5-15-2020

# Brain Volumes and Dual-Task Performance Correlates Among Individuals with Cognitive Impairment: A Retrospective Analysis

Jon Basterrechea
*University of Nevada, Las Vegas*, jonbast3@gmail.com

Daniel Krist
*University of Nevada, Las Vegas*, danielkrist01@gmail.com

Caitlin Moreland
*University of Nevada, Las Vegas*, caitlin.moreland9@gmail.com

Morgan Wise
*University of Nevada, Las Vegas*, morganwise.dpt@gmail.com

# BRAIN VOLUMES AND DUAL-TASK PERFORMANCE CORRELATES AMONG INDIVIDUALS WITH COGNITIVE IMPAIRMENT: A RETROSPECTIVE ANALYSIS

By


Jon A. Basterrechea

Daniel J. Krist

Caitlin A. Moreland

Morgan A. Wise


A doctoral project submitted in partial fulfillment
of the requirements for the

Doctor of Physical Therapy


Department of Physical Therapy
School of Integrated Health Science
The Graduate College

University of Nevada, Las Vegas

May 2020

UNLV | GRADUATE COLLEGE

**Doctoral Project Approval**

The Graduate College
The University of Nevada, Las Vegas

May 16, 2020

This doctoral project prepared by

Jon A. Basterrechea

Daniel J. Krist

Caitlin A. Moreland

Morgan A. Wise

entitled

Brain Volumes and Dual-Task Performance Correlates Among Individuals with Cognitive Impairment: A Retrospective Analysis

is approved in partial fulfillment of the requirements for the degree of

Doctor of Physical Therapy
Department of Physical Therapy

Daniel Young, Ph.D.
*Research Project Coordinator*

Kathryn Hausbeck Korgan, Ph.D.
*Graduate College Dean*

Merrill Landers, Ph.D.
*Research Project Advisor*

Merrill Landers, Ph.D.
*Chair, Department of Physical Therapy*

**ABSTRACT**

**Background:** Cognitive impairment (CI) is a prevalent condition characterized by loss of brain volume and changes in cognition, motor function, and dual-tasking ability.

**Objective:** To examine associations between brain volumes, dual task performance, and gait and balance in those with CI to elucidate the mechanisms underlying loss of function.

**Methods:** We performed a retrospective analysis of medical records of patients with CI and compared brain volumes, dual task performance, and measures of gait and balance.

**Results:** Greater cognitive function and combined dual task effect (DTE) is associated with smaller brain volumes. In contrast, greater motor DTE is associated with larger motor relevant brain volumes. As brain volumes decrease, dual task performance becomes more motor prioritized. Cognitive DTE is more strongly associated with decreased performance on measures of gait and balance than motor DTE. Decreased gait and balance performance are also associated with increased motor task prioritization.

**Conclusions:** Cognitive DTE appears to be more strongly associated with decreased automaticity and gait and balance ability than motor DTE and should be utilized as a clinical and research outcome measure in this population. The increased motor task prioritization associated with decreased brain volume and function indicates a potential for accommodative strategies to maximize function in those with CI. Counterintuitive correlations between motor brain volumes and motor DTE in our study suggest a complicated interaction between brain pathology and function.

TABLE OF CONTENTS

## LIST OF FIGURES

## INTRODUCTION

Dementia is a prevalent problem affecting cognition and function in 46.8 million individuals worldwide, with this number expected to grow to 74.7 million by 2030 and 131.5 million by 2050.[1] Dementia care has a tremendous global financial impact, estimated to cost 1 trillion dollars worldwide and expected to double by 2030.[1] Alzheimer's Disease (AD) is the leading cause of dementia and is characterized by cortical atrophy with concomitant memory loss, slowness of performance, and difficulty in performing previously familiar tasks.[2,3] Other common causes of dementia have changes similar to those found in AD.[4,5]

Traditionally, people with dementia are thought to have mainly cognitive deficits; however, these individuals can demonstrate motor deficits as well. These include decreased gait speed/quality and balance deficits, which have been associated with fall risk and survival in older adults.[7-13] Additionally, the effects of dementia are seen at the intersection of cognitive and motor function as an impairment of automaticity.[14-16] Automaticity is the ability to perform motor and cognitive functions simultaneously without a decline of performance in either task. This automaticity of dual task performance has been shown to be significantly decreased in those with AD,[17] and slow walking speed during dual task gait has been shown to be associated with and predictive of both falls and the progression of dementia in people with mild cognitive impairment (MCI), a precursor to AD and other dementias.[14,18]

