike or toe-off point - time patient actually spends in locomotion during TUG test
- Average swing time (s) - Average swing time over all gait cycles, averaged across both legs, swing time is defined as the time between a toe-off point and the heel strike point on the same foot.
- Average stance time (s) - Average stance time over all gait cycles, stance time is defined as the time between a heel-strike and toe off point on the same foot

  Average stride time (s) - Time for one stride (time between successive heel-strikes), averaged over all gait cycles.
- Average step time (s) - Average of times between heel-strike of one foot to heel strike of the opposite foot measured in seconds (sec)
- Swing time variability (%) - Coefficient of variability in swing time
- Stance time variability (%) - Coefficient of variability in stance time during TUG test
- Stride time variability (%) - Coefficient of variability in stride time during TUG test
- Step time variability (%) - Coefficient of variability in step time during TUG test
- Single support variability (%) - Coefficient of variability in the proportion of a gait cycle spent on a single foot

- Double support variability (%) - Coefficient of variability in the proportion of a gait cycle spent on both feet
- Average stride velocity (cm/s) Average walking speed during the TUG test
- Stride velocity variability (%) Coefficient of variability in walking speed during the TUG test
- Average stride length (cm) Average stride length during the TUG test
- Stride length variability (%) Coefficient of variability in stride length over the TUG test
- Pre-turn time (s) Time from ‘go’ to median gait event of TUG test
- Post-turn time (s) Time from median gait event of TUG to end of the test
- Ratio of pre-turn to post-turn times - Ratio of Time from ‘go’ to median gait event of TUG to Time from median event of TUG to end of the test
- Time taken to turn (s) - Time taken to turn
- Number of strides in turn - Number of steps in turn
- Turn steps/time ratio - Ratio of the number of steps taken to turn to the time taken to turn

Independent variables were the five conditions for the testing protocol, SAFE score, and ABC score.

1) TUG- TUG test alone - TUGcontrol
2) TUG + Visual Confrontation Naming - TUGvisual
3) TUG + Auditory Confrontation Naming – TUGaudible
4) TUG + Reading - TUGread
5) TUG + Serial 3’s Subtraction – TUGsubtract

3.15 Data Analysis

All statistical tests were performed using SPSS 25 software (IBM SPSS Statistics 25, USA). Descriptive statistics included age, number of falls in 12 months, mean QTUG, and QTUG for each of the four dual-task conditions.

This study used a linear mixed model with a randomized block design. The $p < 0.05$ level of significance was used for the gait variables. Covariate factors that could affect the TUG performance include age, weight (BMI), SAFE, and ABC scores. Data analysis compared the dual-task cost effect of the four cognitive tasks and the TUGcontrol. Linear mixed effects models were used to analyze the difference in gait parameter variability between the five conditions. Pearson's correlation coefficient analysis was used to assess whether there was a correlation between the ABC Scale and SAFE scores and the temporal and spatial parameters of interest. Lastly, this study investigated if the parameter means for the four cognitive dual-task tests are different between fallers and non-fallers.

Demographics included means for age (years) ± S.D., Height (m) ± S.D., weight (kg) ± S.D., BMI (kg/m^2) ± S.D., ABC (score) ± S.D., and SAFE (score) ± S.D. Graphs included a comparison of the five conditions for the duration of the task, gait speed, cadence, and stride length means including ± S.D.

The difference in the performance of TUG parameters for fallers and non-fallers under the five conditions; TUG, TUGvisual, TUGaudible, TUGreading, and TUGsubtract, were analyzed using an independent samples t-test

CHAPTER IV

Results

4.0 Introduction

This chapter will provide a summary of the results of the descriptive investigation on the effect of different cognitive dual-tasks using a QTUG to measure gait variability in community dwelling adults. Participants characteristics, including demographic data and results of the five research questions proposed in the study. The study results are presented in a variety of tables, figures, and tests to illustrate the findings and address research questions. This chapter provides information addressing five specific research questions. Additional figures and tables can be found in the appendix due to the extensive nature of the number of parameters measured.

4.1 Participants descriptions

The demographic characteristics of the 44 participants who volunteered to participate in this study are summarized in Table 4.1. The information was collected between December 2018 and March 2019 at two different facilities. Twenty-two participants were recruited from each of the two locations. The mean age of the sample was 73 ± 6 years, with an age range of 65-88 years. The participants' mean BMI was 27 ± 5 kg/m^2. The participants' median number of prescription medications was 3, with an interquartile range of 1-4. Five participants took no medication at all, 21 took 0-2 medications, and 21 took 3-5 medications. One subject took 7, and another subject took 10 medications.

Participants were divided into two age groups. The subject characteristics for age, fall, and balance scores are provided in Table 4.2. Originally three age groups were planned, 65-74, 75-84, and 85 and older. There were only three participants over the age of 85. It was determined that two groups would be appropriate. There were 27 (61%) participants ages 65-74 and 17 (39%) participants ages 75 and over. 10 (23%) of participants reported a fall in the previous 12 months.

Table 4.1

Descriptive Characteristics for Community-dwelling participants N = 44

	Gender					
	Male N = 14		Female N = 30		All	
Characteristic	Mean	SD	Mean	SD	Mean	SD
Age (years)	74.79	5.02	72.33	6.57	73.11	6.17
Height (cm)	175.26	7.18	163.75	6.39	167.4	8.5
Weight (kg)	90.59	14.02	70.13	6.39	76.6	16.3
BMI kg/m²	29.52	4.39	26.18	4.95	27.24	4.98
SAFE (Mdn) Q1-Q3	7	7-8	7	6.5-8	7	7-8
ABC Score % (Mdn) Q1-Q3	94.37	83-97	95	89-98	95	86-98
Meds (Mdn) Q1-Q3	2	1-3	3	1-4	3	1-4

Note. SD: standard deviation; m: meters; kg: kilograms; BMI: body mass index; kg/m^2: kilograms per meter Squared; SAFE: screening assessment for falls evaluation; ABC: activities-specific balance confidence; Mdn: Median; Q1-Q3: interquartile ranges 25%-75%.

Those with a history of a fall demonstrated a mean score of 88 on the ABC scale, 5% lower than the participants without a fall whose mean score was 92. The high ABC mean scores indicates that the participants in the study had high balance confidence. Lajoie et al. suggested a cut-off score of ≤ 67% for low balance confidence.[231] Using this cut-off score, only two participants, .045% (2/44), had low balance confidence. Fallers scored a mean of 6.3 on the SAFE, 14% lower than the mean of 7.4 for those without a fall.

4.2 Comparisons of the Characteristics by Location and Block Order

The two locations were analyzed to determine if there were any disparities in demographics. The mean age for Site 1 was 74 ± 1.5 years and 72 ± 1 years of age at Site 2. ABC scores at Site 1 were 87.8 ± 11.5 and 94.1± 6.0 at Site 2. The ABC Scores did not have a normal distribution; therefore a Mann Whitney U test was performed to determine if the ABC scores from site 1 and site 2 were different. The results were significant, p = .029. Thus, Site 1's participants' ABC scores were significantly lower than the subject's ABC scores at Site 2. The number of participants who reported no falls at Site 1 was 18 (82%) and 16 (73%) at the Site 2 location. The two participants who reported more than 1 fall in the past 12 months were both from Site 2. Gender was equally distributed, with 15 females and 7 males at each facility. No other statistically significant differences were found between the sites.

The descriptive characteristics of the four blocks are compared in Table 4.2. Blocks represent the order in which the dual-tasks were presented to the participants. There were 11 participants assigned to each block. Block two had the fewest number of men; there were only 2 men and 9 women. Block one had the fewest number of fallers with only 1, and all others had 3 fallers and 8 participants with no falls. An analysis of variance showed that the effect of the block order on age was not significant, F(3,40) = .824, p = .488. Analysis of variance for effect of ABC score on block order was not significant, F(3,39) = .671, p = .575. The analysis of variance for effect of SAFE score on block order was not significant, F(3,40) = 1.35, p = .273. Thus, age, SAFE, and ABC scores were evenly distributed across the blocks.

Statistical comparisons were made to analyze the mean of gait parameters by location. There were no significant differences detected between the two locations where testing was completed or the block order of conditions. It was determined appropriate to combine all data for analysis.

Table 4.2

Descriptive characteristics of the 4 Blocks

Characteristic	Block 1	Block 2	Block 3	Block 4
Gender Female N	7	9	8	6
Age (years) Mean/SD	72 ± 1.6	71.5 ± 2.0	75.3 ± 2.0	73.4 ± 2.0
Falls N	1	3	3	3
SAFE (0-8) Mdn	7	7	7	7
ABC (0-100) Mdn	95	97.5	92.2	94.4

N = 11 Note. SAFE: screening assessment for falls evaluation; ABC: activities-specific balance confidence;^{b} SD: standard deviation; Mdn: Median

Most gait parameters demonstrated excellent test-retest reliability in the two repeated trials for the five conditions. Results of the interclass correlation coefficient can be found in Table 4.3. Exceptions included the number of steps taken in the turn and support time variables.

This table demonstrates the poor test-retest reliability of both spatial and temporal coefficients of variation with the QTUG under the five conditions.

Table 4.3

Reliability of Trial 1 vs. Trial 2

	Condition				
	Control	Subtract	Reading	Audible	Visual
Parameter	ICC	ICC	ICC	ICC	ICC
Record Time	**.989**	**.977**	**.982**	**.953**	**.985**
Walk Time	**.964**	**.958**	**.959**	**.941**	**.951**
Pre-Turn	**.970**	**.964**	**.932**	**.949**	**.945**
Stride Length	**.868**	**.906**	**.917**	**.869**	**.896**
Cadence	**.767**	**.857**	**.884**	**.838**	**.873**
Stride Time	.687	**.908**	**.874**	**.833**	**.790**
Stride Velocity	**.877**	**.853**	**.939**	**.864**	**.848**
Swing Time	**.864**	**.747**	**.876**	**.896**	**.835**
# of Steps	**.878**	**.929**	**.915**	**.872**	**.903**
Step Time	**.778**	**.824**	**.827**	.673	**.769**
Gait Cycle	**.824**	**.944**	**.891**	**.831**	**.850**
Time to Stand	**.834**	**.796**	**.707**	**.898**	.432
Strides in Turn	.573	.014	-.062	.575	.219
Double Support Time	.629	**.781**	**.887**	**.837**	**.772**
Single Support Time	.658	**.727**	**.704**	**.854**	.669

Interclass Correlation Coefficient to determine the reliability of analysis of Trial 1 vs. Trial 2. 2-way mixed model fixed measures with random subjects. 0.00- .30: negligible correlation, .30 to .50: low correlation; .50 to .70 moderate correlation; .70-.90: **high correlation;** .90 to 1.00: **very high correlation.**

The following table 4.4 provides the mean data with SD for the two trials of each condition. The sixteen spatio-temporal parameters measured by the QTUG for each of the five conditions.

Table 4.4

Reliability of Trial 1 vs. Trial 2 for variability parameters

	Condition				
	Control	Subtract	Reading	Audible	Visual
Parameter	ICC	ICC	ICC	ICC	ICC
Stance Time Variability	.403	.216	.579	.647	.628
Swing Time Variability	.576	.368	.507	.644	.084
Double Support Variability	**.834**	.636	**.763**	.669	.520
Single Support Variability	.347	.697	.027	.259	.327
Stride Time Variability	.318	**.754**	.593	**.763**	.556
Stride Length Variability	.183	.193	.608	.141	.482
Stride Velocity Variability	.151	.339	.437	.342	.401

Interclass Correlation Coefficient to determine the reliability of the analysis of Trial 1 vs. Trial 2. 2-way mixed model fixed measures with random subjects. 0.00- .30: negligible correlation, .30 to .50: low correlation; .50 to .70: moderate correlation; .70-.90: **high correlation**; .90 to 1.00: very high correlation**.**

The following table contains the raw data for sixteen of the QTUG parameters that were analyzed. The mean and standard deviation was calculated by combining the two trials and dividing them by two.

Table 4.5

Mean and SD for spatio-temporal parameters for Control and each condition

	Condition				
	Control	Subtract	Reading	Audible	Visual
Parameter	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Record Time (s)	9.83 (2.0)	10.67 (2.45)	10.17 (2.06)	9.96 (2.03)	9.99 (2.03)
Walk Time (s)	6.88 (1.53)	7.73 (2.04)	7.21 (1.68)	7.04 (1.62)	7.15 (1.75)
Pre-Turn (s)	4.50 (1.13)	4.79 (1.22)	4.65 (1.07)	4.47 (1.03)	4.57 (1.10)
Stride Length (cm)	153.7 (11.88)	148.2 (12.31)	150.6 (11.20)	151.9 (11.54)	151.7 (11.16)
Cadence (step/min)	103.7 (12.59)	97.7 (13.21)	102.4 (14.93)	103.8 (14.52)	102.8 (13.0)
Stride Time (s)	1.27 (.15)	1.32 (.18)	1.28 (.17)	1.27 (.16)	1.25 (.16)
Stride Velocity (cm/s)	130.3 (19.2)	123.4 (21.4)	127.8 (20.9)	127.0 (20.4)	129.4 (23.2)
Swing Time (s)	.47 (.04)	.49 (.05)	.48 (.05)	.47 (.05)	.47 (.04)
Ratio	1.18	1.20	1.17	1.19	1.17
# of Steps	11.69 (1.94)	11.96 (2.18)	12.05 (2.20)	11.92 (1.98)	12.02 (2.26)
Step Time (s)	.58 (.08)	.61 (.09)	.60 (.09)	.59 (.08)	.57 (.08)
Gait Cycle	5.54 (.97)	5.95 (1.35)	5.77 (1.08)	5.75 (.97)	5.78 (1.11)
Time to Stand (s)	1.38 (.42)	1.41 (.41)	1.40 (.38)	1.33 (.46)	1.38 (.38)
Steps in Turn	1.68 (.72)	1.56 (.52)	1.60 (.59)	1.64 (.70)	1.70 (.60)
Double Support (s)	.19 ± (.06)	.20 (.07)	.19 (.06)	.20 (.06)	.19 (.06)
Single Support (s)	.40 ± (.04)	.39 (.04)	.40 (.04)	.39 (.04)	.40 (.04)

^{a}SD: standard deviation; s: seconds; Pre-Turn Time:Time it takes to reach the turn; cm: centimeters; cm/s: centimeter per second; Ratio: Stride Length to Velocity Ratio; # : number.

4.3 Research Questions

Question 1- Is there a difference in the dual-task cost (DTC) for the TUGvisual, TUGaudible, TUGreading, TUGsubtract in community dwelling adults?

The following formula was used to determine the difference in the dual-task cost. (TUGcontrol mean variable – TUG condition mean variable / TUGcontrol mean variable) X 100.[232,233] This provides a percentage of change between the control and the condition.

Ho: There is no difference in the dual-task costs of the four conditions.

H1: There is a difference in the dual-task costs.

Linear mixed effect models were used to examine the effect of the cognitive task on gait parameters. Mean dual-task cost as calculated above for Subtract, Read, Audible, and Visual conditions were compared to Control as reference TUG only (Control = 0). The Control reference line of 0 is highlighted in figures for Dual-Task means. The first three parameters analyzed measured different components of TUG times. Recording time measured the total time taken to perform the TUG from the word go to sitting back down. Pre-turn time only measured the time from the word go to the turn. Walk time excluded the time it takes to stand up and sit down.

Results of the adjusted linear mixed model compared each condition to the control for recording time. The condition of Subtract was significantly different (estimate = -8.29; 95% CI = -12.88 to -1.12, p <.0001) from Control. Read condition was also significantly different from Control (estimate = -3.62; 95% CI = -6.41 to -.83, p <.006) (Figure 4.1).

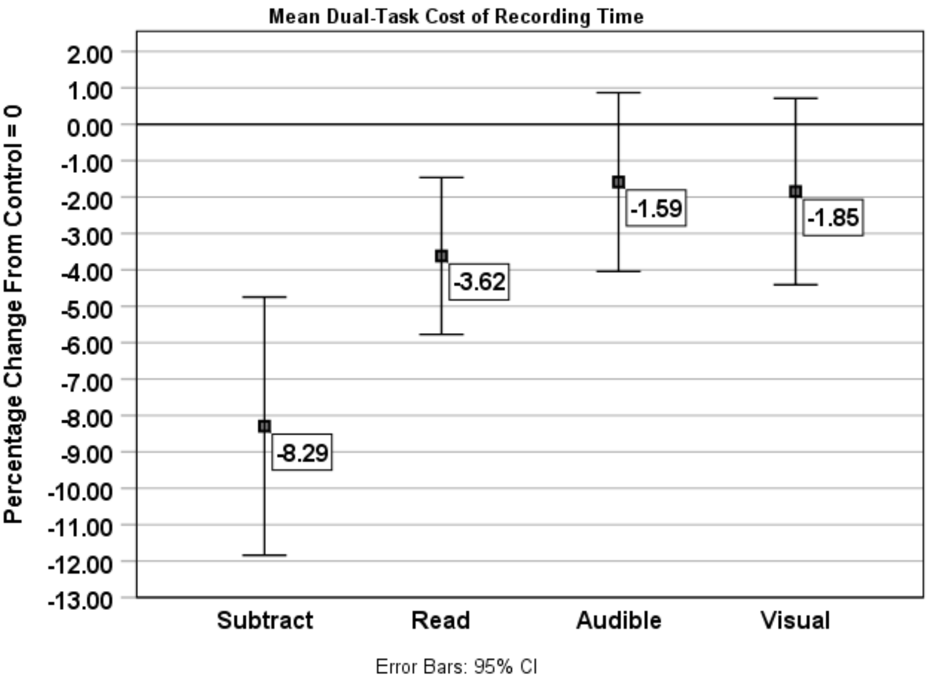


Figure 4.1 Mean Dual-Task Cost of Recording Time as a percentage of change of each condition compared to the Control mean.

Table 4.6

Least Square Means for DTC Recording Time

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	-8.29	1.76	43	-4.72	<.0001*	-12.88	-1.12
Read	-3.62	1.07	43	-3.38	.006*	-6.41	-0.83
Audible	-1.59	1.22	43	-1.30	.798	-4.76	1.59
Visual	-1.85	1.27	43	-1.46	.610	-5.16	1.46

Note**.** * Indicates a significant difference between the condition and control at $p < 0.05$; adj.: adjusted lower confidence interval.

Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract and Read for recording time when compared to Control = 0. A post hoc Tukey-Kramer test was used to determine if there were significant differences, and pairwise comparisons were used on the four groups with six total comparisons. The condition of Subtract was significantly different from the other three conditions; Read (estimate = 4.67; 95% CI = 0.34 to 9.02, *p* = .03), Audible (estimate = 6.71; 95% CI = 1.71 to 11.70, *p* = .004), and Visual (estimate = -6.45; 95% CI = -10.33 to -2.55, *p* = .0004). Therefore, we reject the null hypothesis that there is not a significant difference between the dual-task cost of the cognitive condition of Subtract compared to Read, Audible, and Visual for recording time.

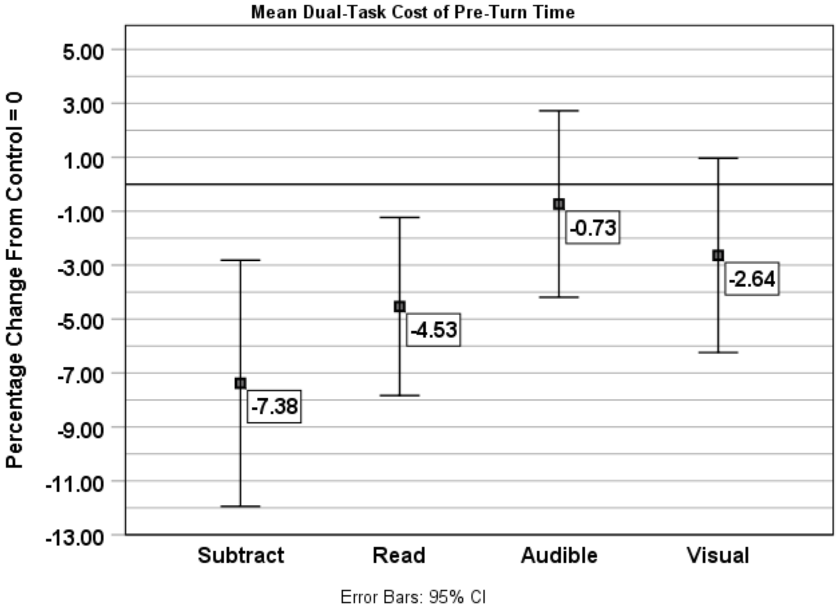


Figure 4.2 Mean Dual-Task Cost of Pre-Turn Time as a percentage of change.

Results of the adjusted linear mixed model compared each condition to the control for pre-turn time. The condition of Subtract was significantly different (estimate = -6.84; 95% CI = -13.01 to -.68, *p* = .024) from Control. Read and Visual conditions were not significantly different from Control, and Audible was virtually the same as the Control means. (Figure 4.2)

Table 4.7

Least Square Means for DTC Pre-Turn Time

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	-6.84	2.36	42	-2.90	.024*	-13.01	-0.68
Read	-4.12	1.67	43	-2.47	.07	-8.47	.23
Audible	-.34	1.67	45	-.21	>.99	-4.69	4.00
Visual	-2.35	1.74	45	-1.35	.73	-6.88	2.17

Note**.** * Indicates a significant difference between the condition and control at $p < 0.05$; adj.: adjusted lower confidence interval.

Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract condition. A post hoc Tukey-Kramer test was used to determine if there were significant differences between the conditions for pre-turn time. Subtract was the only significant finding for the pairwise comparisons. Subtract was different from Audible, (estimate = 6.49; 95% CI = 1.53 to 11.46, $p = .005$). Therefore, we reject the null hypothesis that there is not a significant difference between the dual-task cost of the cognitive conditions of Subtract and Audible for pre-turn time.