There is much we do not know about the mechanisms underlying the dementias and how they relate to automaticity and other functional deficits. Studies have shown that the cognitive and executive deficits in people with AD are associated with atrophy in specific cognitive-related brain areas such as the frontal lobes and hippocampus.[19-21] Moreover, the severity and progression of cognitive impairment in other dementias and MCI have also been shown to be related to atrophy and damage in areas such as the hippocampus and striatum.[4,22-24] However, there is little known about motor relevant brain areas and how they relate to motor and dual task function. Likewise, there is little known about the relationship between dual task function and cognitive relevant brain areas. Previous studies have identified brain areas uniquely correlated with dual task performance, including frontal, temporal, and cingulate regions.[25,26] There is also evidence that motor-related areas, such as the basal ganglia and primary motor cortex, can be affected in AD and other causes of dementia. Further research is needed to determine if and how the decreased motor and dual task function is related to brain volume changes or other factors.[21,27,28]

The first aim of this study was to examine if brain volumes are associated with dual task performance in a mixed clinical sample of individuals with cognitive impairment. We hypothesized that motor relevant brain volumes will be more associated with motor dual task effects (mDTE). We also hypothesized that cognitive relevant brain volumes will be more associated with cognitive dual task effects (cogDTE). The second aim of this study was to determine if task prioritization (i.e., a choice to focus more attention on one of two competing and concurrent tasks, cognitive or motor) related to DTE can provide information about brain volumes in individuals with cognitive impairment. We hypothesized that individuals who prioritize cognition (i.e., their cognitive DTE decreases less than motor DTE) and individuals who prioritize motor function (i.e., their motor DTE decreases less than cognitive DTE) will have different associations with motor and cognitive relevant brain areas. The third aim of this study was to determine how general automaticity, as represented by combined dual task effect (cDTE), is associated with brain regions and gait/balance impairments. We hypothesized that the cDTE will be associated with more brain volumes and gait/balance impairments than either the motor or cognitive DTEs.

## METHODS

### Design

A retrospective analysis of data extracted from medical records for patients diagnosed with memory loss who received physical therapy (PT) treatment at the Cleveland Clinic Lou Ruvo Center for Brain Health (CCLRCBH) from January of 2017 to December of 2018 was conducted. Items that were extracted from the patient medical records include the following: demographic information (ie, sex, age, year of first cognitive symptom, fall history, etc.), diagnoses, cognitive outcome measures, gait and balance outcome measures, and brain volumetric data from MRI. None of the treating physical therapists were involved in the data extraction process. All data were collected under CCLRCBH Institutional Review Board approval.

### Patients

All patients with an initial PT evaluation were identified from billing records and screened for inclusion in the study. CCLRCBH considers PT an integral part of memory loss treatment;

therefore, patients diagnosed with cognitive impairment or dementia are referred to PT to address motor-related impairments regardless of severity. Clinical diagnosis of disorders of cognition was completed by neurologists using contemporary evidence-based criteria.[29-33] Patients without data regarding their dual task performance or without MRI imaging from within 6 months of dual task assessment were excluded. The final data for analysis came from a mixed clinical sample of community dwelling individuals with cognitive impairment (Figure 1). Clinical diagnoses of those included in the sample included the following: AD (n=14), MCI (n=13), dementia with Lewy bodies (n=8), vascular cognitive impairment (n=10), normal pressure hydrocephalus (n=2), mixed cognitive impairment (n=6), Parkinson's disease dementia (n=5), cognitive impairment related to other neurodegenerative process (n=4), and dementia of unknown etiology (n=3).

**Sample Size Estimation**

The sample size was estimated using PASS 15.0.2 (NCSS, LLC. Kaysville, Utah, USA, www.ncss.com/software/pass) and was powered based on Aims 1 and 2. For Aims 1-2, a sample size of 46 would achieve 80% power to detect a Pearson correlation difference of -0.40 between the null hypothesis correlation of 0.00 and the alternative hypothesis correlation of 0.40 using a two-sided hypothesis test with $\alpha = 0.05$.