Results of the adjusted linear mixed model compared each condition to the control for walk time. The adjusted linear mixed model results revealed that the condition of Subtract was significantly different (estimate = -12.09; 95% CI = -18.81 to -5.37, $p < .0001$) from Control. Read condition was also significantly different from Control (estimate = -4.92; 95% CI = -9.42 to -.42, $p < .026$) (Figure 4.3).

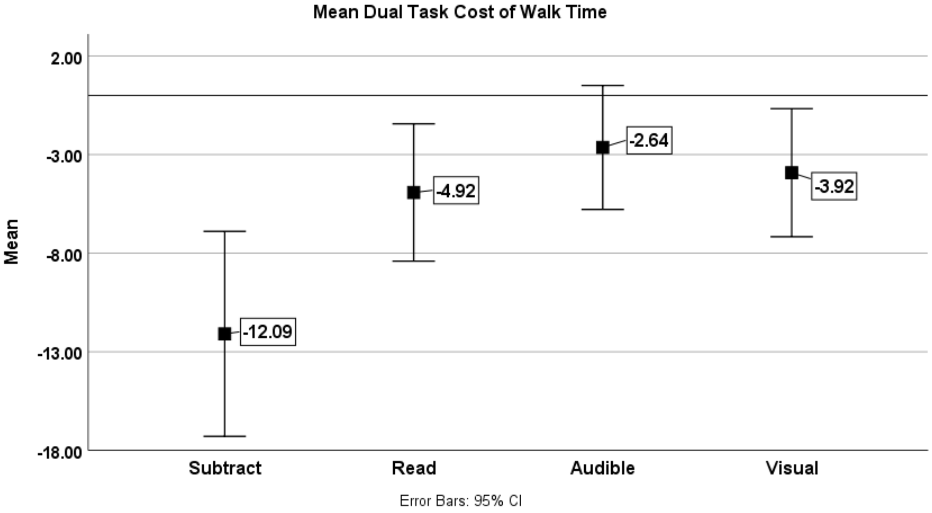


Figure 4.3 Mean Dual-Task Cost of Walk Time as a percentage of change.

Table 4.8

Least Square Means for DTC Walk Time

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	-12.09	2.58	43	-4.69	<.0001*	-18.81	-5.37
Read	-4.92	1.73	43	-2.85	.026*	-9.42	-.42
Audible	-2.64	1.56	43	-1.69	.390	-6.70	1.42
Visual	-3.92	1.61	43	-2.44	.075	-8.12	.27

Note**.** * Indicates a significant difference between the condition and control at $p < 0.05$; adj.: adjusted lower confidence interval.

Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract and Read from Control for walk time. A post hoc Tukey-Kramer test was used to determine if there were significant differences between the conditions. Pairwise comparisons revealed the condition of Subtract was significantly different from the other three conditions; Read (estimate = 7.17; 95% CI = 1.46 to 12.88, *p* = .0087), Audible (estimate = 9.45; 95% CI = 2.56 to 16.34, *p* = .0036, and Visual (estimate = -8.17; 95% CI = -13.45 to -2.90, *p* = .0009). Therefore, we reject the null hypothesis that there is not a significant difference between the dual-task cost of the cognitive conditions of Subtract compared to Read, Audible, and Visual for walk time.

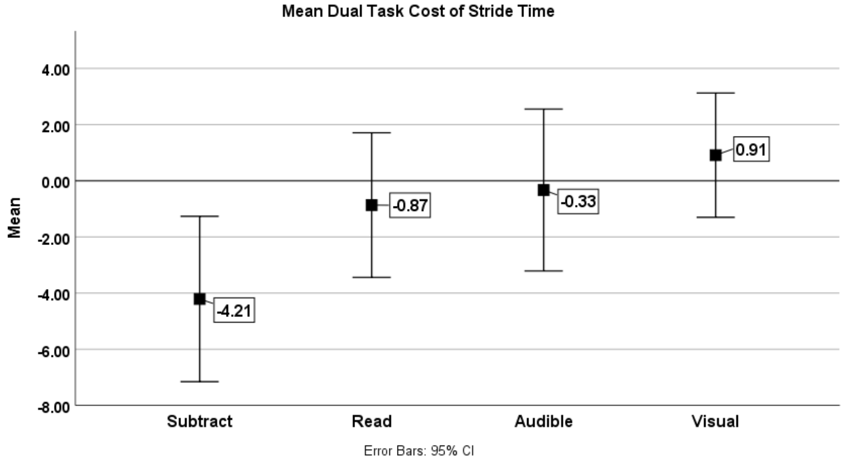


Figure 4.4 Mean Dual-Task Cost of Stride Time as a percentage of change.

Results of the adjusted linear mixed models were used to compare each condition to the control for stride time. The condition of Subtract was significantly different (estimate = -4.21; 95% CI = -8.15 to -.27, *p* = .032) from Control. The other three conditions Read, Audible, and Visual conditions, virtually had the same mean as the Control (Figure 4.4). Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract condition and Control for stride time.

A post hoc Tukey-Kramer test was used to determine if there were significant differences between the conditions for stride time. Pairwise comparisons showed the condition of Subtract was significantly different from Audible (estimate = 3.88; 95% CI = .22 to 7.53, *p* = .033) and Visual (estimate = 5.12; 95% CI = -8.50 to -1.74, *p* = .0008).

Therefore, we reject the null hypothesis that there is not a significant difference between the dual-task cost of the cognitive conditions of Subtract compared to Audible and Visual for stride time. There was a difference between Subtract and Read (estimate = 3.34; 95% CI = -0.13 to 6.82, p = .064), but it was slightly above the $p < 0.05$ level for significance.

Table 4.9

Least Square Means for DTC Stride Time

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	-4.21	1.51	44	-2.79	.032*	-8.15	-.27
Read	-.87	1.23	46	-.70	>.99	-4.08	2.35
Audible	-.33	1.41	44	-.23	>.99	-4.03	3.37
Visual	.91	1.10	43	.83	>.99	-1.96	3.78

Note**.** * Indicates a significant difference between the condition and control at $p < 0.05$; adj.: adjusted lower confidence interval.

Results of the adjusted linear mixed estimated models were used to compare each condition to the control for step time. The condition of Subtract was significantly different (estimate = -5.27; 95% CI = -9.52 to -1.01, p = .009) from Control. Audible and Visual conditions were virtually the same as the Control means (Figure 4.5).

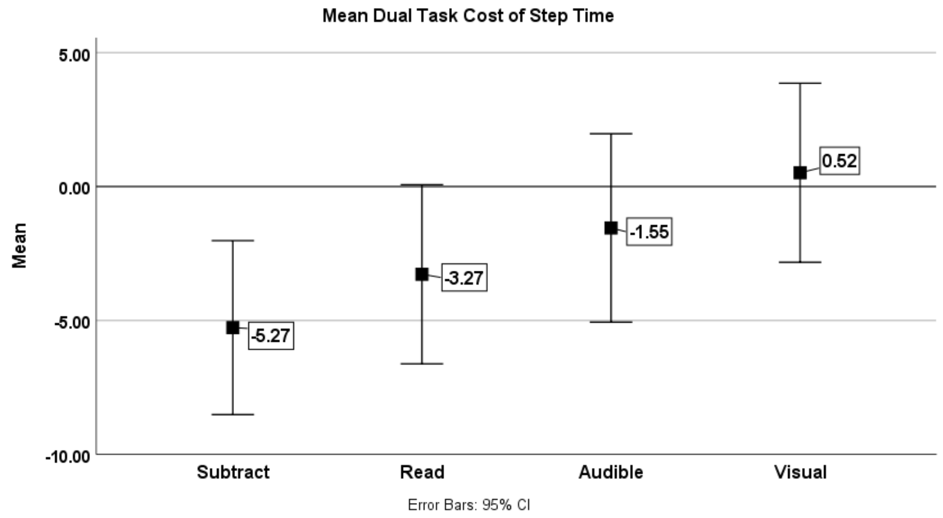


Figure 4.5 Mean Dual-Task Cost of Step Time as a percentage of change.

Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract condition for step time. A post hoc Tukey-Kramer test was used to determine if there were significant differences between the conditions, and pairwise comparisons showed the condition of Subtract was significantly different from Visual (estimate = 5.78; 95% CI = -9.85 to -1.71, *p* = .0018). Reject the null hypothesis that there is not a significant difference between the dual-task cost of the cognitive conditions of Subtract and Visual for step time. The mean for step time in the Audible condition was positive, indicating that step time decreased compared to Control.

Table 4.10

Least Square Means for DTC Step Time

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	-5.27	1.74	88	-3.16	.009*	-9.51	-1.01
Read	-3.72	1.66	88	-1.96	.211	-7.52	.98
Audible	-1.55	1.61	88	.93	>.99	-5.79	2.70
Visual	.51	1.65	88	.31	>.99	-3.74	4.77

Note**.** * Indicates a significant difference between the condition and control at $p < 0.05$; adj.: adjusted lower confidence interval.

Results of the adjusted linear mixed models showed the condition of Subtract was significantly different (estimate = -3.86; 95% CI = -7.46 to -0.27, *p* = .030) from Control for stance time (Figure 4.6).

Read, Audible, and Visual conditions had virtually the same mean as the Control for stance time. Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract condition and Control for stance time. Audible and Visual means were positive, indicating that stance time was less than the Control mean.

A post hoc Tukey-Kramer test was used to determine if there were significant differences

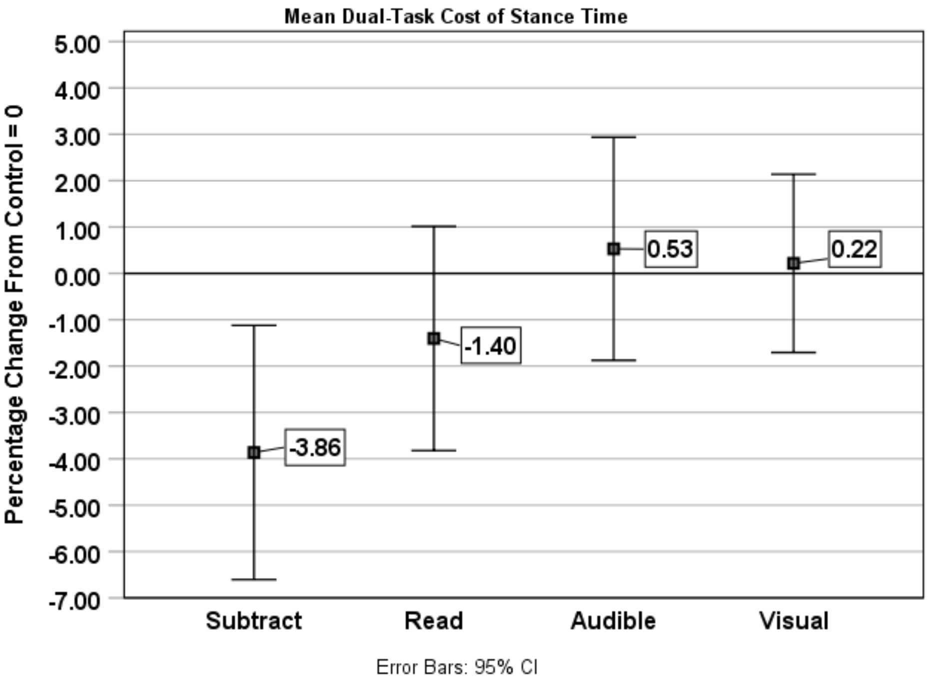


Figure 4.6 Mean Dual-Task Cost of Stance Time as a percentage of change.

and pairwise comparisons revealed the condition of Subtract was significantly different from Audible (estimate = 4.39; 95% CI = 1.03 to 7.76, $p = .005$) and Visual (estimate = -4.08; 95% CI = -7.28 to -0.88, $p = .0065$). Therefore, we reject the null hypothesis that there is not a significant difference between the dual-task cost of the cognitive conditions of Subtract compared to Audible and Visual for stance time.

Table 4.11

Least Square Means for DTC Stance Time

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	-3.86	1.38	43	-2.80	.030*	-7.45	-.27
Read	-1.40	1.20	44	-1.17	>.99	-4.53	1.72
Audible	.53	1.17	45	.45	>.99	-2.52	3.58
Visual	.22	.96	43	.23	>.99	-2.27	2.71

Note**.** * Indicates a significant difference between the condition and control at $p < 0.05$; adj.: adjusted lower confidence interval.

Results of the adjusted linear mixed model compared each condition to the control for stride length. The condition of Subtract was significantly different (estimate = -3.48; 95% CI = 1.35 to 5.61, *p* <.0001) from Control (Figure 4.7).

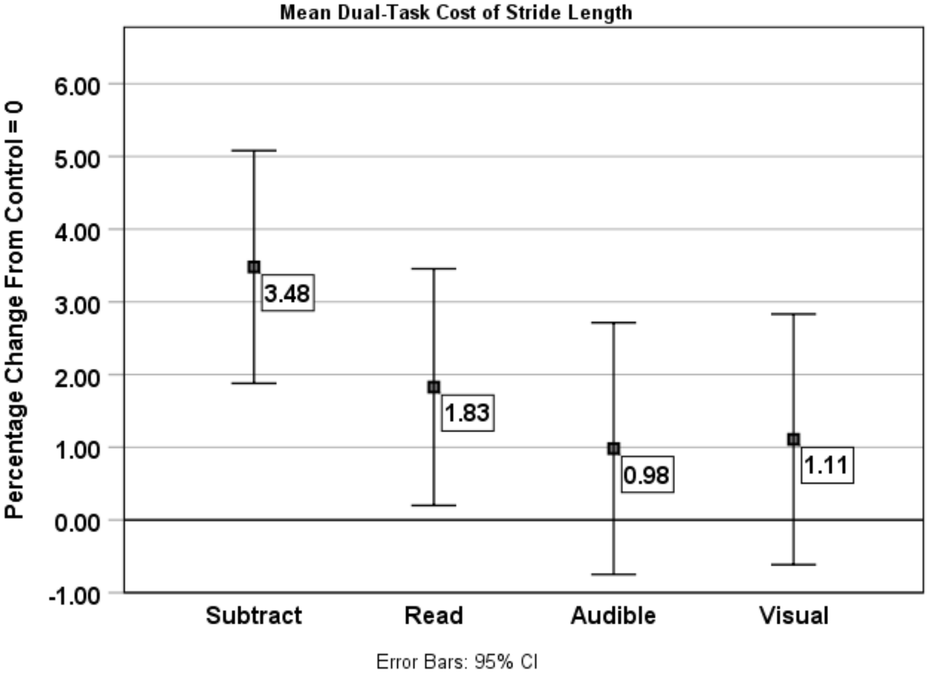


Figure 4.7 Mean Dual-Task Cost of Stride Length as a percentage of change.

Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract from Control for stride length. A post hoc Tukey-Kramer test was used to determine if there were significant differences between the conditions. Pairwise comparisons demonstrated the condition of Subtract was significantly different from the other three conditions; Read (estimate = -1.65; 95% CI = -3.16 to -.14, *p* = .026), Audible (estimate = 2.50; 95% CI = -4.01 to -.98, *p* = .0002, and Visual (estimate = 2.37; 95% CI =.86 to 3.88, *p* = .0004). Therefore, we reject the null hypothesis that there is not a significant difference between the dual-task cost of Subtract compared to Read, Audible, and Visual conditions for stride length.

Table 4.12

Least Square Means for DTC Stride Length

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	3.48	.83	63	4.20	<.0001*	1.35	5.61
Read	1.82	.83	63	2.20	.124	-.30	3.96
Audible	.98	.83	63	1.18	.962	-1.15	3.11
Visual	1.11	.83	63	1.34	.744	-1.02	3.24

Note**.** * Indicates a significant difference between the condition and control at $p < 0.05$; adj.: adjusted lower confidence interval.

Results of the adjusted linear mixed models showed the condition of Subtract was significantly different (estimate = 5.14; 95% CI = 1.53 to 8.75, $p = .002$) from Control for the condition of stride velocity (Figure 4.8).

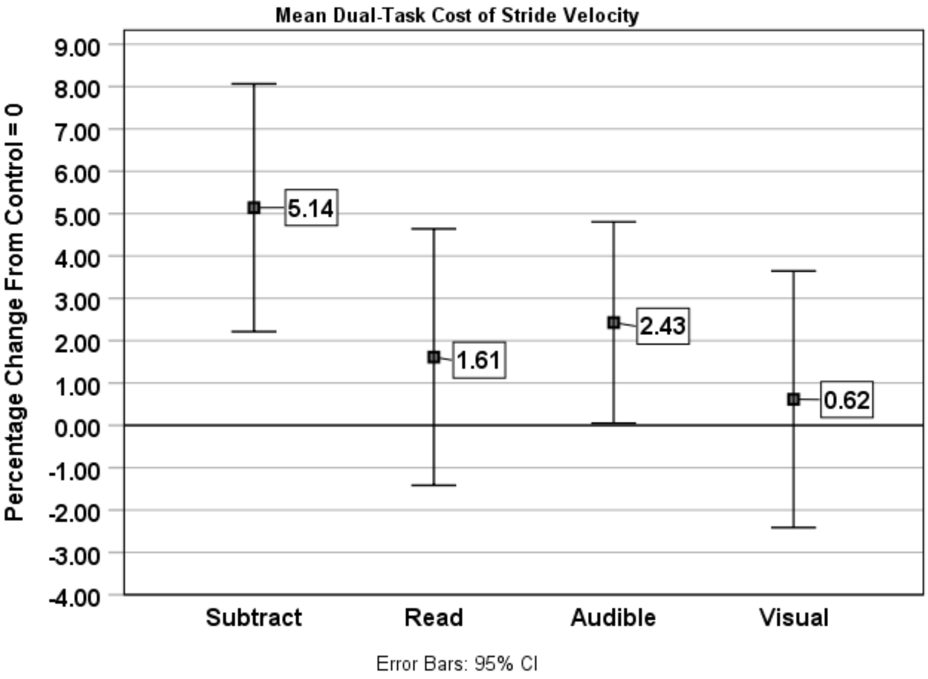


Figure 4.8 Mean Dual-Task Cost of Stride Velocity as a percentage of change.

Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract from Control for stride velocity. A post hoc Tukey-Kramer test was used to determine if there were significant differences between the conditions. Pairwise comparisons showed the condition of Subtract was significantly different from Read (estimate = -3.53; 95% CI = -7.01 to -.04, p = .046) and Visual (estimate = 4.52; 95% CI = 1.05 to 8.00, p = .005). Therefore, we reject the null hypothesis that there is not a significant difference between the dual-task cost of Subtract compared to Read and Visual conditions for stride velocity.

Table 4.13

Least Square Means for DTC Stride Velocity

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	5.14	1.41	89	3.63	.002*	1.53	8.75
Read	1.61	1.41	89	1.14	>.99	-1.99	5.22
Audible	2.43	1.41	89	1.72	.358	-1.18	6.03
Visual	.62	1.41	89	.43	>.99	-2.99	4.22

[a]* Indicates a significant difference between the condition and control at $p < 0.05$.
[b] CI : confidence interval; % : percent.

Results of the adjusted linear mixed model were used to compare each condition to the control for cadence. (Figure 4.9) The condition of Subtract was significantly different (estimate = 5.62; 95% CI = 2.18 to 9.05, p <.0001) from Control. (Table 4.14) Therefore, we reject the null hypothesis that there is no difference in the dual-task cost of Subtract from Control for cadence. A post hoc Tukey-Kramer test was used to determine if there were significant differences and pairwise comparisons revealed the condition of Subtract was significantly different from the other three conditions; Read (estimate = -4.47; 95% CI = -8.34 to -.60, p = .017), Audible (estimate = -5.99; 95% CI = -9.87 to -2.12, p = .0006, and Visual (estimate = 4.99; 95% CI = 1.11 to 8.87, p = .0058).

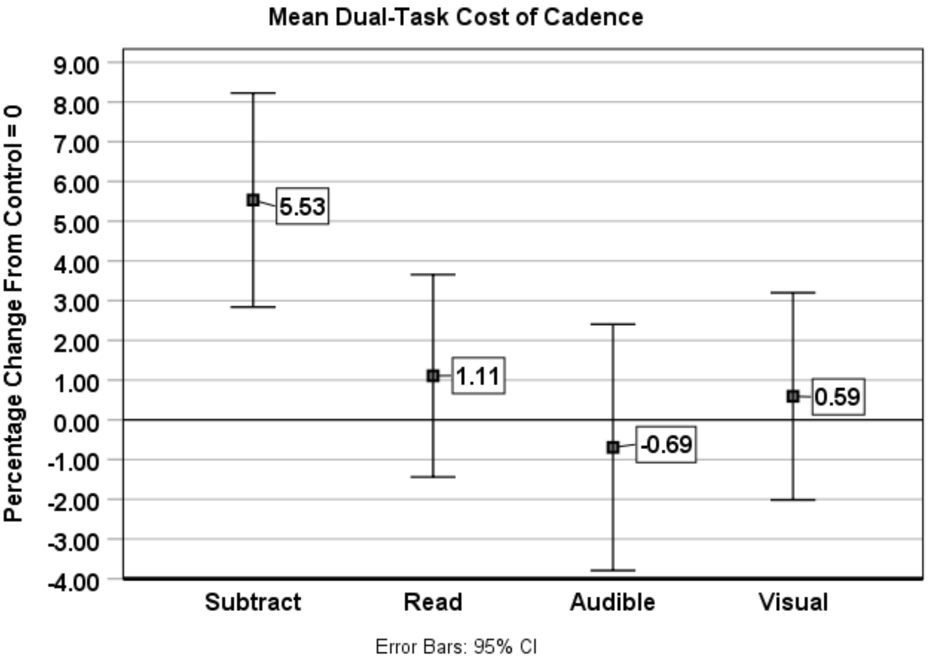


Figure 4.9 Mean Dual-Task Cost of Cadence as a percentage of change.

Therefore, we reject the null hypothesis that there is not a significant difference between the dual-task cost of Subtract compared to Read, Audible, and Visual conditions for cadence. The dual-task cost of Cadence under the Audible condition demonstrated a negative mean, indicating that participants' steps/min increased compared to the control condition. This represents a dual-task gain.