**Instrumentation**

**Brain volumes.** All patients were scanned with the same Siemens TIM Verlo 3T scanner. Volumes were measured using NeuroQuant© (CorTechs Labs Inc, La Jolla, California, USA, www.cortechslabs.com/products/neuroquant), an automated program for calculating brain volumes approved by the Food and Drug Administration[34] and good to excellent reliability.[35,36] The brain areas we considered to be motor relevant were the caudate, putamen, pallidum, cerebellum, brainstem, paracentral, primary motor, parietal lobes, primary sensory, medial parietal, superior parietal, and inferior parietal regions. The areas we considered to be cognitive relevant were the forebrain parenchyma, hippocampus, amygdala, temporal lobes, transverse and superior temporal, posterior superior temporal sulcus, middle temporal, inferior temporal, fusiform, parahippocampal, entorhinal cortex, temporal pole, cingulate, anterior cingulate, posterior cingulate, isthmus cingulate, lateral orbitofrontal, medial orbitofrontal, frontal lobes, superior frontal, middle frontal, inferior frontal, and nucleus accumbens regions. The data also included whole brain volume, cortical gray matter, and cerebral white matter volumes.

**Dual Task Effect - Battery.** Dual task performance was obtained from performance on the Timed Up and Go Test (TUG), and Timed Up and Go – Cognitive (TUGcog). Recorded times for the Timed Up and Go Test (TUG) and the TUGcog were used. The TUG exhibits excellent test-retest reliability (ICC=.985) in individuals with AD.[37] For community dwelling older adults, the TUGcog has excellent interrater reliability (ICC= 0.99), and intrarater reliability (ICC= 0.94).[38,39] Prior to performing the TUGcog, individuals performed the cognitive task of serial subtraction by three from a number between 80 and 100 in a seated position to measure their single task (ST) cognitive performance. The number of correct responses in 20 seconds was recorded and from that was calculated the average number of seconds per correct response, a measure adapted from previous studies that have used correct response rate.[40,41] Cognitive performance during dual tasking (DT) was measured using the same method but beginning at a different number between 80 and 100 to minimize learning effects. Patients were instructed to perform both the motor and cognitive tasks as quickly and accurately as possible. These instructions were intended to encourage equal priority between motor and cognitive tasks. Motor and cognitive dual task effects (DTE) were then calculated using the equation:

$$DTE(\%) = \frac{-DT-ST}{ST} \times 100\%$$ [42,43]

Calculation of combined dual task effect (cDTE) was designed from the equation for DTE with modifications to include an assessment of the cognitive and motor aspects of the dual task interference.[44] cDTE was measured using the following equation:

$$cDTE\ (\%) = \frac{-(motorDT\ \times Cognitive\ DT) - (motorST\ \times cognitiveST)}{(motorST\ \times cognitiveST)} \times 100\%$$

The cognitive variable is the number of seconds per correct response, which gets larger as performance declines. The motor variable is simply time (in seconds); thus, increased time connotes worse performance. A negative was inserted into the numerator of the equation so that negative DTEs are indicative of a poorer dual-task performance relative to single task performance (dual-task cost), while positives DTE are indicative of improved performance under dual-task conditions relative to single task performance (dual task facilitation).[41,45,46] Task prioritization, for the second aim, was measured using the modified Attention Allocation Index (mAAI) with a lower value indicating motor prioritization and a higher value indicating cognitive prioritization.[41,47] mAAI was calculated using the following equation:

$$mAAI = motor\ DTE - cognitive\ DTE$$

**Cognition.** Scores from the Montreal Cognitive Assessment (MoCA) were used to measure global cognition.[48] The MoCA has excellent test-retest reliability (correlation coefficient = 0.92) and excellent positive and negative predictive values for AD (89% and 100%, respectively).[48]