Table 4.14

Least Square Means for Cadence

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Subtract	5.62	1.35	119	4.15	<.0001*	2.18	9.05
Read	1.14	1.34	117	.85	>.99	-2.26	4.55
Audible	-.38	1.34	117	-.28	>.99	-3.78	3.02
Visual	.63	1.34	117	.47	>.99	-2.78	4.03

[a]* Indicates a significant difference between the condition and control at $p < 0.05$.
[b] CI : confidence interval; % : percent.

Question 2- Is there a significant difference in gait parameter variability between the TUGcontrol and the four distinct cognitive conditions: TUGvisual, TUGaudible, TUGreading, TUGsubtract?

The specific variable parameters of interest are stance time variability, stride time variability, swing time variability, stride velocity variability, stride length variability, single support variability, and double support variability.

Ho: There is no difference in gait parameter variability between each of the four measures compared to the TUGcontrol.

H1: There is a difference in gait parameter variability between each of the four measures compared to the TUGcontrol.

Several of the parameters that measured a coefficient of variation demonstrated violations of normality in the conditions. A natural log transformation was used to deal with the violation of normality. Parameters with significant findings were treated with a reverse transformation for estimates and standard error reporting.

A linear mixed model was used to compare the four conditions to the control. Figure 4.10 shows the actual mean and 95% CI before transformation for stride velocity variability for all five conditions. The Audible stride velocity variability was significantly different from Control (estimate = 25.06; 95% CI = 23.34 to 26.91, *p* = .024), reject the null hypothesis that there was no difference.

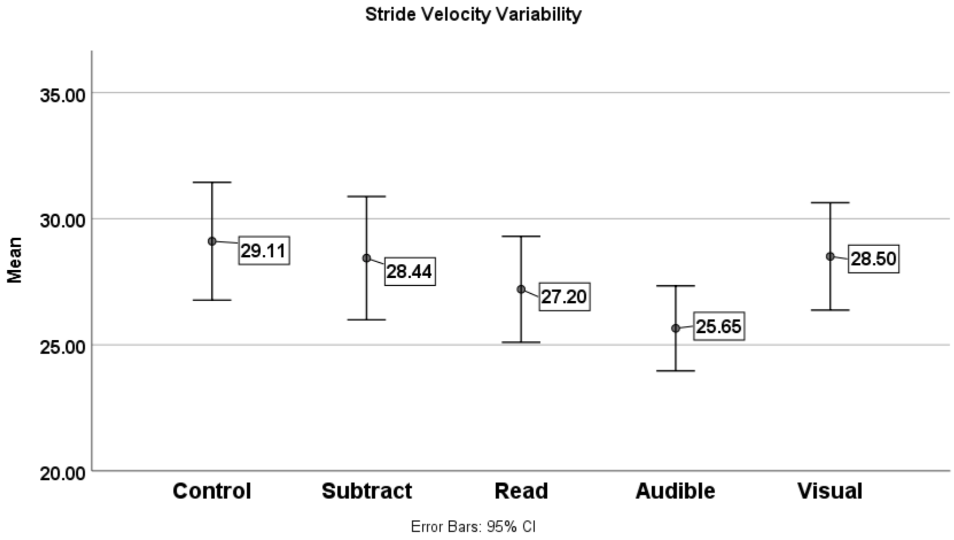


Figure 4.10 Mean of Stride Velocity Variability of each TUG condition.

An adjusted linear mixed model was used to compare transformed data, and then reverse transformation was done to report the data for each condition compared to the Control. (Table 4.15) The Type III Test of fixed effects shows that task 4(43), F = 2.81, *p* = .037. We thus reject the null hypothesis that there is no difference between the Audible condition and Control.

Table 4.15

Least Square Means for Stride Velocity Variability

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Control	28.30	1.03	162	.000	>.99	26.35	30.39
Subtract	27.48	1.03	162	-.054	.88	25.59	29.51
Read	26.44	1.03	162	-1.05	.29	24.62	28.39
Audible	25.06	1.03	162	-2.28	.02*	23.34	26.91
Visual	27.66	1.03	162	-.062	.94	25.76	29.70

* Indicates a significant difference between the condition and control at $p < 0.05$.

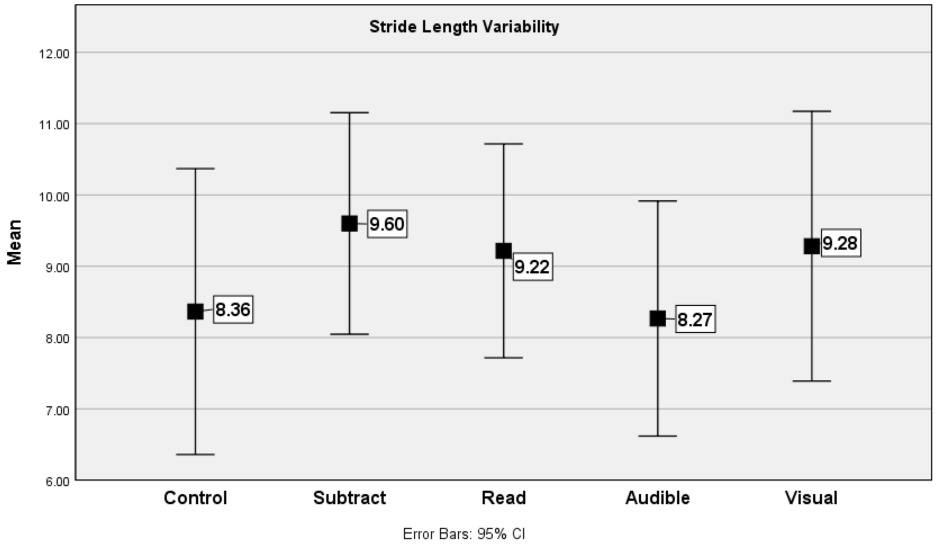


Figure 4.11 Mean of Stride Length Variability of each TUG condition.

Table 4.16

Least Square Means for Stride Length Variability

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Control	8.36	.86	187	.000	>.99	6.67	10.06
Subtract	9.60	.86	187	1.61	.115	7.91	11.29
Read	9.22	.86	187	1.15	.256	7.52	10.91
Audible	8.27	.86	187	-.114	.901	6.57	9.96
Visual	9.28	.86	187	.981	.332	7.58	10.97

An adjusted linear mixed model was used to compare transformed data, and then reverse transformation was done to report the data for each condition compared to the Control. (Table 4.16) The Type III Test of fixed effects shows that task 4(172), F = 1.67, *p* =.159. So, there is no significant difference between the five conditions for stride length variability.

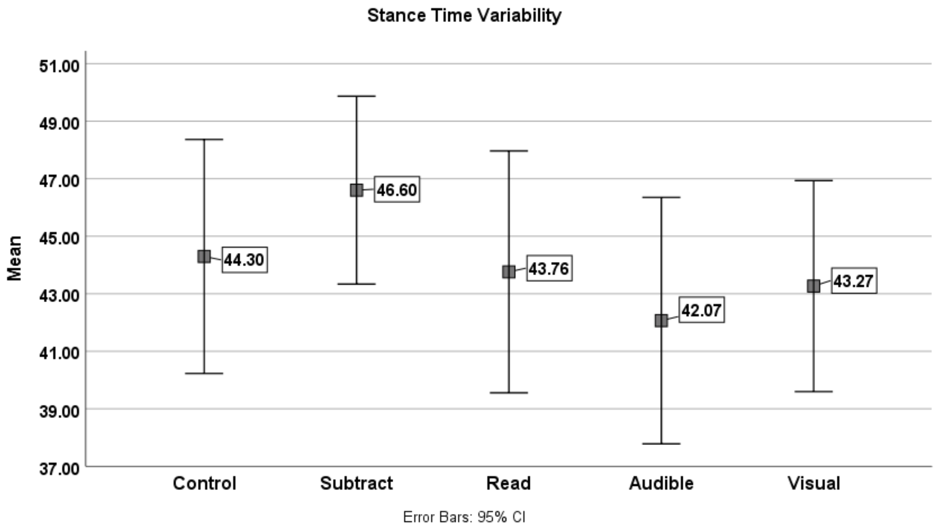


Figure 4.12 Mean of Stance Time Variability of each TUG condition.

Table 4.17

Least Square Means for Stance Time Variability

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Control	44.30	2.02	43	-.002	>.99	37.78	46.36
Subtract	46.60	1.62	43	1.42	.163	40.23	48.36
Read	43.76	2.09	43	-.269	.797	39.56	47.96
Audible	42.07	2.13	43	-1.05	.299	37.78	46.35
Visual	43.27	1.82	43	-.57	.573	39.59	46.93

The Type III Test of fixed effects shows that task 4(172), F = 1.461, *p* =.216. So, there is no significant difference between the five conditions for stance time variability.

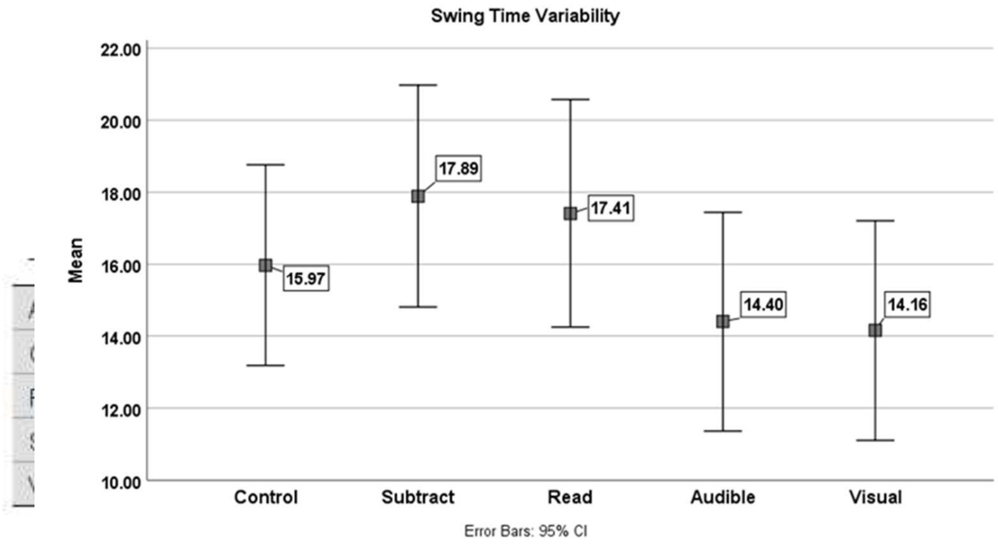


Figure 4.13 Mean of Swing Time Variability of each TUG condition.

Table 4.18

Least Square Means for Swing Time Variability

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Control	13.92	1.08	43	.000	>.99	11.90	16.30
Subtract	15.33	1.30	43	1.25	.217	12.92	18.20
Read	15.02	1.21	43	.918	.364	12.75	17.69
Audible	12.28	.98	43	-1.04	.304	10.45	14.42
Visual	12.03	.96	43	-1.20	.237	10.23	14.14

Table 4.18 shows the results of the linear mixed model analysis using a log transformation of the data due to the violation of normality. The type III tests of fixed effects indicated that task 4(43), F = 2.41, $p = .064$. The results indicate that there is a difference, but it does not meet the $p < 0.05$ level of significance.

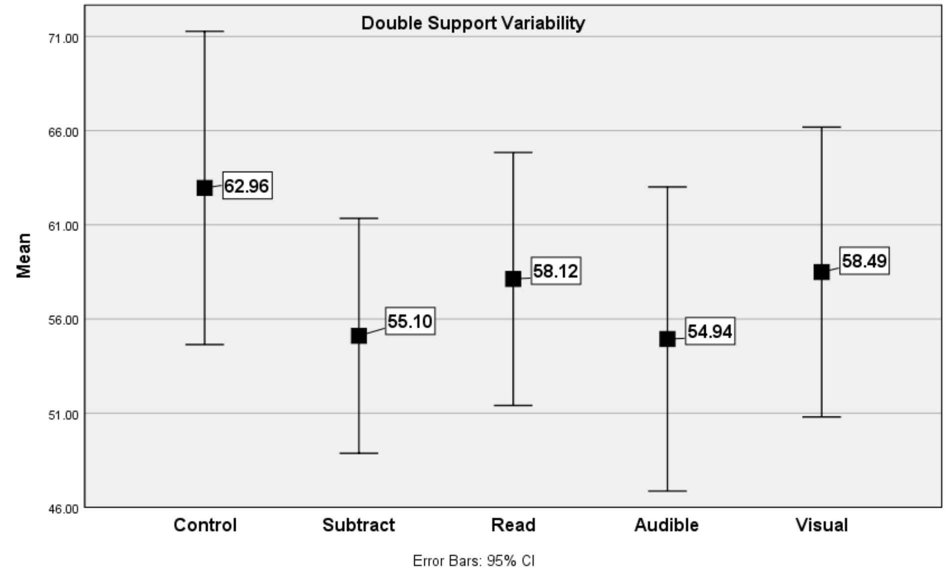


Figure 4.14 Mean of Double Support Variability of each TUG condition.

Table 4.19

Least Square Means for Double Support Variability

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Control	62.96	4.12	43	.000	>.99	54.64	71.27
Subtract	55.10	1.62	43	-1.74	.089	48.87	61.34
Read	58.12	3.33	43	-.978	.333	51.41	64.84
Audible	54.94	4.00	43	-1.95	.056	46.86	63.01
Visual	58.49	3.81	43	-.950	.348	50.80	66.19

The linear mixed model analysis for the Type III test of fixed effects indicated for task 4(43), F = .854, *p* = .499. There is not a significant difference between the four cognitive conditions and control for double support variability. The effect is practically zero across all conditions, and we can say so with good certainty.

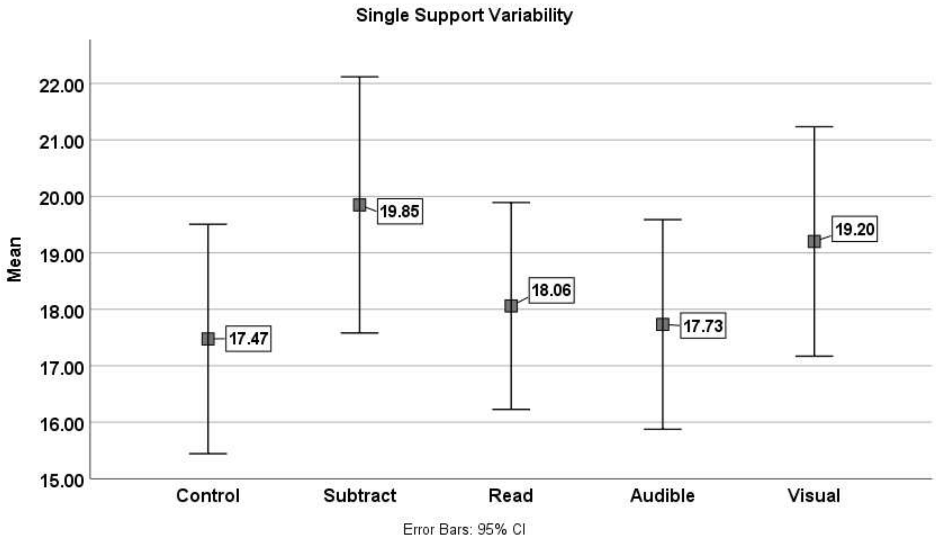


Figure 4.15 Mean of Single Support Time Variability of each TUG condition.

Table 4.20

Least Square Means for Single Support Variability

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Control	17.47	.997	198	.000	>.99	15.51	19.44
Subtract	19.85	.997	198	1.94	.068	17.88	21.81
Read	18.06	.997	198	.644	.523	16.09	20.03
Audible	17.73	.997	198	.280	.781	15.77	19.70
Visual	19.20	.997	198	1.71	.094	17.24	21.17

Linear mixed model analysis indicated that the Type III test of fixed effects Task 4(172), F = 1.218, *p* = .305. There is not a significant difference between the four cognitive conditions and control for single support variability. The effect is practically zero across all conditions, and we can say so with good certainty.

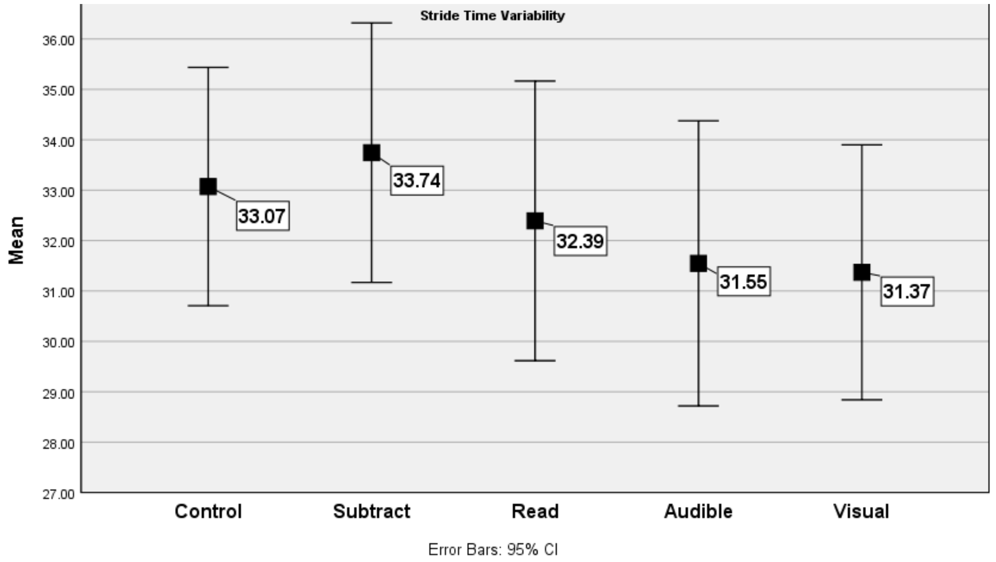


Figure 4.16 Mean of Stride Time Variability of each TUG condition.

Table 4.21

Least Square Means for Stride Time Variability

Condition	Estimate	Standard Error	df	t value	*p*-value	Adj. Lower Level	Adj. Upper Level
Control	33.07	1.35	43	.00	>.99	30.50	35.65
Subtract	33.74	1.22	43	.53	.217	31.17	36.32
Read	32.39	1.38	43	-.49	.364	29.82	34.96
Audible	31.55	1.28	43	-1.09	.304	28.97	34.65
Visual	31.37	1.21	43	-1.35	.237	28.80	33.94

Linear mixed model analysis indicated that the Type III test of fixed effects Task 4(172), F = 1.095, *p* = .361. There is not a significant difference between the four cognitive conditions and control for stride time variability. The effect is practically zero across all conditions, and we can say so with good certainty.

For Research Question #3, groups were dichotomized into fallers and non-fallers based on a history of falls in the past 12 months.

Research Question # 3 Are the ABC and SAFE scores and mean TUG time for each of the cognitive conditions associated with fallers?

Ho: There is no association between the ABC and SAFE scores and mean TUG times for each of the cognitive conditions with fallers.

H1: There is an association between the ABC and SAFE scores with fallers.

This study examined the associations of fall history and gait parameters. Given the small number of participants with multiple falls (n = 2), falls status was included as a dichotomous variable (faller/non-faller). Faller and non-faller descriptive characteristics for age, gender, SAFE scores, ABC scores, and location sites can be found in Table 4.23. Statistical analysis performed revealed that there were no significant differences in age, gender, or any other covariates.

Community dwelling participants who reported a fall had a significantly lower SAFE scores (M = 6.3, SD = 1.34) than those who did not have a fall (M = 7.35, SD = .59), t(44) = 8.495, *p* = .004. Mann Whitney U test was conducted due to the non-normal distribution of both the SAFE and ABC scores.

Table 4.22

Descriptive Characteristics for Falls

	Faller N = 10		Non-Faller N = 34	
Characteristic	Mean/N	(SD) / %	Mean/N	(SD) / %
Age (years) N = 44	74.4	(8.0)	72.74	(5.6)
Gender Female/Male	7/3	70%/30%	23	67.60%
Age Group 65-74	6	60.0%	21	77.80%
Age Group 75-older	4	40.0%	13	76.50%
Location (Site 1)	4	40.0%	18	77.30%
(Site 2)	6	60.0%	16	72.70%

Note. SD: standard deviation; % percentage.

Table 4.23

Descriptive Characteristics for ABC and SAFE

	Faller N = 10		Non-Faller N =34	
Characteristic	Median	Q1-Q3	Median	Q1-Q3
SAFE	6.5	7-8	7	7-8
ABC Score	87.5	78-97%	95	89-97%

Note. SD: standard deviation; SAFE: screening assessment for falls evaluation; Mdn: Median; ABC: Activities-specific Balance Confidence; Q1-Q3: Quartile 1-Quartile 3.

The test indicated that the ABC scores were not different in fallers compared to non-fallers. Mann-Whitney U= 134 n^1= 33, n^2= 10, p = .386. The Mann-Whitney U test for SAFE scores indicated there was a statistically significant difference between fallers and non-fallers. The results were U= 75, n^1= 34, n^2= 10, p = .007. The conclusion is to fail to reject the null hypothesis that there are no differences in the SAFE scores between the two groups.

The following three figures demonstrate the mean differences and 95% CI in the three QTUG measures of time recording. Recording time measures the total time from the word "Go" until the subject contacts the seat of the chair. Pre-turn time only measures the time from the word “Go” to the initiation of the turn. Walk time eliminates the sit to stand and stand to sit transfer time. Figure 4.17 shows the mean for record time and 95% CI for fallers and non-fallers.