**Balance.** Sensory orientation, anticipatory postural responses, reactive postural control, and dynamic gait were quantified using scores from the Mini-BESTest (MBT), a performance-based balance measure with excellent interrater reliability (ICC = 0.98).[49] Scores from the Berg Balance Scale (BBS), a performance-based measure of static and dynamic balance and good internal reliability (Cronbach's α = 0.77) and inter-rater reliability (ICC = 0.87) were was also recorded.[50] PT patients at CCLRCBH are typically assessed for balance using either the MBT or BBS depending on their level of function. Because patients with a history of falling or imbalance may develop a fear of falling that results in self-imposed activity restrictions, Fear of Falling Avoidance Behavior Questionnaire (FFABQ) scores were used to assess avoidance behavior. The FFABQ has good test-retest reliability (ICC=.812 with 95% confidence interval=.706-.883) and validity in people with neurologic diagnosis.[51,52]

**Gait.** Self-selected and fast gait speed from the 10 Meter Walk Test (10MWT and 10MWT-fast) were utilized to measure gait performance. The 10MWT has excellent test-retest reliability (ICC=0.98).[53] Similar methods for measuring fast speed to those used in this study have also shown excellent reliability among older adults (ICC = 0.96).[54]

**Strength and Endurance.** Scores from the Six Minute Walk Test (6MWT) and Five Times Sit to Stand Test (5STS) were used to represent walking endurance and lower extremity functional strength respectively. The 6MWT exhibits excellent test-retest reliability (ICC = 0.982-0.987),[37] as well as both interrater (ICC = 0.97 - 0.99)[55] and intra-rater reliability (ICC = 0.76 - 0.9) for individuals with AD.[55] The 5STS exhibits excellent test-retest reliability (ICC = 0.957) for the community-dwelling elderly.[56]

**DATA ANALYSIS**

All analyses were conducted using SPSS 24.0 (IBM SPSS Statistics for Windows, Armonk, New York, USA: IBM Corp) with $\alpha = 0.05$. For Aim 1 (brain volumes and DTE aim), brain volumetric data was compared to mDTE and cogDTE using Pearson correlation coefficient analyses. For Aim 2 (brain volumes and task prioritization aim), mAAI was used to determine associations with brain volumes using Pearson correlation coefficients. For Aim 3 (DTE, brain volumes, and physical performance aim), the strength of relationships between brain volumes and mDTE, cogDTE, and cDTE were compared using Pearson correlation coefficients. The strength of relationships between measures of gait (Preferred Gait Speed, Fast Gait Speed, Timed Up and Go test, and TUGcog), balance (Mini-BESTest, Berg Balance Scale and Fear of Falling Avoidance Behavior Questionnaire), and strength and endurance (Six Minute Walk Test and Five Times Sit to Stand Test) and mDTE, cogDTE, and cDTE were also compared using Pearson correlation coefficients.

## RESULTS

**Aim 1 (brain volumes and DTE aim).** Correlations of motor relevant brain volumes and DTE are found in Figure 2. Warm colors are associated with an inverse relationship between motor brain volume and DTE. Cool colors are associated with a positive correlation between motor brain volume and DTE. A heat map of the correlations for cognitive relevant brain volumes and DTE are found in Figure 3, and for whole brain volumes and DTE in Figure 4. Greater cogDTE was associated with decreased volume in both motor and cognitive relevant brain regions. While mDTE was not consistently associated with cognitive relevant brain volumes, greater mDTE was associated with slightly larger motor brain areas.

**Aim 2 (brain volumes and task prioritization aim).** Correlations of task prioritization and brain volumes are coded on Figures 2-4 using heat maps. A lower value mAAI represents motor prioritization, so a positive correlation means that smaller brain volumes are associated with motor prioritization. Our results indicate that as brain volumes decreased DT performance became more motor prioritized.

**Aim 3 (DTE, brain volumes, and physical performance aim).** Correlations of cDTE and brain volumes are coded on Figures 2-4 using heat maps. Correlations of DTE and task prioritization on gait and balance measures are contained in heat maps in Figure 5. To determine which of the DTEs (cognitive, motor, and combined) are most associated with measures of gait and balance a heat map was created to show the strongest and weakest associations (Figure 6). The pattern of association of the cDTE and brain volumes was similar to cogDTE alone. Decreased gait and balance performance were associated with greater motor task prioritization. CogDTE is more strongly associated with performance on measures of gait and balance compared to mDTE.