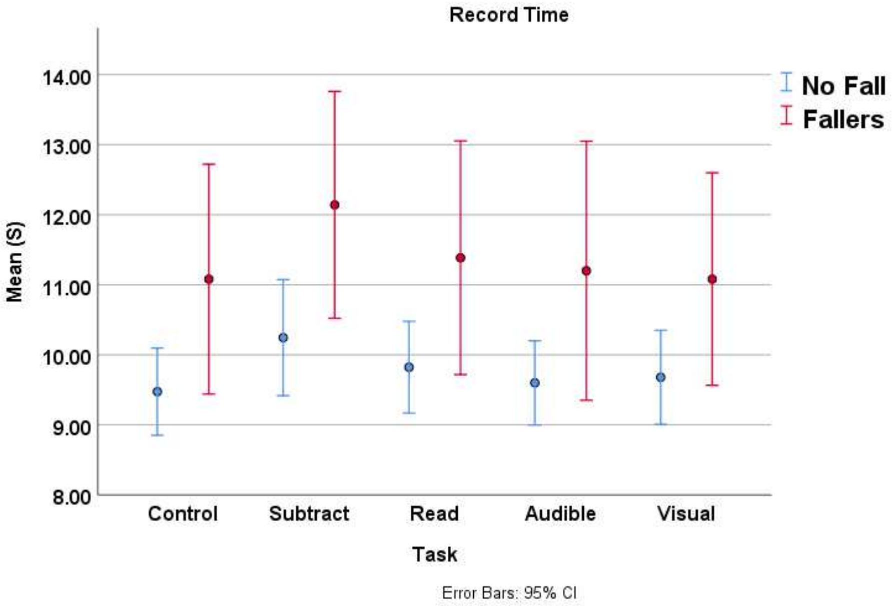


Figure 4.17 Mean Recording Time of each TUG condition.

An independent-samples t-test was conducted to compare the means of fallers and non-fallers with the recording time mean parameter for each of the 5 test conditions (see Table 4.24). There was a significant effect for fallers compared to non-fallers for Control [F(42) = .043, *p* = .024], Subtract [F(42) = .196, p = .030], Reading [F(42) = .287, *p* = .034], Audible [F(42) = 2.23, *p* = .027], Visual [F(42) = .427, *p* = .054]. The mean time was not significantly different for the Visual *p* = .054, which is greater than the ($p < 0.05$), but was approaching significance. Interpretation: There was a significant difference in the p values of the control and four conditions for total recording time for the TUG test comparing the means of fallers to non-fallers. In summary, we reject the null hypothesis that there is no difference in the mean of the fallers and non-fallers for recording time control, subtract, reading, and audible.

Table 4.24

Recording Time (s) Independent Samples t-test

Condition	Faller N= 10	Non-Faller N= 34	Statistical significance
	Mean (SD)	Mean(SD)	*p*-value
Control	11.08 (2.29)	9.47 (1.79)	**.024***
Subtract	12.14 (2.26)	10.24 (2.38)	**.030***
Read	11.38 (2.33)	9.82 (1.87)	**.034***
Audible	11.20 (2.58)	9.60 (1.72)	**.027***
Visual	11.08 (2.12)	9.68 (1.92)	.054

*$p < 0.05$

Figure 4.18 demonstrates the mean for pre-turn time and 95% CI for fallers and non-fallers. There is a proportional and consistent difference between the two groups across all five conditions with much larger 95% confidence intervals for fallers.

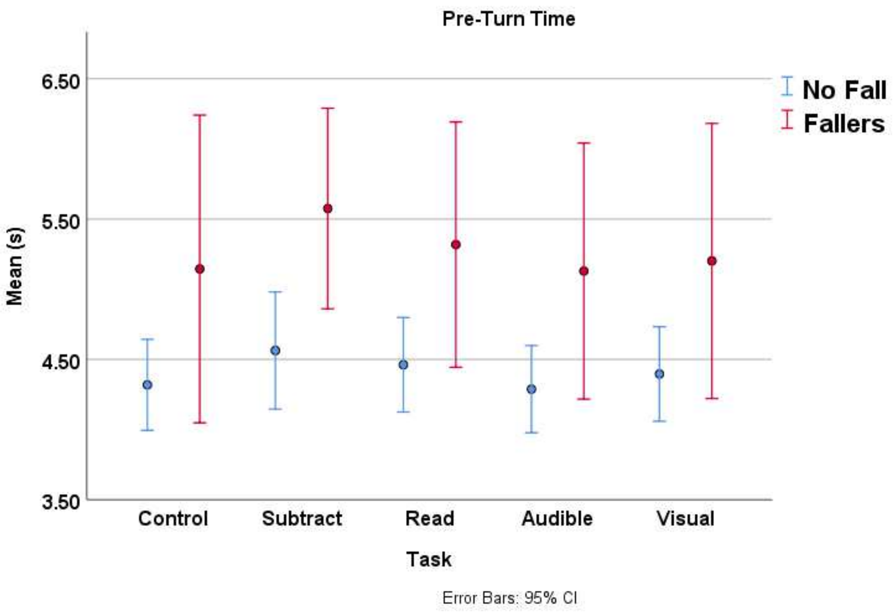


Figure 4.18 Mean Pre-Turn Time of each TUG condition.

An independent-samples t-test indicated that pre-turn times (Table 4.25) were significantly higher for the Subtraction condition for participants who reported a fall (M = 5.58, SD = 1.00), than for non-fallers (M = 4.56, SD = 1.19) t(42) = -2.43, p = .019, $p < 0.05$.

Table 4.25

Pre-Turn Time (s) Independent Samples t-test

Condition	Faller	Non-Faller	Statistical significance
	Mean (SD)	Mean(SD)	*p*-value
Control	4.70 (.68)	4.32 (.93)	.252
Subtract	5.58 (1.00)	4.56 (1.19)	**.019***
Read	5.32 (1.22)	4.46 (.97)	**.025***
Audible	5.13 (1.28)	4.29 (.89)	**.022***
Visual	5.20 (1.37)	4.40 (.97)	**.042***

*$p < 0.05$

Pre-turn time means for the Reading conditions for fallers (M = 5.32, SD = 1.22), for non-fallers (M = 4.46, SD =.97) t(42) = -2.32, p = .025, $p < 0.05$. Audible conditions for fallers (M = 5.13, SD = 1.28), for non-fallers (M = 4.29, SD = .89) t(42) = -2.37, p = .022, $p < 0.05$. Visual condition for fallers (M = 5.20, SD = 1.37), for non-fallers (M = 4.40, SD = .97) t(42) = -2.10, p = .042, $p < 0.05$. There is a significant difference between fallers and non-fallers for all cognitive conditions except the control.

Figure 4.19 demonstrates the mean for walk time and 95% CI for fallers and non-fallers. There is a proportional and consistent difference between the two groups across all five conditions, with 95% confidence intervals for fallers measuring almost twice the value of non-fallers.

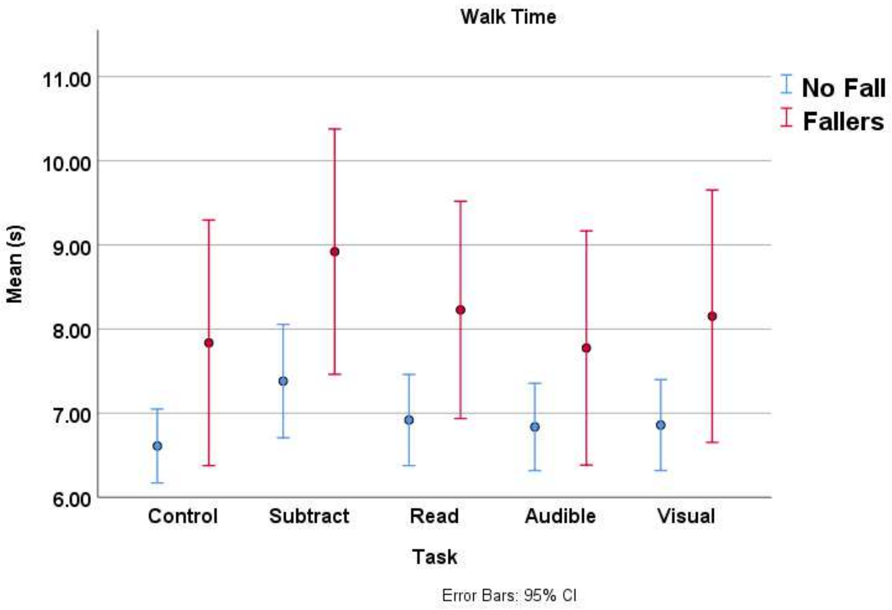


Figure 4.19 Mean Walk Time of each TUG condition.

Due to the non-normal distribution of Control and Visual conditions, a log transformation was used for all conditions. Parametric statistical analysis was then able to be performed on the transformed data. Independent samples t-test indicated that mean walk times were significantly slower for fallers in all conditions except Audible.

Table 4.26

Walk Time (s) Independent Samples t-test

Condition	Faller	Non-Faller	Statistical significance
	Mean (SD)	Mean(SD)	*p*-value
Control	7.84 (2.04)	6.61 (1.26)	**.031***
Subtract	8.92 (2.04)	7.38 (1.93)	**.035***
Read	8.23 (1.80)	6.92 (1.55)	**.033***
Audible	7.77 (1.95)	6.84 (1.49)	.119
Visual	8.15 (2.10)	6.86 (1.55)	**.039***

Note: Control and Visual data sets were skewed, and all data underwent a Log transformation. Statistical analysis for comparing means was completed with transformed data. *$p < 0.05$

Stride length means with 95% CI for fallers and non-fallers reveal a consistent decrease in stride length in participants that reported a fall in the past 12 months. (Figure 4.20)

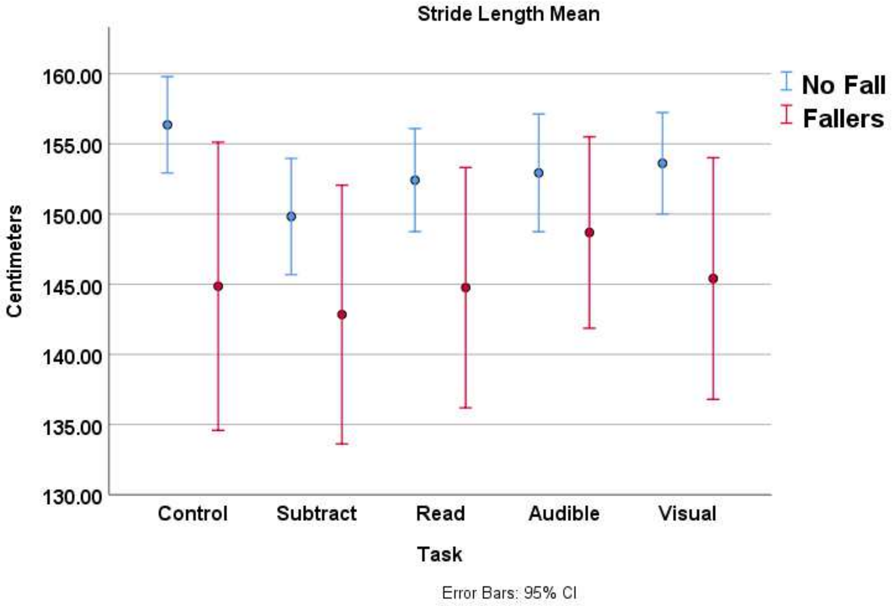


Figure 4. 20 Mean Stride Length of each TUG condition.

Independent samples t-test indicated that stride length mean distances were statistically significantly smaller fallers for Control and Visual conditions. The 95% confidence intervals were almost twice as large for fallers compared to non-fallers in all stride length distances and all conditions. Stride length mean for subtraction condition for participants who reported a fall (M = 114.85, SD = 14.35), for non-fallers (M = 156.36, SD = 9.84) t(2.91) = .006, $p < 0.05$. Stride length mean for visual condition for participants who reported a fall (M = 145.40, SD = 12.04), for non-fallers (M = 153.61, SD = 10.35) t(2.12) = .040, $p < 0.05$. Stride length mean for read condition for participants who reported a fall (M = 144.76, SD = 11.97), for non-fallers (M = 152.42, SD = 10.53) t(1.96) = .056 greater than $p < 0.05$ but is approaching significance.

Table 4.27

Stride Length (cm) Independent Samples t-test

Condition	Faller	Non-Faller	Statistical significance
	Mean (SD)	Mean (SD)	*p*-value
Control	144.85 (14.35)	156.36 (9.84)	**.006***
Subtract	142.84 (12.89)	149.82 (11.87)	.116
Read	144.76 (11.97)	152.42 (10.53)	.056
Audible	148.68 (9.54)	152.93 (12.03)	.312
Visual	145.40 (12.04)	153.61 (10.35)	**.040***

*$p < 0.05$

Figure 4.21 demonstrates the mean for stride velocity and 95% CI for fallers and non-fallers. This figure indicates that Stride velocity mean speeds were all slower for those participants with a history of falls. The 95% CI is much larger for those with a history of falls.

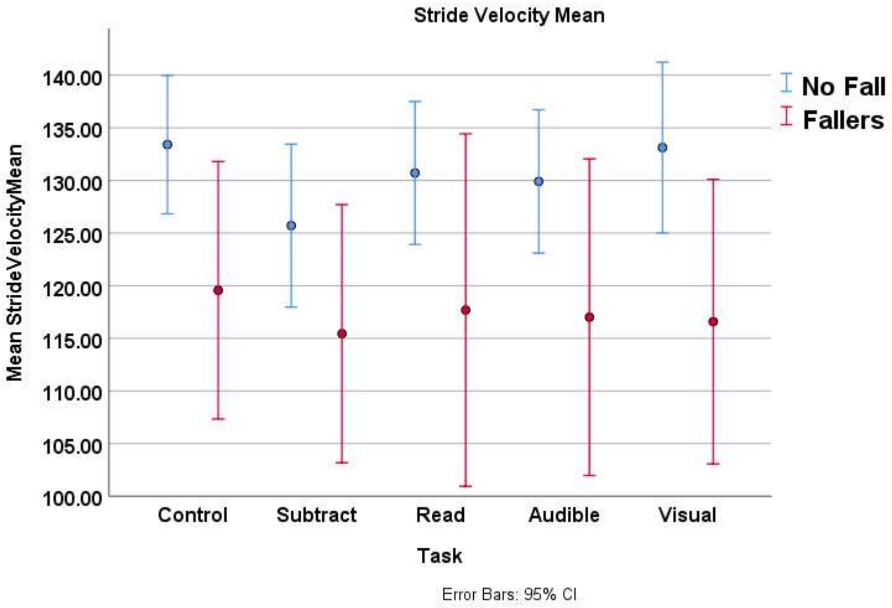


Figure 4.21 Mean Stride Velocity cm/sec of each TUG condition.

Independent samples t-test results for stride velocity are found in Table 4.28. Stride velocity mean for Control condition for participants who reported a fall (M = 119.56, SD = 17.10), for non-fallers (M = 133.41, SD = 18.86), t(2.08) = .044, $p < 0.05$. Stride velocity mean for visual condition for participants who reported a fall (M = 116.59, SD = 18.90), for non-fallers (M = 133.12, SD = 23.27) t(2.05) = .046, $p < 0.05$.

Table 4.28

Stride Velocity (cm/s) Independent Samples t-test

Condition	Faller	Non-Faller	Statistical significance
	Mean (SD)	Mean(SD)	*p*-value
Control	119.56 (17.10)	133.41 (18.86)	**.044***
Subtract	115.44 (17.14)	125.71 (22.17)	.185
Read	117.68 (23.41)	130.71 (19.45)	.083
Audible	117.00 (21.03)	129.91 (19.53)	.078
Visual	116.59 (18.90)	133.12 (23.27)	**.046***

*$p < 0.05$

Figure 2.22 demonstrates the difference in stance times for fallers vs. non-fallers. The mean stance time is increased for fallers when compared to non-fallers. The largest mean stance time was found with the Read condition in fallers, and the largest stance time in non-fallers was present in the Subtract condition.

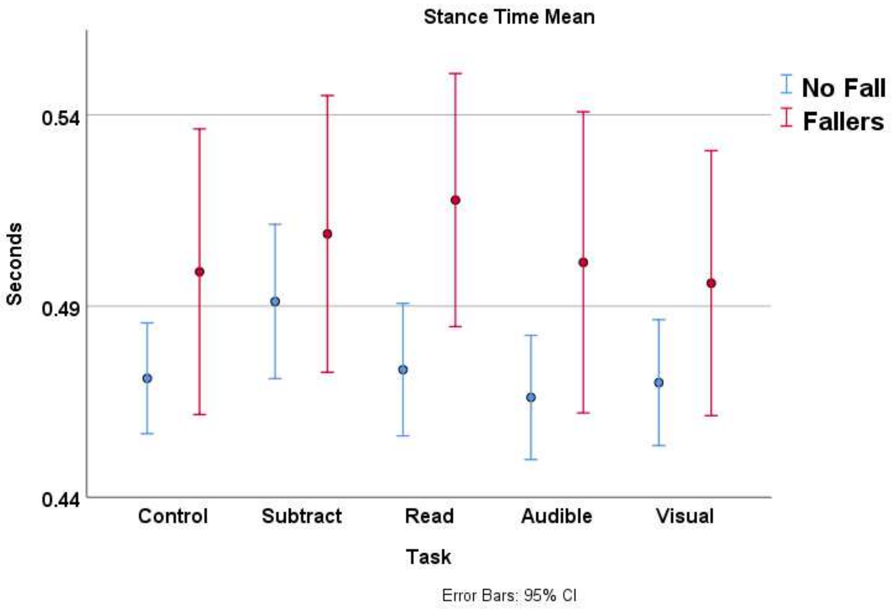


Figure 4.22 Mean Stance Time of each TUG condition.

Table 4.29 shows that there is a significant difference between stance time means for the Read and Audible conditions. Stance time mean for read condition for participants who reported a fall (M =.51, SD = .05), for non-fallers (M = .47, SD = .05) t(-2.52) = .016, $p < 0.05$. Stance time mean for audible condition for participants who reported a fall (M = .50, SD = .06), for non-fallers (M = .46, SD = .05) t(-2.02) = .049, $p < 0.05$.

Table 4.29

Stance Time (s) Independent Samples t-test

Condition	Faller	Non-Faller	Statistical significance
	Mean (SD)	Mean(SD)	*p*-value
Control	.49 (.05)	.47 (.04)	.086
Subtract	.51 (.05)	.49 (.06)	.389
Read	.51 (.05)	.47 (.05)	**.016***
Audible	.50 (.06)	.46 (.05)	**.049***
Visual	.49 (.05)	.47 (.05)	.135

*$p < 0.05$

Research Question # 4 Is there a correlation between the ABC and SAFE scores and each QTUG parameter?

Ho: There is no linear correlation between the QTUG parameters and the SAFE and ABC scores.

H1: There is a linear correlation between the QTUG parameters and the SAFE and ABC scores.

A Pearson's correlation was performed to assess the magnitude of the linear relationship between the balance confidence and screening for falls risk scores. The following table 4.28 shows the Pearson's correlations coefficients for the ABC scores and eight of the QTUG parameters.

Table 4.30

Pearson Correlation Coefficient for ABC Score with QTUG Parameters

	Condition N= 43				
	Control	Subtract	Reading	Audible	Visual
Parameter					
Record Time	**-.362***	**-.467****	**-.343***	**-.361***	**-.447****
Pre-Turn	-.281	**-.446****	**-.375***	**-.409****	**-.497****
Stride Length	.256	**.431****	**.378***	**.391****	**.393****
Cadence	.189	.156	-.012	.059	.263
Stride Time	-.153	-.087	-.007	.007	-.152
Stride Velocity	.171	.266	.161	.214	.295
Swing Time	-.007	-.012	.074	.087	.031
Step Time	-.057	-.094	-.001	-.032	-.184

Note; **p* < 0.05. ***p* < 0.01. 0-0.19: very weak; 0.2- 0.39: weak; 0.4 – 0.59: Moderate; 0.6 - 0.79: strong

The ABC scores had a weak to moderate negative correlation to recording time for all conditions Control r = -.362, n = 43, *p* = .017, Subtract r = -.467, n = 43, *p* = .002, Read r = -.343, n = 43, *p* = .024, Audible r = -.361, n = 43, *p* = .017, and Visual r = -.447, n =

43, *p* = .003. The highest correlation for the ABC score and record time parameter was with the subtract condition. The highest overall correlation coefficient for the ABC score was with the pre-turn time mean and the visual condition. The visual condition for pre-turn time had a moderate negative correlation r = -.497, n = 43, *p* = .001. An increase in ABC score was moderately correlated to a decrease in pre-turn time. The ABC scores had a weak to moderate positive correlation for stride length under the following conditions; Subtract r = .431, n = 43, *p* = .004, Read r = .378, n = 43, *p* = .013 , Audible r = .391, n = 43, *p* = .010, and Visual r = .393, n = 43, *p* = .009. An increase in ABC scores demonstrated a weak to moderate correlation to an increase in stride length. There were no significant findings between ABC scores and stride velocity, swing time, stride time and step time.

Scatter plots were created comparing the ABC score and SAFE scores with the QTUG parameters of stride length, record time, and pre-turn time with best fit lines for fallers, non-fallers, and total.

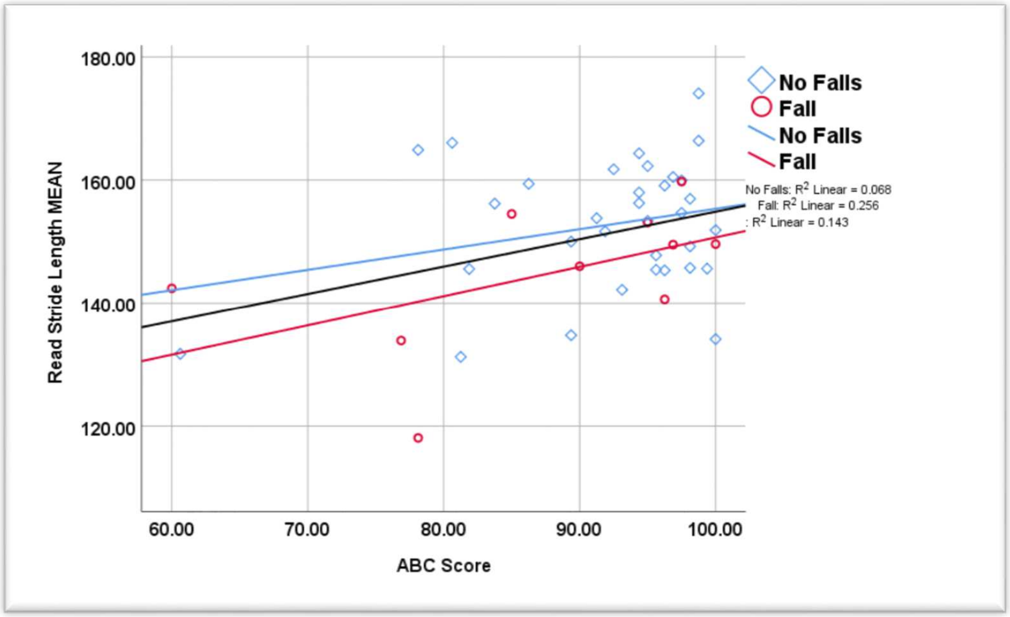


Figure 4.23 A scatterplot for Stride length Mean and ABC score for Read Best fit lines for those with falls, non-fallers, and a total of all participants.

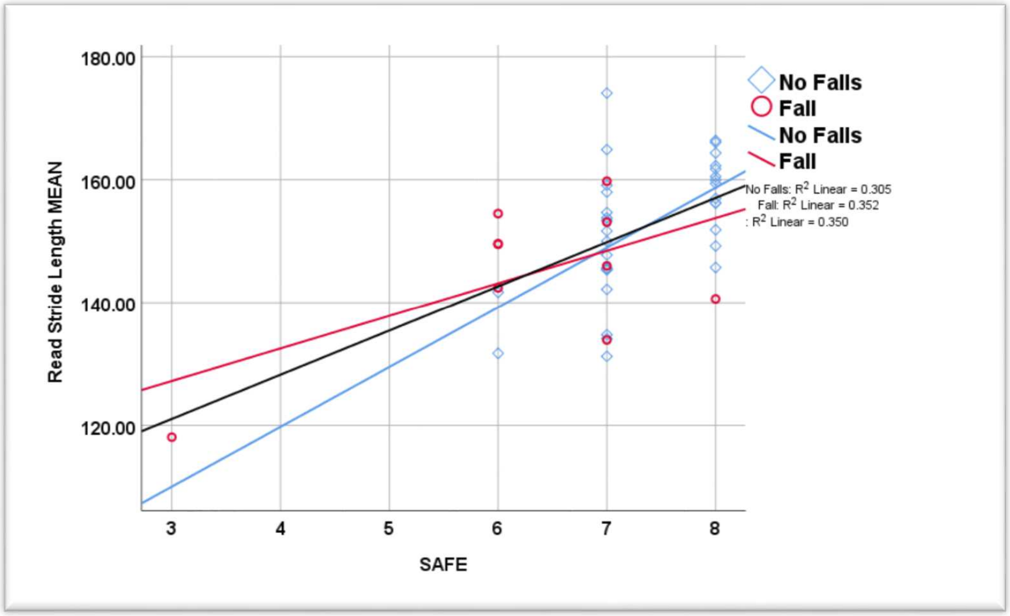


Figure 4.24 A scatterplot showing Stride length means during the read condition against the SAFE score. Best fit lines for those with falls, non-fallers, and a total of all participants.

The SAFE scores also had a moderate positive correlation for stride length under all conditions; Control r = .511, n = 44, *p* = .000, Subtract r = .488, n = 44, *p* = .001, Read r = .592, n = 44, *p* = .000, Audible r = .462, n = 44, *p* = .000, and Visual r = .554, n = 44, *p* = .000.

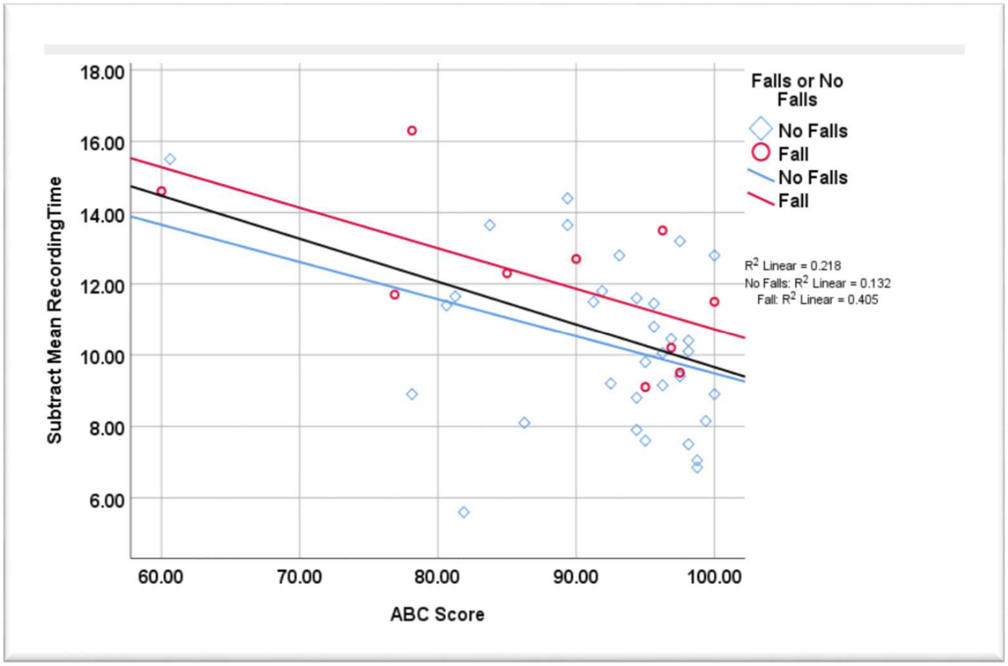


Figure 4.25 A scatterplot showing recording time means during the Subtract condition against the ABC score. Best fit lines for those with falls, non-fallers, and a total of all participants.

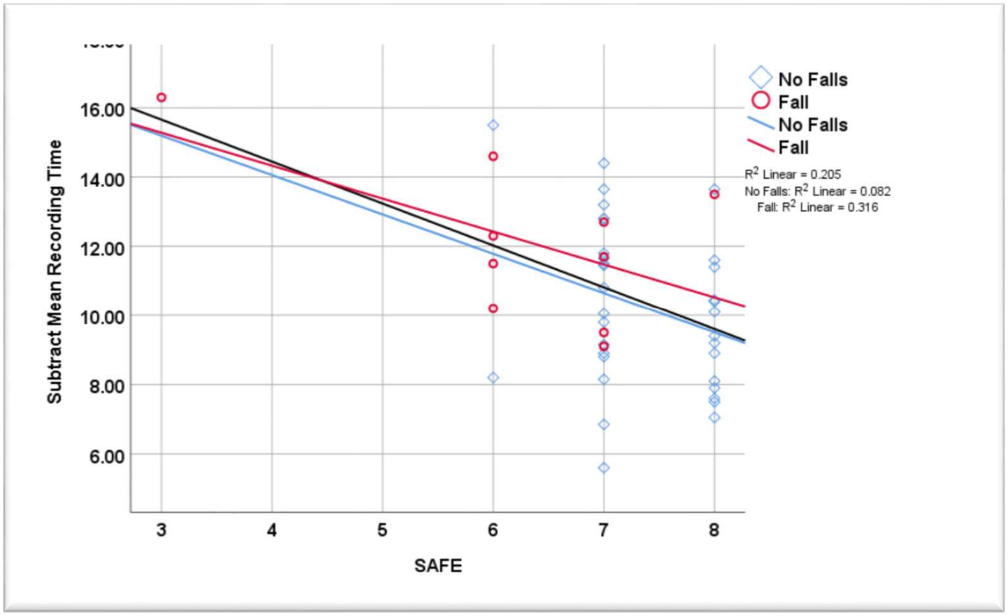


Figure 4.26 A scatterplot showing recording time means during the Subtract condition against the SAFE score. Best fit lines for those with falls, non-fallers, and a total of all participants.

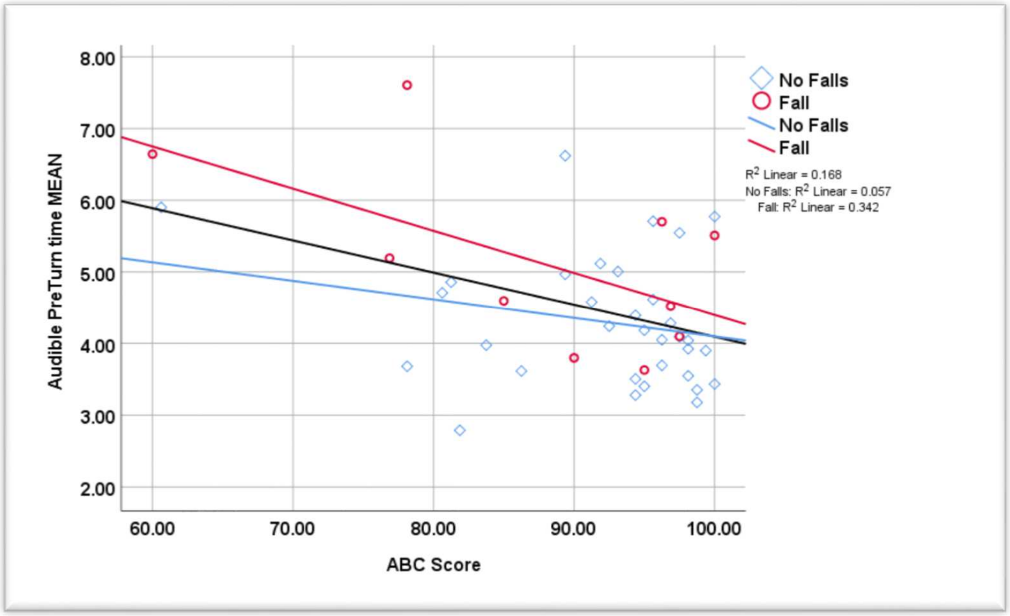


Figure 4.27 A scatterplot showing pre-turn time means during the Audible condition against ABC score. Best fit lines for those with falls, non-fallers, and a total of all participants.

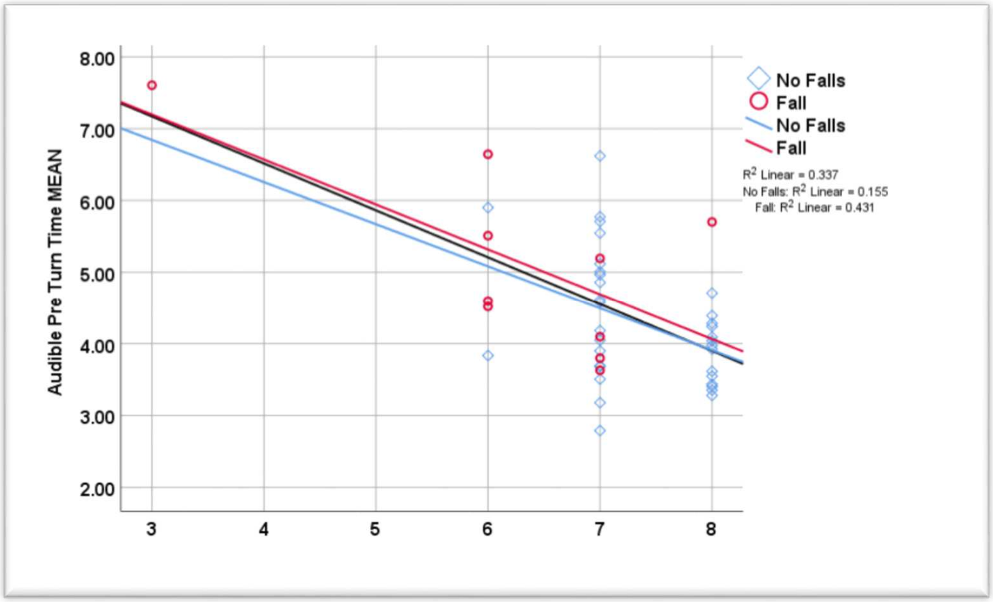


Figure 4.28 A scatterplot showing pre-turn time means during the Audible condition against the SAFE score. Best fit lines for those with falls, non-fallers, and a total of all participants.

Table 4.31

Pearson Correlation Coefficient for SAFE Scores

			Condition	N= 43	
	Control	Subtract	Reading	Audible	Visual
Parameter					
Record Time	**-.509****	**-.453****	**-.472****	**-.472****	**-.427****
Pre-Turn	-.227	**-.528****	**-.523****	**-.580****	**-.577****
Stride Length	**.511****	**.488****	**.592****	**.462****	**.554****
Cadence	**.299***	.239	.194	.264	.292
Stride Time	-.219	-.138	-.151	-.258	-.208
Stride Velocity	**.444****	.279	**.355***	**.422****	**.332***
Swing Time	-.267	-.225	-.284	**-.360***	-.244
Step Time	-.144	-.116	-.212	-.190	**-.333***

Note; *$p < 0.05$. **$p < 0.01$. 0-0.19: very weak; 0.2- 0.39: weak; 0.4 – 0.59: Moderate; 0.6 - 0.79: strong

The ABC and SAFE scores were similar in the correlation directions. SAFE scores were negatively correlated for recording time for all conditions Control r = -.509, n = 44, *p* = .000, Subtract r = -.453, n = 44, *p* = .002, Read r = -.472, n = 44, *p* = .001, Audible r = -.472, n = 44, *p* = .001, and Visual r = -.427, n = 44, *p* = .004.

Weak to moderate positive correlations were found for the SAFE score and stride velocity for Control, r = .444, n = 44, *p* = .027, Read r = .355, n = 44, *p* = .018, Audible r = .422, n = 44, *p* = .004, and Visual r = .332, n = 44, *p* = .027. As the SAFE score increased the stride velocity increased with a weak to moderate correlation.

A weak correlation was found between SAFE scores and Cadence for the Control condition r = .299, n = 44, *p* = .049. Weak negative correlations were found between SAFE score for step time for the visual condition r = -.333, n = 44, *p* = .027, and swing time for Audible condition r = -.360, n = 44, *p* = .016, but no significant correlations were found for the ABC scores for those parameters. There were no significant findings between ABC scores and stride velocity, swing time, stride time, and step time. There were no significant correlations for either score for stance time, single stance, and double stance times.

Research Question # 5 Is the change in swing time variability associated with fallers? Calculations were performed for other variability parameters such as stride length variability, single and double support variability, stride velocity variability, stance time variability, stride time variability, and cadence.

Ho: There is no association in variability parameters in fallers

H1: There is an association in variability parameters in fallers

Log transformation was required for the parameters that violated normality. This allowed parametric testing for differences between groups. Independent t-tests were performed using the Log transformation data to determine if the mean of fallers was significantly different from non-fallers.

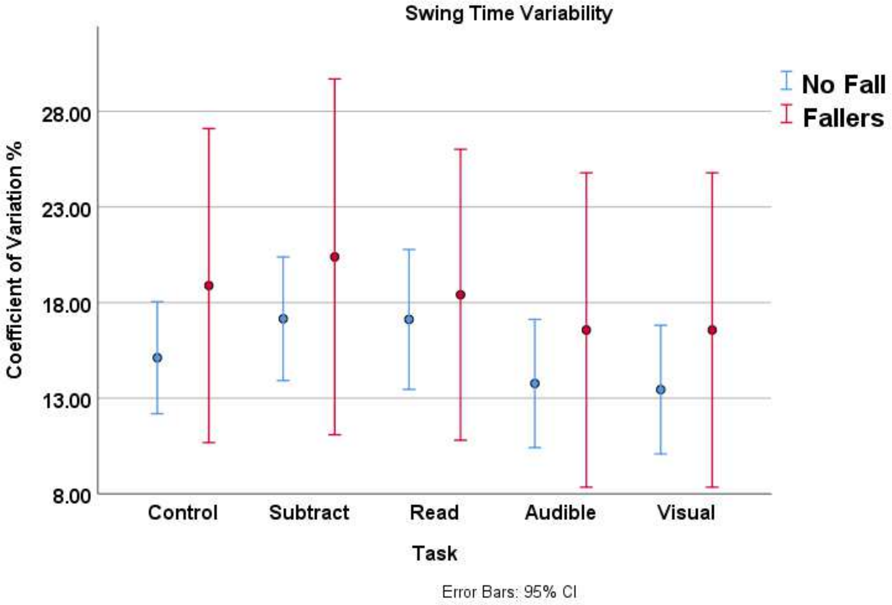


Figure 4.29 Mean and 95% CI for Swing Time Variability of Fallers and Non-Fallers.

Table 4.32

Swing Time Variability (%) Independent Samples t-test after Log Transformation

Condition	Faller N=10	Non-Faller N=34	Statistical significance
	Mean (SD)	Mean (SD)	*p*-value
Control	18.89 (11.48)	15.11 (8.40)	.244
Subtract	20.39 (13.01)	17.15 (9.26)	.633
Read	18.41 (10.64)	17.12 (10.49)	.753
Audible	16.56 (11.50)	13.77 (9.62)	.461
Visual	16.56 (11.49)	13.45 (9.64)	.383

Results of the independent t-test using log transformation revealed no significant differences in the means of fallers vs. the non-fallers in the study. The conclusion is to fail to reject the null hypothesis that there is no difference.

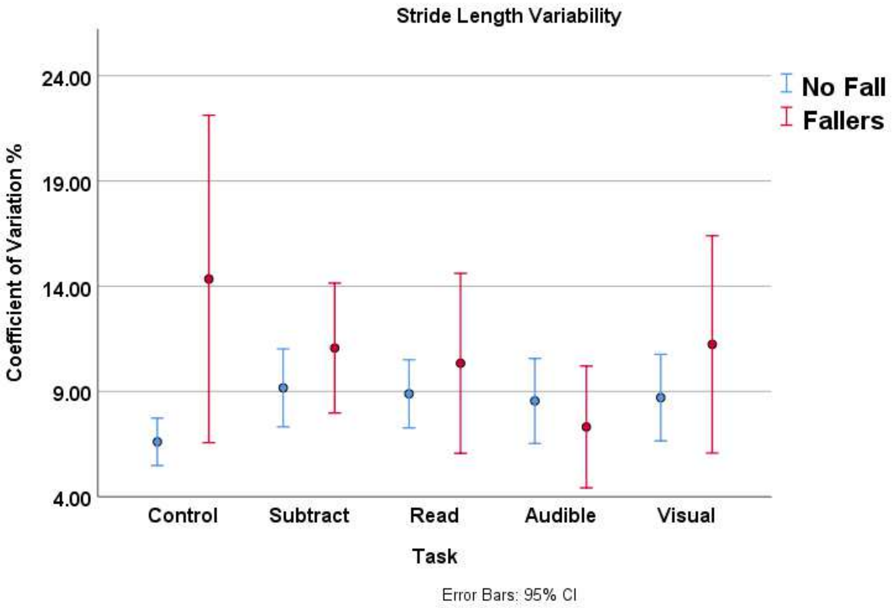


Figure 4.30 Mean and 95% CI for Stride Length Variability of Fallers and Non-Fallers.

Table 4.33

Stride Length Variability (%) Independent Samples t-test after Log Transformation

Condition	Faller	Non-Faller	Statistical significance
	Mean (SD)	Mean (SD)	*p*-value
Control	14.34 (10.87)	6.61 (3.23)	**.005***
Subtract	11.06 (4.31)	9.16 (5.30)	.155
Read	10.34 (5.98)	8.89 (4.64)	.517
Audible	7.31 (4.05)	8.54 (5.79)	.451
Visual	11.23 (7.22)	8.71 (5.89)	.521

*$p < 0.05$

Log transformation was performed to normalize the stride length variability parameter. Results of the transformation were used in a t-test to compare the means stride length variability of fallers and non-fallers. Control was the only condition that demonstrated a statistically significant result. We thus reject the null hypothesis that there is no difference in stride length variability between fallers and non-fallers under a normal TUG test.

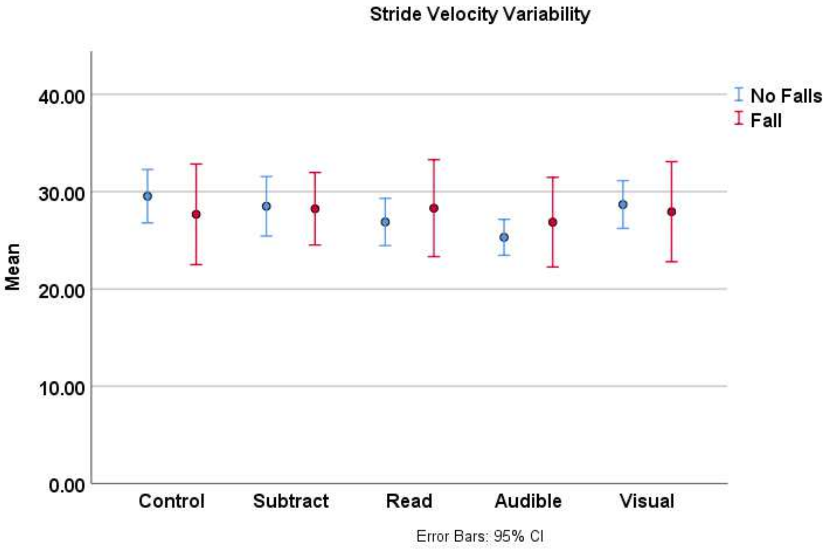


Figure 4.31 Mean and 95% CI for Stride Velocity Variability of Fallers and Non-Fallers.

Table 4.34

Stride Velocity Variability (%) Independent Samples t-test after Log Transformation

Condition	Faller N=10	Non-Faller N=34	Statistical significance
	Mean (SD)	Mean (SD)	*p*-value
Control	27.66 (7.23)	29.53 (7.86)	.460
Subtract	28.24 (5.21)	28.49 (8.77)	.882
Read	28.30 (6.97)	26.88 (6.96)	.543
Audible	26.86 (6.44)	25.30 (5.31)	.503
Visual	27.93 (7.19)	28.67 (7.05)	.790

Log transformation of stride velocity variability means was required to perform parametric testing. No significant differences found between fallers and non-fallers for this parameter under any condition. The conclusion is to fail to reject the null hypothesis that there is no difference.