## DISCUSSION

**Motor Relevant Brain Volumes and DTE**. Higher motor DTE (which represents greater loss of motor performance while dual tasking) appears to be associated with larger brain volumes in motor relevant areas (Figure 2). This is counterintuitive since one would expect decreased motor performance to be associated with atrophy of motor areas. A study by Fischer et al in 2017 found a greater motor DTE to be associated with decreased caudate volume in those with AD and MCI, but did not consider other brain motor areas or investigate other components of the DTE-B.[57] Although we saw a positive association between motor brain volumes and motor DTE, our findings for the caudate specifically are comparable to Fischer et al. They also found an association between higher cerebellar gray matter volume and worse performance on the TUG, an isolated motor task. This is consistent with the positive association we saw between cerebellar gray matter and motor DTE and reinforces the counterintuitive conclusion that larger brain volumes may be associated with decreased motor function in this population. Another study by Annweiler et al in 2013 found decreased motor cortex volume to be associated with slower gait speeds during both single and dual task gait in those with MCI, and found no association with other brain volumes.[58] This is in contrast to our findings, which were of no correlation between primary motor cortex volume and any aspect of DTE. It is unclear why larger motor brain volumes would be correlated with greater motor DTE, but relative preservation of motor structures may affect that way that the brain allocates resources when there is competing demand from both the motor and cognitive aspects dual tasking.

Higher cognitive DTE, which represents a decline in cognitive performance while dual tasking, was associated with a decrease in motor-related brain volumes (Figure 2). This is in line with general expectations that decreased brain volumes will be accompanied by decreased function in those with cognitive impairment. Some exceptions were the caudate and cerebellar white matter, in which larger brain volumes were correlated with more cognitive DTE. Although the caudate is considered a motor relevant region, its function is thought to be more executive and associative than other components of the basal ganglia.[59] It could be that if this region is relatively spared, it is called upon more to compensate for loss of function in other areas and thus contributes less to its original function. Cognitive DTE is an under-utilized metric and there is a lack of research describing how it relates to motor relevant brain volumes.

Motor relevant brain volumes were positively associated with mAAI in our study (Figure 2). This indicates that atrophy in motor brain areas was associated with increasing motor prioritization. The exceptions were for the same brain areas noted above, the caudate and cerebellar white matter. Motor prioritization during dual tasking means the individual either mostly maintains their gait speed, has poorer cognitive performance, or both. This could be the result of an intentional focus on gait for safety despite the neutral instructions to encourage both tasks equally, or an unconscious default strategy to prioritize gait. Other researchers have suggested that individuals with limited attentional resources may adopt a “posture first” strategy of prioritizing gait during dual tasking to avoid falling.[45,60] Individuals with AD have even been found to increasingly prioritize postural control during a dual task as the difficulty of the postural control component increases, which suggests that dual task training may be utilized to reduce fall risk by manipulating the parameters of the component tasks in a clinical setting.[61]

When we look at combined DTE, which is a representation of the combined cognitive and motor DTE, we see a very similar correlation pattern with that of cognitive DTE for motor relevant brain areas (Figure 2). This indicates that the cognitive loss during dual tasking may be the primary driver of loss of overall automaticity and dual task performance among individuals with cognitive impairment. Our results suggest that parietal lobe volumes (sensory perception and spatial orientation) had the strongest and most consistent association with cognitive DTE and combined DTE, indicating that atrophy in these regions may have the greatest effect on function. A study on cognitive measures and TUG performance in people with MCI found TUG time to be no different from healthy adults, but turning quality was significantly compromised and associated with decreased visual-spatial cognitive function.[62] Additionally, a study on people with Parkinson Disease found sway during standing balance to be associated with visuospatial function, while gait speed is more associated with executive function.[63] Gait speed has also been linked to executive function in those with cognitive impairment.[64] So, while gait speed in this and other neurologic populations may be primarily affected by executive function, loss of automaticity and functional mobility may be primarily driven by decreased standing balance and turning ability secondary to parietal lobe atrophy and visuospatial deficits. Clinical dual task training strategies may therefore be optimized by focusing on visuospatial perception challenges rather than executive tasks. Further research in this area is warranted.