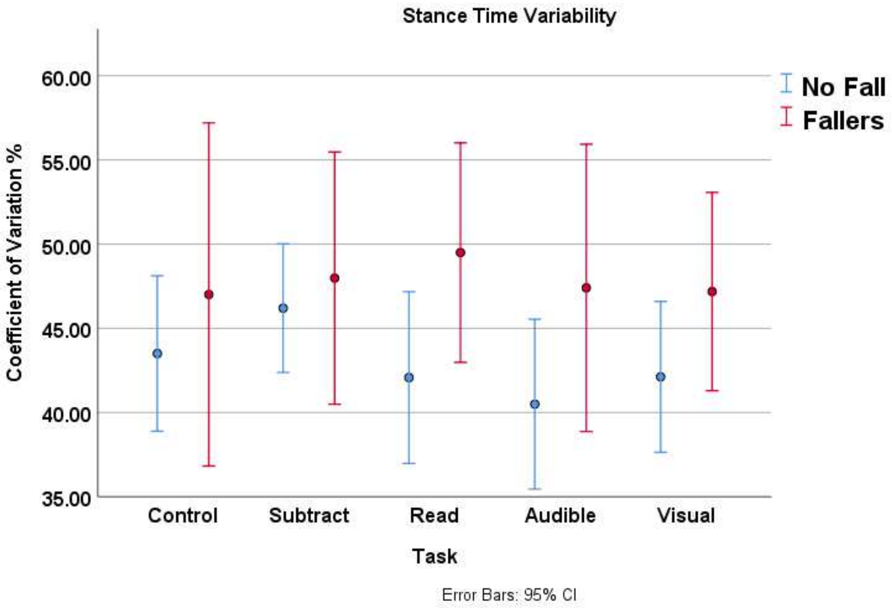


Figure 4.32 Mean and 95% CI for Stance Time Variability of Fallers and Non-Fallers.

Independent t-test results and *p*-values for stance time variability can be found in Table 4.35. There was a difference in the Read condition for stance time variability, but it failed to meet the $p < 0.05$ level. We thus fail to reject the null hypothesis that there is no statistical difference in the conditions for the parameter of stance time variability.

Table 4.35

Stance Time Variability (%) Independent Samples t-test

Condition	Faller N=10	Non-Faller N=34	Statistical significance
	Mean (SD)	Mean (SD)	*p*-value
Control	47.01 (14.24)	43.50 (13.23)	.470
Subtract	47.98 (10.47)	46.19 (10.94)	.649
Read	49.50 (9.11)	42.07 (14.62)	.064
Audible	47.40 (11.93)	40.50 (14.45)	.176
Visual	47.18 (8.23)	42.11 (12.85)	.248

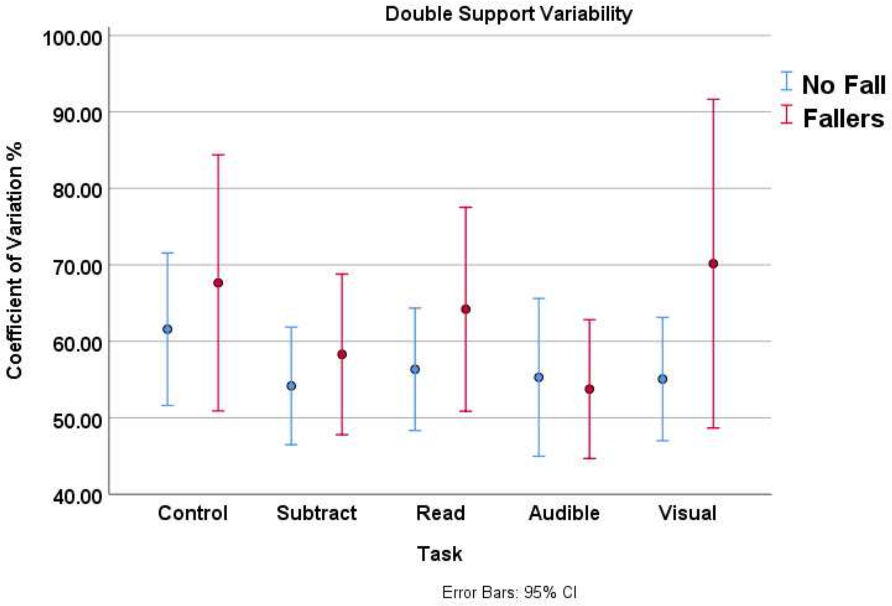


Figure 4.33 Mean and 95% CI for Double Support Variability of Fallers and Non-Fallers.

Table 4.36

Double Support Variability (%) Independent Samples t-test after Log Transformation

Condition	Faller N=10	Non-Faller N=34	Statistical significance
	Mean (SD)	Mean (SD)	*p*-value
Control	67.64 (23.40)	61.58 (28.57)	.544
Subtract	58.29 (14.68)	54.17 (22.04)	.582
Read	64.19 (18.64)	56.34 (22.95)	.329
Audible	53.75 (12.69)	55.29 (29.57)	.813
Visual	70.15 (30.05)	55.06 (23.13)	.094

Double support variability for the visual condition demonstrated a skewness of 1.29. A log transformation was used to normalize the distribution and allow parametric analysis. The log transformation caused the Subtract condition to be become skewed. Control, Subtract, Read and Audible conditions were analyzed before the log transformation with results in Table 4.36. Control, Read, Audible and Visual were evaluated after the log transformation. There is a difference between fallers and non-fallers for Visual condition, but it was not statistically significant. The conclusion is to fail to reject the null hypothesis that there is no difference for the parameter of double support variability.

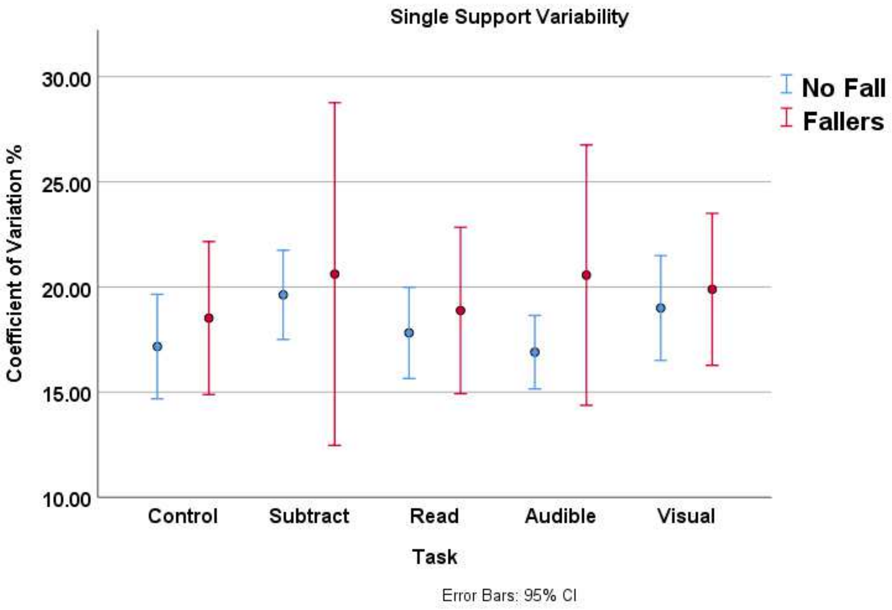


Figure 4.34 Mean and 95% CI for Single Support Variability of Fallers and Non-Fallers.

Table 4.37

Single Support Variability (%) Independent Samples t-test after Log Transformation

Condition	Faller N=10	Non-Faller N=34	Statistical significance
	Mean (SD)	Mean(SD)	*p*-value
Control	18.52 (5.09)	17.17 (7.12)	.580
Subtract	20.61 (11.39)	19.62 (6.08)	.892
Read	18.88 (5.53)	17.82 (6.22)	.629
Audible	20.56 (8.65)	16.90 (5.00)	.228
Visual	19.89 (5.05)	19.00 (7.15)	.716

Single support variability for the Subtract condition demonstrated a skewness of 1.20. A log transformation was used for analysis. Control, Subtract, Read, and Audible were compared in an independent t-test. Control, Read, Audible, and Visual were evaluated before the log transformation with results in Table 4.37 after the log transformation. There is no difference between fallers and non-fallers for any of the conditions. Fail to reject the null hypothesis that there is no difference for the parameter of double support variability.

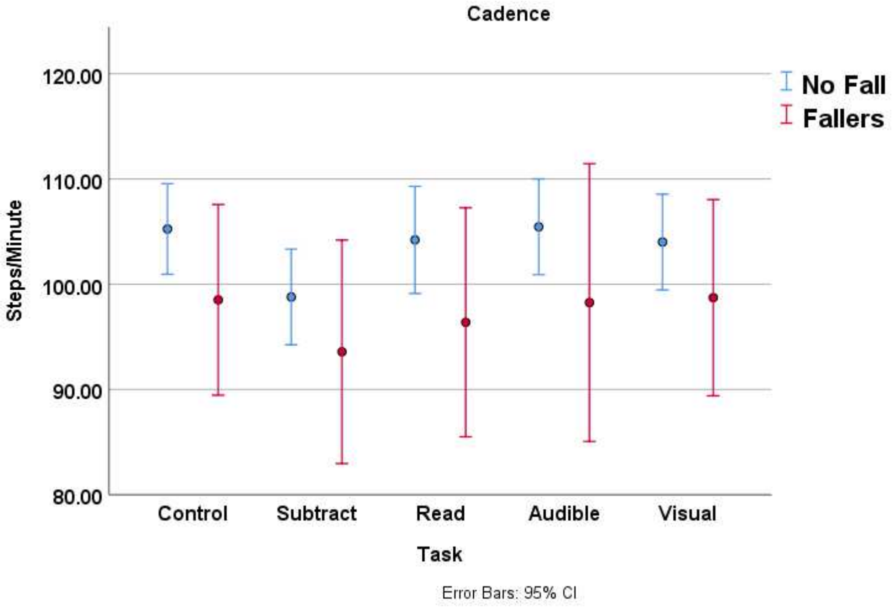


Figure 4.35 Mean and 95% CI for Cadence of Fallers and Non-Fallers.

Independent t-test results indicate that there is no significant difference between the mean for cadence for fallers and non-fallers. Fail to reject the null hypothesis that there is no difference between the groups.

Table 4.38

Cadence (steps/min) Independent Samples t-test

Condition	Faller N=10	Non-Faller N=34	Statistical significance
	Mean (SD)	Mean(SD)	*p*-value
Control	98.51 (12.66)	105.25 (12.34)	.139
Subtract	93.58 (13.82)	98.79 (13.04)	.299
Read	96.38 (15.21)	104.21 (14.60)	.147
Audible	98.25 (18.45)	105.45 (13.03)	.171
Visual	98.72 (13.04)	104.01 (13.04)	.266

Additional Results

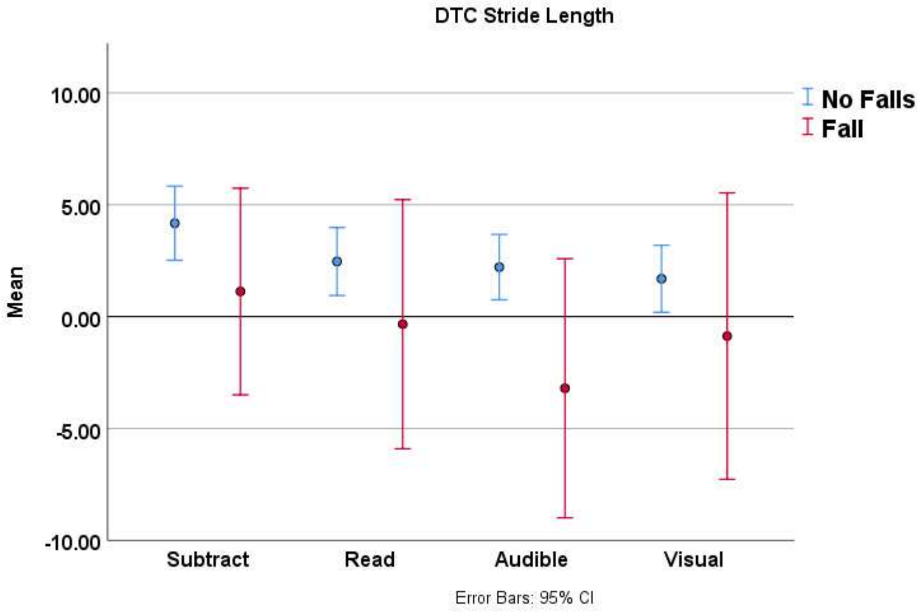


Figure 4.36 Mean and 95% CI for DTC of Stride Length for Fallers and Non-Fallers.

DTC parameters were analyzed for differences between fallers and non-fallers. The only significant findings were in the stride length parameter. A non-parametric Kruskal-Wallis test was performed comparing the four conditions. There was evidence that there is a $p < .022$ difference between the mean ranks of at least one pair of groups.

Table 4.39

Dual Task Cost Stride Length

Condition	Faller N=10	Non-Faller N=34
	Mean (SD)	Mean(SD)
Subtract	1.12 (6.46)	4.17 (4.75)
Read	-.34 (7.78)	2.46 (4.35)
Audible	-3.20 (8.09)	2.21 (4.18)
Visual	-.87 (8.94)	1.69 (4.29)

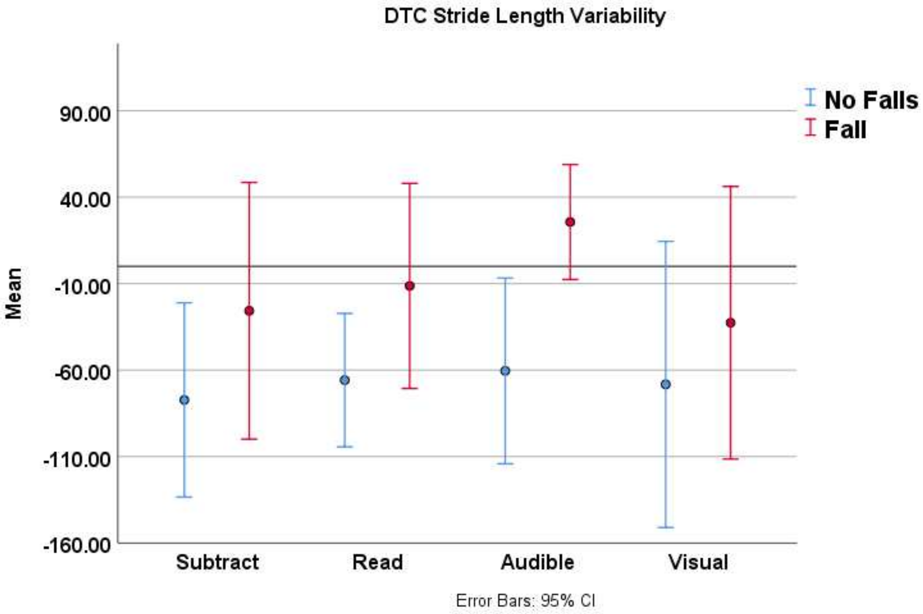


Figure 4.37 Mean and 95% CI for DTC of Stride Length Variability Fallers and Non-Fallers.

Table 4.40

Dual-Task Cost for Stride Length Variability

Condition	Faller N=10	Non-Faller N=34
	Mean (SD)	Mean(SD)
Subtract	-25.72 (103.78)	-77.28 (161.01)
Read	-11.32 (82.89)	-65.83 (110.56)
Audible	25.64 (46.51)	-60.49 (153.98)
Visual	-32.64 (110.22)	-68.30 (237.16)

DTC of stride length variability was analyzed for differences between fallers and non-fallers. A non-parametric Kruskal-Wallis test was performed comparing the four conditions. There was evidence that a p = .015 difference between the mean ranks of at least one pair of conditions. After the correction for three comparisons, there is still a p = .045, and the audible condition was different between fallers and non-fallers. There was no evidence of a difference between the other pairs.

CHAPTER V

Discussion

5.0 Introduction

Included in this chapter are the introduction to the discussion section, discussion of the results of statistical analysis, and research questions. This chapter also includes suggestions for future research and the conclusion of this study.

5.1 Discussion

The specific aim of this study was to determine if there is a measurable difference in spatio-temporal gait parameters in community-dwelling adults under different cognitive demands when performing a TUG test. There is an abundance of research on the effect of dual-task activities on gait, but this study was focused on the selection of cognitive demands.

The QTUG provided reliable sensor-derived measurement of many temporal and spatial gait parameters. The sensor-derived measurements provide an extraordinary amount of data, including phases of movement such as sit to stand time, pre-turn time, and walk time in addition to total TUG time. Instrumented TUG research has shown the ability to detect age related changes in gait in older adults.[234] The results of this study suggest the QTUG is sensitive enough to measure patterns of gait parameters under different and unique cognitive demands. It appears to be a useful resource for clinicians to evaluate healthy and frail older adults.

Discussion of Research Question 1

The first research question was: Is there a difference in the dual-task cost for the TUGvisual, TUGaudible, TUGreading, TUGsubtract in community dwelling adults? The QTUG produced three times components of the TUG. The measurements of record time, walk time, and pre-turn time demonstrated not only rank order, but similar confidence intervals, and characteristics in response to the cognitive conditions. The Subtract condition demonstrated the greatest dual task cost, followed second by Reading with Visual third and Audible fourth. Audible demonstrated the least dual task cost for the timed parameters listed above. The degree that serial subtraction resulted in greater degradation of gait in this study is similar to other research findings and supports clinicians' use of the cognitive task to challenge their patient's dual-task ability.

Physical therapists can utilize the addition of serial subtraction while gait training to challenge the patient’s attention and assess changes in gait. The literature for serial subtraction is substantial and includes concerns of construct validity due to a large degree of individual variation.[195,196] Researchers should use caution when comparing results for serial subtraction in dual-task studies due to the question of construct validity. Prior experience with math can impact the task difficulty as math teachers and retail workers in this study were more effective or automatic in their performance. This study did not track responses for accuracy or frequency, but some participants struggled more than others to perform serial subtraction and suggests that the task is harder for some to perform than others.

The DTC means for stride time and step time were positive under the visual condition, meaning that participants reduced stride and step time compared to control. All other conditions for these two parameters demonstrated a negative DTC mean, meaning stride and step time increased. The positive visual DTC mean was only slightly different from control. Dual-task costs are typically measured by their detrimental effect on gait speed, meaning the speed gets slower during the dual-task. The faster times under the visual condition indicates that the participants found it easier to perform the dual-task compared to the single task. The quickening of gait speed during a dual-task is difficult to find in prior literature. It is possible that because of the small sample size, the positive DTC means were within the margin of error. The purpose of the study was to look for differences based on neural pathways, and because the difference was not significant does not mean no difference existed. There may be several factors to consider why the DTC in the Visual cognitive task was different. Bock et al. suggest that locomotion is visually demanding, such that stability and optical processing already occur with the performance of the TUG.[235] Thus, adding a visual cognitive task to the TUG may only generate a slight additional cognitive load. In this study, the monitor displaying the pictures were directly in front of the participants. The visual stream of information did not have to shift to the left or right, and the line on the floor for the turnaround point likely remained in view. This, however, does not explain why participants took faster steps when compared to the single task condition.

Plummer developed a classification system to illustrate the concept of the various outcomes that can occur during dual task activity.[236] Plummer describes mutual facilitation as an improvement of cognitive and motor performance, and motor facilitation is described as having a stable cognitive performance while the motor performance improves.[236] It is not possible for this study to distinguish between motor and cognitive performance because it did not control for measuring cognitive responses. The primary goal was to investigate the effect of a secondary cognitive task on walking performance. Identifying pictures in the visual confrontation naming task had less impact on some of the temporal parameters, but not all, suggesting those demands were less taxing on the same attention networks than other cognitive tasks.

The DTC mean for cadence (steps/min) under the Audible condition demonstrated a negative mean while the other three conditions had positive means, meaning participants took more steps/minute and reduced the stance time compared to the control. If the other cognitive tasks experienced detrimental effects under the dual-task, Audible stance time means appeared to improve under the same conditions. What would cause a participant to increase steps/min during an audible cognitive task when the other conditions resulted in slower steps/min? This conflicts with the assumption that performing two tasks at once will cause a decline in the performance of one or both tasks. There are several possible explanations. First, it could be within the margin of sampling error because of the small sample size, and it represents a small difference from the control mean. When a task difficulty is too low, participants would be able to perform dual-task conditions as well as a single task. This does not answer the question of why under a second task was the performance better or easier? There could be a difference in levels of available attention between trials and the four cognitive tasks. Yechiam theorizes that mediated attentional processes could be responsible for gains in cognitive models.[237] Performance improvement may occur because of increased attention capacity, and the neural tract for the audible cognitive component mediates attention during dual-task conditions.[237] Another possibility is that allocating auditory cognitive attention mediates attention during dual-task conditions.[238] Another possibility is that allocating auditory cognitive attention to a very easy task such as listening allows spare resources to be applies to the motor task of walking.[238]

It is interesting to note the rank order, patterns of confidence intervals, and contrasting direction of changes in the DTC results of gait parameters under different cognitive conditions even though the results did not reach a $p < 0.05$ level.

Audible and visual condition effects on gait variables were similar in many QTUG parameters. Several studies by Wahn et al. suggests that auditory and visual resources are shared. In addition, if two tasks are performed in separate sensory modalities and interfere less or not at all, then attentional resources are shared. [239,240] This is consistent with the findings in this study, which demonstrates that Audible and Visual conditions had similar effects on several gait parameters.