**Cognitive Relevant Brain Volumes and DTE.** There does not appear to be any consistent pattern of association between motor DTE and cognitive brain volumes in our study (Figure 3). We did observe that cognitive DTE increases as cognitive brain area volume decreases. This is logical and consistent with research that has demonstrated that cognitive deficits in this population are associated with atrophy of cognitive brain areas.[19,20]

We found that decreased brain volume in cognitive areas was associated with motor task prioritization. Since dementia is primarily characterized by atrophy of cognitive related brain areas and loss of cognitive function, this indicates that the more advanced a person's cognitive impairment, the more they prioritize motor function while dual tasking. Motor prioritization may be a useful adaptation in those with cognitive impairment, since it could minimize fall risk during activities requiring dual tasking. It is important to note that even healthy older adults tend to prioritize walking when a more demanding secondary task is added.[65,66] Theill et al showed that healthy older adults tend to motor prioritize and those with cognitive impairment tend to prioritize cognition, in contrast to our findings.[67] However, that study excluded individuals with severe cognitive impairment, who may perform differently than less impaired individuals. They also utilized an easier working memory task (counting backward from 50 by 2s). Research on this topic has been inconsistent, with some studies showing healthy older adults to prioritize cognition during a dual task.[68,69] It is generally acknowledged that response to dual task conditions is context dependent and can be altered by the characteristics of the individual, the task, and the environment.[70]

We also observed that combined DTE was associated with decreased volume in cognitive brain areas. Just as for the motor areas, combined DTE appears to be more similar to cognitive DTE than motor DTE, indicating that most of the overall loss of automaticity is driven by a loss of cognitive function. In general, our findings on cognitive relevant brain volumes are consistent with other research showing that decreased volume is associated with a worse performance during dual tasks in those with cognitive impairment.[25]

**Whole Brain Volumes and DTE.** With decreased whole brain volumes, we found that cognitive DTE increased, dual tasking became more motor prioritized, and automaticity (combined DTE) decreased (Figure 4). There was no clear association with motor DTE. Existing research on brain volumes in this population has focused on specific brain regions rather than whole brain trends. Extensive patterns of gray matter involvement throughout the brain have been identified and associated with dual task performance in those with cognitive impairment and would be expected to drive whole brain patterns such as those seen in our findings.[25]

**Physical Performance and DTE.** We found little to no association between motor DTE and gait and balance in those with cognitive impairment (Figure 5). This is notable because motor DTE is a common clinical outcome measure and the most commonly used measure in research on the effect of dual task gait training in those with AD.[46] In our study, this measure did not tell much about gait and balance function in this population. It is known that decline in motor functions such as gait speed can be one the earliest and best predictors of progression to dementia;[15] however, it is unclear which measures of physical performance are most usefully clinically in this population. Our study did find cognitive DTE to be associated with decreased performance in almost all measures of gait and balance, which indicates that cognitive DTE may be a better representation of global function than motor DTE in those with cognitive impairment.

Motor task prioritization appears to be associated with decreased gait and balance as well. In light of our brain volumes observation, this suggests that those with worse cognitive impairment have worse gait and balance and more motor prioritization during dual tasking. As noted previously, a “posture first” framework for task prioritization would suggest that individuals prioritize gait over a simultaneous cognitive task when fall avoidance has a more immediate perceived value.[70] Other researchers have suggested that task prioritization depends on factors such as the individual’s perception of postural hazards and capacity to respond to postural destabilization.[60] Adults with decreased sensory and motor capabilities, such as those seen in cognitive impairment, have less capacity to respond to postural threats and may utilize more attentional cognitive resources to compensate, thus incurring a greater cognitive DTE.[60] However, other studies have shown adults with neurological conditions can demonstrate a maladaptive “posture second” strategy if they are unable to accurately perceive postural hazards.[71]

Combined DTE is also correlated with decreased gait and balance performance, and just as with brain volumes shows a similar pattern relative to cognitive DTE. Combined with the lack of correlations for motor DTE, this reinforces the suggestion that cognitive DTE may be the driving factor in the loss of dual task performance in this population. It is worth noting that different causes of cognitive impairment have different underlying brain changes and different patterns of brain activation during dual tasking.[66] Our study looks at a mixed clinical sample with multiple diagnoses. It may be challenging to generalize about DT performance and the implications in our population, as the trends that we found may not hold true for all types and causes of cognitive impairment.

Interestingly, fall history was not associated with loss of dual tasking ability in our sample, indicating that dual task performance may not be a good identifier of fall risk among individuals with cognitive impairment. Other studies have found conflicting results; Muir et al found dual task gait assessment to be effective for detecting fall risk in MCI and AD.[72] Taylor et al found both single and dual task conditions to be equally effective at determining fall risk in those with cognitive impairment, in which case it would be clinically easier to perform a single task walking test.[73] Another study with an unexpected result showed that dual tasking in individuals post brain injury was not correlated with fall risk; the authors speculated that the participants were not sufficiently distracted in the research environment.[74] Dual task impairments have been shown to be associated with fall risk in community dwelling older adults in general,[75] but it may be different for those with cognitive impairment specifically. It could be that those with cognitive impairment decrease their activity level and exposure to situations in which falls may occur, either secondary to cognitive deficits or intentionally due to fear of falling, and balance and functional deficits are therefore not reflected in fall history.

Cognitive DTE was most strongly associated with measures of gait and balance in our sample (Figure 6), while motor DTE was least associated with measures of gait and balance. The exception was the 6MWT, which was more strongly associated with combined DTE. This makes sense, because combined DTE is a representation of automaticity, and a six-minute ambulation task is more automatic in character than the other measures.[76] It could be that cognitive DTE is more relevant than combined DTE for most clinical outcome measures where tasks are discrete, short in duration, and unfamiliar to the patient. This may or may not be the case for household functional mobility.

**LIMITATIONS**

This was a cross-sectional retrospective analysis that took outcome measures from single physical therapy sessions for each patient; these measures may not have been representative of each patient's functional level due to normal daily variations in performance, differences in methods on the part of the treating therapists, or learning effects depending on when in the plan of care the measures were administered. The visits used were determined by availability of cognitive DTE data, which were inconsistently taken across patients and visits. Our study also investigated the broad category of cognitive impairment as a whole and utilized a mixed clinical sample comprised of individuals with different pathologies resulting in cognitive impairment. Different causes of CI can have different underlying disease processes and may have showed different correlations individually, however there were insufficient sample sizes to investigate them separately or control for other potential confounding variables. Our study also used brain volumes from MRI imaging to represent the structural changes of cognitive impairment. Other studies have shown that regional microstructure, neuronal integrity, and glucose metabolism may have a better correlation with gait quality and be more sensitive to early changes in cognitive impairment.[28] We may have seen more or different associations if we had access to these measures.

## CONCLUSION

Overall, our results suggest several interesting patterns and directions for future research. First, the cognitive cost of dual tasking appears to be more prominent and the primary driver for lost automaticity when compared to the motor cost in those with cognitive impairment. This is notable because clinicians and researchers have often used change in gait speed during a dual task as the only outcome measure for dual task ability in this population. While motor DTE may be seen as more relevant due to potential associated fall risk and functional limitation, cognitive DTE may have a stronger association with gait and balance ability in this population and should not be overlooked when assessing function and response to treatment. Second, with decreased volume of both cognitive and motor related brain areas, those with dementia appear to increasingly prioritize the motor component of a dual task. In other words, as dementia progresses, individuals tend to sacrifice cognition while concentrating on their gait speed. This indicates a potential for accommodative strategies in this population that could be exploited through neuro-rehabilitation interventions to maximize function. Finally, while most of the brain volume and dual task effect correlations in our results are intuitive and expected, some are not. The positive correlation between the increased volume of motor relevant brain areas and loss of motor function while dual tasking suggests a more complicated interaction between specific brain regions, disease processes, and function in those with cognitive impairment and warrants further research in this area.