The degree to which each cognitive demand impacts gait parameters can be seen in the data. The results of this study indicate that there is a stratification of four cognitive demands. Clinicians can easily utilize these common tasks with gait activity in the clinic. The introduction of meaningful cognitive demands may assist with floor or ceiling effects that may exist with testing different populations. Clinical applications can include therapists progressively increasing the difficulty of the dual-task by asking single response questions while walking, scanning a room or hallway to identify a picture or sign, progressing to reading a sign, and advancing to serial subtraction. Successful completion of the secondary task can be objectively documented and can include descriptions of impairments for the outcome. Further research is needed to evaluate the impact of progressive dual-task training on functional outcomes and fall risk in older adults.

Discussion of Research Question 2

The second research question was: Is there a significant difference in gait parameter variability between the TUGcontrol and the four distinct cognitive conditions: TUGvisual, TUGaudible, TUGreading, TUGsubtract?

Skewed data complicated the analysis of the seven different parameters of variability. Sixteen of the thirty-five data sets were skewed, and log transformation was required to perform the analysis.

Gait variability is an important indicator of walking function and fall risk in older adults.[16,36,241-245] This current study found weak test-retest reliability of all gait variability measures in the two trials. This low reliability is consistent with other studies suggesting that a larger number of strides are required to reliably assess variability.[56,246]

Variability in gait can be reported in two different ways. One of the most common ways is using the coefficient of variation (CoV), calculated as the within-subject SD/within subject mean.[114,247,248] Another method looks at the within subject SD. One study suggests that the calculation may explain poor test-retest reliability for CoV as a ratio.[248] If an error is introduced in both the nominator and denominator, then the total error can be larger than the variables. The CoV calculation used in this study was built into the data collection and software output of the Kinesis QTUG. The QTUG CoV data included the variability of stride velocity, stride length, stride time, stance time, swing time, double, and single support parameters. The analysis of variability was likely influenced by acceleration and deceleration with a limited steady state in the TUG test.

The understanding of variability in gait analysis is still limited, and future studies are needed to determine factors that influence variability measures and consistency of testing and analysis.

According to Latash, variability is present in all human movements and can be categorized as good or bad.[249] Good variability speaks to the complex sequences necessary for keeping a variable consistent and having a successful outcome in different conditions. Variability is needed to walk on a sandy beach or slippery sidewalk without falling. Bad variability is the result of errors, which can result in impaired motor control and changes in gait parameters.[249] The variability can result in uneven steps and lateral deviations when walking.

Moe-Nilssen et al. findings suggest that gait variability measures may represent different constructs.[248] Additional analysis of DTC of step length variability and DTC of step time variability was performed, and there was no correlation found between the two parameters. The findings in this study are consistent with that conclusion suggesting that spatial and temporal variability may represent different constructs. The ICC for those parameters in this study did not meet the value of ICC > 0.80, so caution is warranted for any conclusions.

The audible task involved attentive, active listening. Participants knew that they were going to be asked a question, and this anticipation may have elevated or created a heightened state of alertness. Deco et al. suggest that attentional gains can be the result of increased postsynaptic sensitivity, and recent research has shown that when attention is paid to a stimulus, there can be a significant decrease in variability.[81] This effect could have influenced the significant stride velocity variability difference seen with the Audible condition.

There are several clinical implications for these findings. The significant finding for the reduction in variability under the audible condition may not be fully understood and explained until further research in this area can be done. Reproducing the reduction in variability present in both those with a history of falls and non-fallers demonstrates the strength of the relationship between the parameter and the condition. It is possible that clinicians may be able to utilize an audible cognitive task to improve gait by reducing variability, and there may be therapeutic benefits. The effects of audible tasks with pathological conditions such as individuals with Parkinson Disease may provide additional insight.

Reasons for low reliability of CoV can come from innate random variability from one trial to another, gait speed, and measurement error.[250] Recent studies have found that gait speed and gait variability are associated with different functional brain networks.[251] Faster gait speeds are associated with increased connectivity, as confirmed by fMRI results. The fact that this study asked participants to perform the tasks as quickly and safely as possible could have influenced levels of variability. In addition, a longer walking distance may have revealed more variability. This possibility could be explored in a future study using a longer walking distance.

Discussion of Research Question 3

The third research question was: Are the ABC, SAFE scores, and mean TUG time associated with fallers for each of the cognitive conditions?

The ABC scores for fallers and non-fallers were analyzed for group differences to answer this question. Bivariate analysis was performed for research question four. The demographic characteristics of this study differ from numerous studies that have been published. Hatch et al. reported an overall ABC mean score of 78.7 ± 19.08 and a TUG time of 16.00 ± 14.31. [252] Our study's ABC mean score was 91.05 ± 9.53, with a range of 60-100. The TUG mean time was 9.83 ± 2.0. In contrast to this investigation, Cleary et al. allowed individuals with assistive devices, which lowered the mean ABC scores to 50.6 ± 19.1 for fallers and 76.3 ± 21.8 for non-fallers. The changes in gait parameters performing the TUG test and serial subtraction dual-task conditions for fallers in this study are consistent with other studies. Overall, the time to complete the task increases with a secondary task; stride length becomes shorter, the number of steps increases, and double support time increases for those with a history of falls.[69,253,254] The results of this study are different from previous studies that did not show an overall difference in ABC scores between faller and non-faller groups.[127,255]

There is little research data available on the Screening Assessment for Falls Evaluation (SAFE). Kinesis Health Technologies, developer of the QTUG, incorporated the eight questions into the QTUG software. The questions were based on clinical practice guidelines for the American Geriatrics Society/British Geriatrics Society (Appendix E). A yes answer to the question scored a point, and no answer scored 0. The SAFE questionnaire appeared to better discriminate fallers from non-fallers than the ABC scale for the participants of this study. There was a statistically significant difference in the SAFE scores for those with a fall compared to non-fallers. The SAFE questions are a contrast to the confidence questions of the ABC scale. The SAFE questions pertain to medical conditions that can contribute to unsteadiness, such as a fall history, four or more medications, foot problems, dizziness, vision problems, and recent changes in mobility. Such differences might also relate to the difference between the construct of confidence measured in the ABC scale compared to fall risk factors measured in the SAFE.

Significant differences were found in several gait parameters under the conditions of Subtract, Read, Audible and Visual tasks for fallers and non-fallers. The recording time, pre-turn time, and walk time had four of the five conditions that were significantly different in fallers and non-fallers. Pre-turn time is the most interesting because it is the specific period when the participant was affected by the cognitive condition. The results were statistically significant for all conditions except Control. This could be potentially very important to find a testing measure that can accurately identify individuals who have had a fall or exhibit early changes in gait patterns putting them at risk for a fall. The small sample size of this study limits generalization and other conclusions as there were only 10 participants with a history of falls.

Review of Figures 4.19-4.24 reveals that there are strong similarities to the mean for Control and Visual condition as well as similar CI's. For the parameters of stride length and stride velocity, Control and Visual were the only conditions to have significant differences between fallers and non-fallers. The results suggest that there are similar demands between Control and Visual conditions. The ability to answer that question may not be found in the results of this study. Is the task of identifying pictures so easy or is the brain so efficient that it can perform both tasks in the same manner? A possible explanation is that more attentional resources are brought in to perform the demands of that task.

During the Read condition, participants with a history of falls had the highest mean for stance time, but for those without a fall, the longer stand time was during the subtract condition. One factor that could account for this is if the participants had trouble reading the sentence or vision difficulty. The participants were asked in the screening process if they had any difficulties with their vision, but they were not required to take a vision test. It is interesting to note; the data indicates that CI's for gait parameters are much larger for fallers than non-fallers across the all conditions.

The clinical implications of this finding are that clinicians could measure and track changes in pre-turn testing under the four cognitive conditions to identify fallers. A test with construct validity could be a powerful tool to identify those with increased risk of falling and objectively measure and track gait changes.

Discussion of Research Question 4

The fourth research question was: Is there a linear correlation between the ABC and SAFE scores and the QTUG parameters? The ABC and SAFE scores do have a linear correlation to several but not for all parameters. Both the ABC and SAFE scores correlated to all five conditions for the recording time. The ABC had a moderate negative correlation to Subtract and Visual for recording time, and it is interesting to note the two conditions were the only correlations that were higher than the SAFE correlations. This research question did not address a direct comparison of the ABC to the SAFE scores.

There are significant differences between the two types of assessments. The SAFE consists of eight questions about participant's physical and medical status, and the ABC is a measure of self-confidence. It appears to have a higher correlation between fallers and non-fallers than the ABC scale. The lower correlation of the ABC could be related to self-reporting. Participants could be uncomfortable admitting to not functioning as well as they would like to. The ABC could be affected by both social desirability bias and recall bias. The scores could indicate that participants overestimated their confidence levels, which would have impacted the results. The SAFE questions, which were seeking yes or no answers, could be less influenced by self-reporting bias. The findings are consistent with studies that find that those participants with a history of falls tend to have lower ABC scores and have slower TUG times.[60,256]

When comparing the correlations of all conditions for record time, pre-turn time, and stride length, the lowest correlation statistics were found under the Read condition. The pre-turn parameter returned the highest correlation data for both the ABC scale and SAFE scores. Pre-turn time, the specific time when the participants were subjected to the condition demonstrated an increase in correlation for the Read, Audible, and Visual conditions. It is interesting to note that neither ABC or SAFE had more than a very weak correlation to Control for the pre-turn time but had a moderate negative correlation to Subtract, Read, Audible, and Visual conditions. This supports the theory that information gained in assessing gait parameters under different cognitive conditions provides useful fall and balance information for clinicians.

It is interesting to note that the Subtract condition had several of the lowest correlation statistics for the SAFE score. The impact of the math-related cognitive task may not be as highly correlated to changes in parameters that are associated with fallers. This could be a confounder when trying to interpret or predict falls using that cognitive demand. The SAFE score was also weakly negatively correlated with swing time under the Audible conditions and step time under the Visual condition.

Clinician should be aware that increased variability noted in gait during serial subtraction dual-task would not necessarily mean that a patient is at risk for falling. The results of this study show that changes under the other cognitive conditions had a higher correlation to those participants with a history of falls.

The ability for a self-confidence construct and medical status questionnaire to score similarly on a correlation to performance speaks to the importance of using both constructs in assessing falls risk and interpreting gait parameters.

Discussion of Research Question 5

The fifth research question was: Is the change in swing time variability (measured by the difference between the TUGcontrol and the cognitive condition) associated with fallers? Control TUG stride length variability was the only parameter that demonstrated a difference between fallers and non-fallers in this study. Other research has demonstrated a lack of association between variability and fallers in TUG tests as well as gait variability assessment using a 10 meter walkway.[241]

Many of the sensor derived spatio-temporal gait parameters measured by the QTUG are reliable and can be adapted for use in dual-task conditions.[56] The ICC values for variability were very low. This is consistent with previous research that analyzed test-retest reliability of stride time variability while counting backwards as a dual-task with the ICC of CoV measuring slight to poor in all groups (ICC < 0.20).[250] Higher gait variability has been reported for short interrupted walks versus a longer walk because a steady state or rhythm is not established.[40,110,257] The recommendations to measure gait variability, as a single measure, include a minimum of 20 meters or 25 steps.[258] The effect of the selected cognitive tasks on gait variability was not known for repeated measures and was one of the questions of interest.

There are several clinical implications for the analysis of variance. CoV for variability parameters has questionable value in a three-meter TUG test. A longer TUG test of 10 meters may provide an opportunity for the subject to reach a steady state. It appears that there are too few steps taken in a three-meter TUG before the turn. Participants accelerate, decelerate, turn, accelerate, decelerate, turn, and sit down. Clinicians should be cautious when drawing conclusions about increased variability measures when using the TUG test. Additional research is needed to advance knowledge and clarification of the clinical value of gait variability in dual-task conditions and various distances.

Discussion Summary

There is notable interest in advancing the understanding of motor and cognitive components of the TUG and the detection of early changes in gait in healthy older adults. While the TUG consists of everyday movement, it requires a level of planning, orientation in space, and organization.[47] Herman and others suggest that the TUG may require intact cognitive function for optimal performance.[47,259,260] The TUG is a valuable screening tool for clinicians to use for assessment of gait and functional mobility.

The results of obtained in this study hopefully have contributed to advances in understanding how attentional resources are recruited and influence gait across different sensory modalities. The pursuit of this knowledge is on the leading edge of research in gait, dual-task, cognition, and motor control areas. Adding cognitive demands to the TUG test may provide insight into understanding the complex measurement of movement and cognitive resources needed for successful completion. The addition of cognitive tasks may be able to identify subtle differences in gait that may later be classified as normal or abnormal responses during dual-task conditions.

Nordin suggested that variability could be a consequence of the combination of several sequential movements.[138] Variability can be influenced as a result of declining executive function, motor planning and the selected gait speed by the researcher. Self-selected speed produced higher ICC scores in the original QTUG published data, but other studies noted earlier produced much lower ICC data for variability parameters.

There is a longstanding theory that there is a finite amount of attention available and the performance of two tasks simultaneously would result in the degradation of one or both tasks. Ongoing research can demonstrate the existence of anomalies to a theory, and it does not mean a theory is wrong. Minor anomalies can lead to slight changes in theories. Sometimes, the anomalies can lead to a completely different theoretical view.[261] The interpretation of minimal changes in gait parameters with dual-tasks, such as answering a question and identifying pictures, has been accepted that the task difficulty is simply too low to observe any decrease in performance.[240] Wahn et al. 2015 suggest that audio and visual task performance share spatial and attentional resources. This suggests that additional attentional resources are recruited when visual and audio tasks are performed. These additional attentional resources may contribute to minimal changes being measured compared to control. The results of the dual-task demands may appear to indicate that very little change occurs, but there may be more to the results than meets the eye. This study is not able to discern whether there are separate attentional resources or one common pool.

This study was designed to investigate if there were differences in gait changes in community dwelling adults under distinct cognitive conditions. The cognitive conditions were selected based on their different neural pathways. The results of this study have indicated that there are indeed differences in gait parameters under different conditions. The results of this study also suggest that the nature of the cognitive tasks influence the dual-task cost as measured by changes in gait parameters.

This study contributes new information to the literature toward the understanding of the interaction of motor-cognitive dual-task effects on gait.

5.2 Limitations

Methodology: The research methodology and verbal instructions in this study assumed that participants would consistently perform the TUG tests as quickly and safely as possible. However, each subject determined how fast to go. This resulted in difficulty controlling for performing the task as quickly and safely as possible. Some participants appeared to select a conservative pace while others moved briskly. There is also no way to determine if changes in speed for QTUG tests were due to the condition or fluctuation in participant effort. Changes likely reflect a combination of both. The ICC for test-retest reliability suggests that consistency of effort by each subject was acceptable or better.

The order of tests was randomized into Blocks. The Control condition was performed first for every subject. The advantage was that Control would be measured the same way for every subject. The disadvantage is that there could have been a conditioning effect with each test. Control times might have changed if performed after the other conditions.

It was also assumed that the participants would understand and follow the directions that were given. There were slight variations in participants' responses to the conditions that were difficult to control. There were differences in how participants were able to perform the subtraction task. Some participants laughed at themselves when struggling to say numbers out loud. Some participants were proficient with counting naming five numbers in the pre-turn time, and others were only able to come up with one or two numbers. The accuracy of responses was not recorded or controlled. Working memory appears to impact the serial subtraction task as some participants counted both ways even when specifically instructed to only count backwards until they crossed the line to turn around. Counting both ways was noted on the data sheet, but statistical analysis of those individuals compared to those that only counted in pre-turn time did not meet a $p = 0.05$ level of significance.

Some participants gave more than one answer to the Audible condition. An example would be to the question, "What do we tell time with?" Some participants would say, "A watch or a clock." The TUG is a complex task, and there were errors by participants on occasion, slight pauses upon standing when the screen changed, then asking, "Did I do that right?" when they turned around to walk back to the chair.

We chose not to implement a practice test before each new cognitive condition. TUG parameters could potentially improve slightly with up to three repetitions of the test. Fatigue could impact results and future work could be developed to standardize testing.

A sample size of 40 was determined to be necessary for the effect size of this study. The study was able to recruit 44 participants in two locations, which helps with the generalization but did not control for gender, and there were twice as many women as men in the study. Recent research is suggesting that there may be gender differences in gait strategies, but this study was too small to be able to make any assumptions about this. Caution must be used when contributing changes in gait to dual-task effects when there may be other factors to consider.[147,262,263]

Another possible limitation of the study could be related to the mechanism for starting the dual-task stimulus. The QTUG tablet had a touch screen, and the researcher had to manually hit the button simultaneously when saying the word “Go” and touching the stop button when the participant sat down. A pressure sensor in the seat would have ensured greater accuracy in the time measure.

An additional limitation of this study was the small number of participants who had a fall history. The recruitment of community-dwelling adults resulted in only ten who had a history of falls in the past 12 months. The intent was to recruit healthy older adults with a normal gait pattern. The limited number of individuals with falls restricts generalization to other populations beyond this study.

5.3 Future Research

Future research replicating this study should have a larger sample size to allow for greater generalization of the results, including a larger proportion of older adults with a history of falls. Randomly recruiting equal numbers of fallers, non-fallers, and participants by gender would allow for parametric statistical analysis between groups. Performing the Control condition first and last would help to control for possible effects of conditioning over the performance of ten trials.

Screening of participants in future tests could include a cognitive test such as the MMSE for comparison of the cognitive baseline into the analysis. Asking participants to take an eye exam and hearing screen could help ensure that deficits in those areas did not contribute to changes in QTUG parameter measurements.

Allowing a practice trial for every condition may have improved the subject's confidence of how to perform the test correctly. Participants had to rely on verbal instructions to understand what the next test was going to ask them to do. Performing the same tests on two different occasions would add to the reliability of the results.

The QTUG software measured parameters for the entire TUG duration. The accuracy of the measurements of interest would have improved if parameter data could have been limited to pre-turn time only. The data collection would only include the time when the subject was subjected to the condition. As a result, the changes in gait during the time of interest were averaged over the walk time of the TUG.

The type of objective assessment of gait parameters used in this study has the potential to improve the quality of care and fall prediction ability for community-dwelling older adults. Also, the QTUG can be used to longitudinally track gait and balance changes over time while providing objective clinical data and educating individuals about subtle changes in gait and mobility.

5.4 Conclusion

The cognitive tasks of reading, answering a question, identifying pictures by name and serial subtraction have different impacts on gait variability and dual task costs of certain gait parameters when performed with a TUG test in older community dwelling adults. Of the four dual-task conditions, the cognitive task of subtract significantly impacts dual-task costs for TUG recording time, stride time, step time, stance time, stride length, stride velocity, and cadence. The results indicate that gait variability does not always increase with a secondary task, as previous research has shown. The results suggest that analysis of gait parameters during different cognitive dual-tasks may provide important insight and assessment of different neural pathways.

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Appendix A

NSU IRB APPROVED:
Approved: November 26 , 2018
Expired: November 25, 2019
IRB#: 2018-609-Non-NSU

Dr. Pallavi Patel College
of Health Care Sciences
NOVA SOUTHEASTERN UNIVERSITY
NSU
Florida

Gait, Balance Confidence and Dual-Task Study

Be part of an important study to improve the understanding of how common distractions such as talking, reading and counting impact walking and balance.

- Are you 65 years of age or older?
- Are you able to walk without a cane or walker?

If you answered YES to these questions, you may be eligible to participate in a research study. The purpose of this research study is to compare how simultaneously reading, answering questions, counting backwards and identifying pictures affects walking. If you are 65 years of age or older and can walk without pain or a limp you are eligible to participate. Participation will only require one visit that should not exceed two hours. This study is being conducted in Dubuque, Iowa and the surrounding tri-state area. Please call Laurie Hiatt Physical Therapist at **(563) 580-8708** for more information. This research study is being conducted through Nova Southeastern University's Dr. Pallavi College of Health Care Sciences. 3301 College Avenue, Fort Lauderdale, Florida 33314-7796

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Dr. Pallavi Patel College
of Health Care Sciences
NOVA SOUTHEASTERN UNIVERSITY | NSU Florida

General Informed Consent Form
NSU Consent to be in a Research Study Entitled

Does the Type of Dual Cognitive Task Impact Gait Variability Using the Quantitative Timed Up and Go (QTUG) in Community-Dwelling Adults?

Who is doing this research study?

College: Nova Southeastern University- Ft. Lauderdale, Florida
Dr. Pallavi Patel College of Health Care Sciences
Department of Physical Therapy Ph.D. Program

Principle Investigator:	**Faculty Dissertation Advisor:**
Laurie Hiatt PT, OCS 11499 Chloe Mae Lane Dubuque, Iowa 52001 (563) 580-8708 Email: lhiattpt@mchsi.com	Mary Tischio Blackinton PT, EdD, GCS, CEEAA Director, Professional DPT -Tampa Program Associate Professor, PT Department Nova Southeastern University-Ft. Lauderdale Dr. Pallavi Patel College of Health Care Sciences 3632 Queen Palm Drive Tampa, FL 33619 (813) 574-5311 maryb@nova.edu

Funding Source: Unfunded

Study Site Locations:

Grant Regional Health Center Solutions 507 South Monroe Street Lancaster, WI 53813	Statera Integrated Health and Wellness 3375 Lake Ridge Drive Dubuque, Iowa 52003

IRB protocol #: 2018-609-Non-NSU

This research has been reviewed and approved by the Institutional Review Board (IRB) at Nova Southeastern University, the committee that reviews research on human participants. You may contact them at 954-262-5369 or irb@nova.edu . You may also visit NSU IRB website at www.nova.edu/irb/information-for-research-participants for further information.

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What is this study about?

This is a research study, designed to test and create new ideas that other people can use. The purpose of this study is to determine if there is a difference in walking when you are given different types of tasks to do at the same time. Dual-tasking means doing two tasks at one time. This often happens in daily activities. When we are performing more than one task, it can impact our ability to do each task well. The Timed Up and Go (TUG) test requires you to stand up from a chair, walk 10 feet, turn around, and return to the same chair. This study will ask you to perform this task by itself, and then 4 different tasks will be added one at a time while doing the TUG. The types of tasks that will be added include answering a question, naming a picture, reading a sign, and subtracting numbers. You will also be asked to fill out a form asking questions about your self-confidence when performing common daily activities.

Why are you asking me to take part in this study?

You are being asked to be in this study if you are aged 65 or older and live in Dubuque, Iowa and surrounding area. We are asking 44 people to participate in this study. It is expected that 22 people will be recruited from each location.

What will I be doing if I agree to be in this research study?

While you are taking part in this study, it will require a one-time session of about 45 minutes to complete. Depending on questions and rest periods, it could take longer, but no more than 90 minutes. During this time you will be asked to answer questions about your balance, vision, balance and falls. You will be asked to perform the TUG test 2 times for a baseline measurement, and then two times for each of the 4 different dual tasks. You will be allowed to rest between tests. Each test can be completed in less than 20 seconds. A small sensor will be placed on the front of each lower leg, held in place by an elastic wrap. The sensor will measure how you walk such as how long your steps are and how each leg compares to the other.

What is experimental?

All of the tests you will be performing are tasks done in everyday life and have been used in research previously. This study is researching if there is a difference in walking when you add different types of dual tasks from what has been studied before. These tasks, including reading, answering questions and identifying pictures have not been studied while performing the TUG test. None of the procedures are new.

What is the risk or danger to me?

This research study involves minimal risk to you. To the best of our knowledge, the things you will be doing have no more risk of harm than you would have in everyday life. The instructions for the test are to perform the two tasks as quickly and safely as possible. If at any time you do not feel safe and would like to stop, you can. Safety is very important, and you are in control of how quickly you move. You may find it hard to perform two tasks at the same time. There is a risk of tripping or falling. The investigator will be standing by you while you perform the tests with a safety belt around you to prevent falls.

What if a research-related injury occurs?

The researchers have taken steps to minimize the known or expected risks. However, in the event of a research-related injury or if you have a bad reaction, please contact the Principal Investigator right away. If you believe that you have been injured while participating in the research, immediately tell the principle investigator. Emergency medical treatment for injuries solely and directly related to your participation in this research study will be provided to you. See the contact section of this form for phone numbers and information.

If you sign this form, you do not give up your right to seek additional compensation if you are harmed because of participation in this study.

What if I do not want to participate or I want to leave this study?

Your participation is completely voluntary, whether you participate or not is totally up to you. If you decide that you do not want to participate or choose to withdraw at any time, you can do so
without any penalty. You can agree to take part and then change your mind. You may have a conflict, and you will be able to reschedule the session. Your decision will not be held against you. You may ask all the questions you would like before agreeing to participate.

Are there any benefits for taking part in this research study?

There are no direct benefits from being in this research study. We hope that the information learned from this study will help to understand the influence of doing a task while walking.

Will I be paid or be given compensation for being in this study?

You will not be given any payments or compensation for being in this research study.

Will it cost me anything?

There are no costs to you for being in this research study.

Will clinically relevant research results be shared with me?

The study investigators plan to share certain research results with people who are in the study. The results will be shared in a peer-reviewed publication, and a copy in the form of an abstract will be made available to participants at their request within 6 months of the completion of the study.

How will you keep my information private?

Your information will be kept completely confidential to the extent allowed by the law. Your information will be coded so that it cannot be linked to you by name. Only the investigators will collect data and have access to the data. Data will be stored on paper forms and in a password protected file flash drive. All paper forms and data files will be stored in a locked box in the locked office of the principle investigator.
All information in this study is strictly confidential unless disclosure is required by law. The University IRB, Primary Investigator, and dissertation chair may review relevant research records.

Whom can I contact if I have questions, concerns, comments, or complaints?

If you have questions now, feel free to ask. If you have more questions about the research, your rights, or have a research related injury, please contact:

Primary Contact
Laurie Hiatt PT, OCS can be reached at (563) 580-8708

If primary contact is not available, contact:
Mary Tischio Blackinton PT, EdD, GCS, CEEAA can be reached at (813) 574-5311

NSU IRB APPROVED:
Approved: November 26 , 2018
Expired: November 25, 2019
IRB#: 2018-609-Non-NSU

Research Participants Rights
For questions/concerns regarding your research rights, please contact:

Institutional Review Board

Nova Southeastern University
(954) 262-5369 / Toll Free: 1-866-499-0790
IRB@nova.edu

You may also visit the NSU IRB website at www.nova.edu/irb/information-for-research-participants for further information regarding your rights as a research participant.

Research Consent & Authorization Signature Section

Voluntary Participation - You are not required to participate in this study. In the event you do participate, you may leave this research study at any time. If you leave this research study before it is completed, there will be no penalty to you, and you will not lose any benefits to which you are entitled.

If you agree to participate in this research study, sign this section. You will be given a signed copy of this form to keep. You do not waive any of your legal rights by signing this form.

SIGN THIS FORM ONLY IF THE STATEMENTS LISTED BELOW ARE TRUE:

- You have read the above information.
- Your questions have been answered to your satisfaction about the research.

Adult Signature Section

I have voluntarily decided to take part in this research study.

Printed Name of Participant	Signature of Participant	Date

Appendix B

List of questions that were used for the Auditory Response Naming Cognitive dual-task.

1. What do we tell time with?
2. What do you do with a pencil?
3. What do you do with soap?
4. What do we do with a razor?
5. What do we cut paper with?
6. What color is grass?
7. What do we light a candle with?
8. How many things are in a dozen?
9. What color is coal?
10. Where do you go to buy medicine?

Appendix C

Reading material that used in the Reading dual-task

1) BONELESS CHICKEN BREAST $3.99 lb
2) DAIRY WHOLE MILK $ 3.49 GALLON
3) WHOLE GRAIN WHEAT BREAD $1.98
4) FRESH STRAWBERRIES $2.25 A QUART
5) ORGANIC BLUEBERRY YOGURT $1.99
6) HAM, EGG, AND CHEESE BISCUITS $2.75

Appendix D

Visual Confrontation Naming # 1

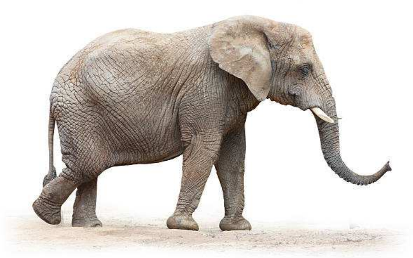

Umbrella


Toaster


Key

Visual Confrontation Naming # 2


Butterfly


Elephant


Carrot

Visual Confrontation Naming # 3


Hammer


Banana


Balloon

Visual Confrontation Naming # 4

Frog

Pencil

Bell

Appendix E

QTUG questions in the Screening Assessment for Falls Evaluation (SAFE)

1) Have you fallen in the last 12 months?
2) Have you had any problems walking or moving around?
3) Are you taking four or more prescription medications?
4) Do you have problems with your feet?
5) Have you had any problems with your blood pressure dropping when you stand up?
6) Do you feel dizzy when you stand up from a sitting position?
7) Do you have any problems with your vision?
8) Have you had any change in your ability to manage your routine activities in the home?

Appendix F

The Activities-specific Balance Confidence (ABC) Scale

For each of the following activities, please indicate your level of self-confidence

by choosing a corresponding number from the following rating scale:

0% 10 20 30 40 50 60 70 80 90

100% **no confidence**

completely confident

"How confident are you that you will not lose your balance or become

unsteady when you.

1. walk around the house?_____ %
2. walk up or down stairs? ____ %
3. bend over and pick up a slipper from the front of a closet floor ____%
4. reach for a small can off a shelf at eye level? ____%
5. stand on your tiptoes and reach for something above your-head? ____%
6. stand on a chair and reach for something? ____%
7. sweep the floor? ____%
8. walk outside the house to a car parked in the driveway? ____%
9. get into or out of a car? ____%
10. walk across a parking lot to the mall? ____%
11. walk up or down a ramp? ____ %
12. walk in a crowded mall where people rapidly walk past you? ____ %
13. are bumped into by people as you walk through the mall? ____%
14. step onto or off an escalator while you are holding onto a railing? ____%
15. step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ____%
16. walk outside on icy sidewalks? ____%

Appendix G

Participant Screening Form

Participant Number: ________________________ Date: ________________________

Age: _______ Height: ___________ft/inches Weight: ___________pounds Gender: M / F

Please answer the following questions below by circling yes or no.

1. Can you walk without assistance or cane in the community? Yes No
2. Have you been diagnosed as having a stroke? Yes No
3. Do you walk with a limp? Yes No
4. Have you had an orthopedic surgery in the past 6 weeks? Yes No
5. Have you been diagnosed with a neurological condition such as Parkinson’s Disease or Multiple Sclerosis? Yes No
6. Do you have any condition that impairs your ability to see and read? Yes No
7. Do you have any condition that impairs your ability to hear and answer questions? Yes No
8. Do you have any trouble with word finding? Yes No
9. Have you had a fall in the past 30 days? Yes No
   (A fall should only be reported if you have fallen to the ground.)
10. Do you have any other medical conditions that might affect your ability to participate in this study? Yes No
11. Do you have any problems withstanding up from a chair, walking about 10 feet, turning around and walking back to a chair? Yes No

If you answered yes to any questions or if you have any other concerns, please explain.

____

____

How many prescription medications do you take? ___________

Highest level of education completed ___________________________________

_______________________________________Investigator Signature Date _______________

Appendix H

Table I.3 CONTROL

Mean and SD for Control comparing Fallers and Non-fallers

	Control Overall	Fallers	Non-Fallers
Parameter	Mean (SD)	Mean (SD)	Mean (SD)
Record Time (s)	9.83 (2.0)	11.08 (2.3)	9.47 (1.8)
Walk Time (s)	6.88 (1.5)	7.83 (2.0)	6.61 (1.3)
Pre-Turn (s)	4.50 (1.1)	4.70 (.7)	4.32 (.9)
Stride Length (cm)	153.7 (11.9)	144.8 (14.4)	156.4 (9.8)
Cadence (step/min)	103.7 (12.6)	97.9 (13.3)	105.2 (12.3)
Stride Time (s)	1.27 (.15)	1.30 (.16)	1.26 (.2)
Stride Velocity (cm/s)	130.3 (19.2)	119.6 (17.1)	133.4 (18.9)
Swing Time (s)	.47 (.04)	.50 (.05)	.47 (.04)
Step Time (s)	.58 (.08)	.59 (.09)	.58 (.09)
Double Support Time (s)	.19 (.06)	.20 (.04)	.18 (.06)
Single Support Time (s)	.40 (.04)	.41 (.03)	.40 (.04)

Table I. 4 SUBTRACT

Mean and SD for Subtract comparing Fallers and Non-fallers

	Subtract Overall	Fallers	Non-Fallers
Parameter	Mean (SD)	Mean (SD)	Mean (SD)
Record Time (s)	10.67 (2.5)	11.08 (2.3)	9.47 (1.8)
Walk Time (s)	7.73 (2.0)	7.83 (2.0)	6.61 (1.3)
Pre-Turn (s)	4.79 (1.2)	5.57 (1.0)	4.56 (1.2)
Stride Length (cm)	148.2 (12.3)	142.8 (12.8)	149.82 (11.8)
Cadence (step/min)	97.7 (13.2)	93.6 (13.8)	98.8 (13.0)
Stride Time (s)	1.32 (.20)	1.35 (.21)	1.31 (.18)
Stride Velocity (cm/s)	123.4 (21.4)	115.44 (17.1)	125.7 (22.2)
Swing Time (s)	.49 (.10)	.50 (.05)	.49 (.06)
Step Time (s)	.61 (.10)	.62 (.10)	.61 (.10)
Double Support Time (s)	.20 (.10)	.21 (.06)	.20 (.07)
Single Support Time (s)	.39 (.0)	.41 (.03)	.40 (.04)

Table I. 5 READ

Mean and SD for Read comparing Fallers and Non-fallers

	Read Overall	Fallers	Non-Fallers
Parameter	Mean (SD)	Mean (SD)	Mean (SD)
Record Time (s)	10.17 (2.1)	11.38 (2.3)	9.82 (1.9)
Walk Time (s)	7.21 (1.7)	8.22 (1.8)	6.92 (1.5)
Pre-Turn (s)	4.65 (1.1)	5.04 (.9)	4.46 (1.0)
Stride Length (cm)	150.6 (11.2)	144.75 (12.0)	152.4 (10.5)
Cadence (step/min)	102.4 (14.9)	95.87 (16.0)	104.2 (14.6)
Stride Time (s)	1.28 (.20)	1.33 (.20)	1.26 (.20)
Stride Velocity (cm/s)	127.8 (20.9)	117.68 (23.4)	130.71 (19.5)
Swing Time (s)	.48 (.0)	.52 (.0)	.47 (.0)
Step Time (s)	.60 (.10)	.63 (.10)	.59 (.10)
Double Support Time (s)	.19 (.10)	.18 (.0)	.19 (.10)
Single Support Time (s)	.40 (.0)	.40 (.0)	.40 (.0)

Table I.6 AUDIBLE

Mean and SD for Audible comparing Fallers and Non-fallers

	Audible Overall	Fallers	Non-Fallers
Parameter	Mean (SD)	Mean (SD)	Mean (SD)
Record Time (s)	9.96 (2.0)	11.20 (2.6)	9.60 (1.7)
Walk Time (s)	7.04 (1.6)	7.77 (1.9)	6.84 (1.5)
Pre-Turn (s)	4.47 (1.0)	4.85 (1.0)	4.29 (.9)
Stride Length (cm)	151.9 (11.5)	148.68 (9.5)	152.93 (12.0)
Cadence (step/min)	103.8 (14.5)	99.16 (19.3)	105.45 (19.3)
Stride Time (s)	1.27 (.20)	1.36 (.2)	1.25 (.1)
Stride Velocity (cm/s)	127.0 (20.4)	117.00 (21.0)	129.91 (19.5)
Swing Time (s)	.47 (.0)	.50 (.0)	.47 (.0)
Step Time (s)	.59 (.10)	.62 (.10)	.58 (.10)
Double Support Time (s)	.20 (.10)	.20 (.10)	.20 (.1)
Single Support Time (s)	.39 (.0)	.39 (.0)	.39 (.0)

Table I.7 VISUAL

Mean and SD for Visual comparing Fallers and Non-fallers

Parameter	Visual Overall Mean (SD)	Fallers Mean (SD)	Non-Fallers Mean (SD)
Record Time (s)	9.99 (2.0)	11.08 (2.3)	9.68 (1.9)
Walk Time (s)	7.15 (1.7)	8.15 (2.1)	6.86 (1.5)
Pre-Turn (s)	4.57 (1.1)	4.87 (1.0)	4.39 (1.0)
Stride Length (cm)	151.7 (11.2)	145.40 (12.0)	153.6 (10.4)
Cadence (step/min)	102.8 (13.0)	98.41 (13.8)	104.0 (13.0)
Stride Time (s)	1.25 (.2)	1.33 (.20)	1.24 (.20)
Stride Velocity (cm/s)	129.4 (23.2)	116.59 (18.9)	133.12 (19.5)
Swing Time (s)	.47 (.0)	.50 (.0)	.47 (.0)
Step Time (s)	.57 (.10)	.61 (.10)	.57 (.10)
Double Support Time (s)	.19 (.10)	.20 (.10)	.19 (.10)
Single S Time (s)	.40 (.0)	.39 (.0)	.39 (.0)

Table I.8

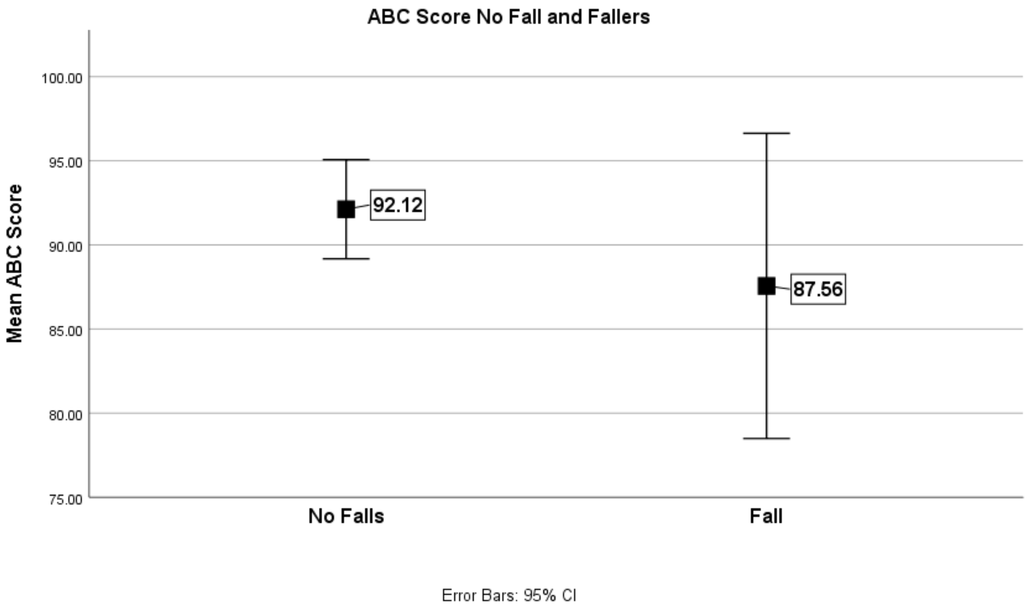
Mean and SD for Dual Cost

Dual Task Cost %	Condition			
	Subtract	Reading	Audible	Visual
Parameter	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Record Time	-8.29 (11.66)	-3.61 (7.09)	-1.58 (8.08)	-1.84 (8.42)
Walk Time	-12.09 (17.10)	-4.92 (11.45)	-2.64 (10.34)	-3.91 (10.68)
Pre-Turn	-7.38 (14.83)	-4.53 (10.73)	-.73 (11.23)	-2.64 (11.71)
Stride Length	3.48 (5.26)	1.83 (5.35)	.98 (5.69)	1.11 (5.67)
Cadence	5.53 (8.75)	1.14 (8.18)	-.38 (10.16)	.63 (8.38)
Stride Time	-4.21 (9.68)	-.87 (8.47)	-.33 (9.47)	.91 (7.28)
Stride Velocity	5.14 (9.62)	1.61 (9.96)	2.43 (7.82)	.62 (9.96)
Swing Time	-3.86 (9.02)	-1.40 (7.95)	.53 (7.91)	.21 (6.32)
# of Steps	-2.25 (6.51)	-3.18 (9.06)	-2.30 (9.18)	-2.77 (9.32)
Step Time	-5.27 (10.68)	-3.27 (11.00)	-1.55 (11.57)	.51 (10.99)
Double Support Time	-18.31 (71.34)	-11.26 (72.12)	-16.18 (59.88)	-17.00 (80.28)
Single Support Time	1.03 (8.42)	-1.00 (9.83)	1.46 (9.02)	.19 (7.81)

Table 4.3

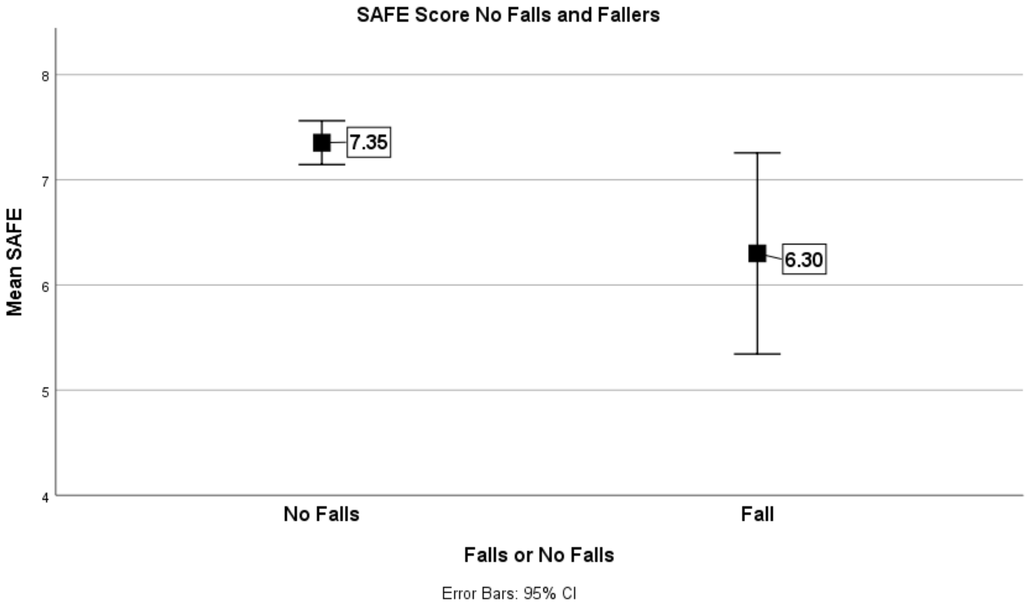
Mean and SD for Dual Cost of Variability Parameters

Dual Task Cost %	Condition			
	Subtract	Reading	Audible	Visual
Parameter	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Stride Velocity Variability	-2.49 (32.06)	2.40 (29.85)	8.63 (23.00)	-1.02 (27.04)
Swing Time Variability	-38.60 (99.27)	-46.08 (130.81)	-15.93 (117.76)	-23.69 (98.52)
Stride Length Variability	-65.56 (150.43)	-53.44 (106.55)	-40.91 (141.36)	-60.20 (214.33)
Stance Time Variability	-23.06 (89.36)	-18.10 (92.47)	-9.15 (72.24)	-13.85 (89.29)
Stride time Variability	-5.72 (30.85)	-1.84 (35.01)	1.72 (31.12)	2.46 (27.31)
Double Support Variability	-.28 (48.10)	-4.07 (51.67)	.75 (61.20)	-6.50 (63.52)
Single Support Variability	-38.08 (91.74)	-26.44 (88.66)	-22.36 (80.84)	-33.35 (103.75)



ABC: Activities-specific Balance Confidence

Figure 4.17 Mean of ABC Scores for Non-Fallers N= 33 and Fallers N = 10.



SAFE: screening assessment for falls evaluation

Figure 4.18 Mean of SAFE Scores for Non-Fallers N= 34 and Fallers N = 10.