## REFERENCES


1. Prince MW, A.; Guerchet, M.; Ali, G.; Wu, Y.; Prina, M. World Alzheimer Report 2015. The global impact of dementia: an analysis of prevalence, incidence, cost and trends. . *Alzheimer's Disease International.* 2015.
2. Khan UA, Liu L, Provenzano FA, et al. Molecular drivers and cortical spread of lateral entorhinal cortex dysfunction in preclinical Alzheimer's disease. *Nature neuroscience.* 2014;17(2):304-311.
3. Jahn H. Memory loss in Alzheimer's disease. *Dialogues Clin Neurosci.* 2013;15(4):445-454.
4. Jiwa NS, Garrard P, Hainsworth AH. Experimental models of vascular dementia and vascular cognitive impairment: a systematic review. *J Neurochem.* 2010;115(4):814-828.
5. Vann Jones SA, O'Brien JT. The prevalence and incidence of dementia with Lewy bodies: a systematic review of population and clinical studies. *Psychol Med.* 2014;44(4):673-683.
6. Association As. 2017 Alzheimer's disease facts and figures. *Alzheimer's & Dementia.* 2017(13):325-373.
7. Sheridan PL, Hausdorff JM. The role of higher-level cognitive function in gait: executive dysfunction contributes to fall risk in Alzheimer's disease. *Dementia and geriatric cognitive disorders.* 2007;24(2):125-137.
8. Studenski S, Perera S, Patel K, et al. Gait speed and survival in older adults. *JAMA.* 2011;305(1):50-58.
9. Bahureksa L, Najafi B, Saleh A, et al. The Impact of Mild Cognitive Impairment on Gait and Balance: A Systematic Review and Meta-Analysis of Studies Using Instrumented Assessment. *Gerontology.* 2017;63(1):67-83.
10. Visser H. Gait and balance in senile dementia of Alzheimer's type. *Age Ageing.* 1983;12(4):296-301.
11. Tangen GG, Engedal K, Bergland A, Moger TA, Mengshoel AM. Relationships between balance and cognition in patients with subjective cognitive impairment, mild cognitive impairment, and Alzheimer disease. *Phys Ther.* 2014;94(8):1123-1134.
12. Mirelman A, Herman T, Brozgol M, et al. Executive function and falls in older adults: new findings from a five-year prospective study link fall risk to cognition. *PLoS One.* 2012;7(6):e40297.
13. Montero-Odasso M, Verghese J, Beauchet O, Hausdorff JM. Gait and cognition: a complementary approach to understanding brain function and the risk of falling. *J Am Geriatr Soc.* 2012;60(11):2127-2136.
14. Montero-Odasso MM, Sarquis-Adamson Y, Speechley M, et al. Association of Dual-Task Gait With Incident Dementia in Mild Cognitive Impairment: Results From the Gait and Brain Study. *JAMA Neurol.* 2017;74(7):857-865.
15. Montero-Odasso M, Speechley M, Muir-Hunter SW, et al. Motor and Cognitive Trajectories Before Dementia: Results from Gait and Brain Study. *J Am Geriatr Soc.* 2018;66(9):1676-1683.
16. Schwenk M, Zieschang T, Oster P, Hauer K. Dual-task performances can be improved in patients with dementia: a randomized controlled trial. *Neurology.* 2010;74(24):1961-1968.

17. Ansai JH, de Andrade LP, de Souza Buto MS, et al. Effects of the Addition of a Dual Task to a Supervised Physical Exercise Program on Older Adults' Cognitive Performance. *J Aging Phys Act.* 2017;25(2):234-239.
18. Goncalves AC, Cruz J, Marques A, Demain S, Samuel D. Evaluating physical activity in dementia: a systematic review of outcomes to inform the development of a core outcome set. *Age Ageing.* 2018;47(1):34-41.
19. Laakso MP, Soininen H, Partanen K, et al. Volumes of hippocampus, amygdala and frontal lobes in the MRI-based diagnosis of early Alzheimer's disease: correlation with memory functions. *J Neural Transm Park Dis Dement Sect.* 1995;9(1):73-86.
20. Bruen PD, McGeown WJ, Shanks MF, Venneri A. Neuroanatomical correlates of neuropsychiatric symptoms in Alzheimer's disease. *Brain.* 2008;131(Pt 9):2455-2463.
21. Jiji S, Smitha KA, Gupta AK, Pillai VP, Jayasree RS. Segmentation and volumetric analysis of the caudate nucleus in Alzheimer's disease. *Eur J Radiol.* 2013;82(9):1525-1530.
22. Venkat P, Chopp M, Chen J. Models and mechanisms of vascular dementia. *Exp Neurol.* 2015;272:97-108.
23. Chen J, Zhang Z, Li S. Can multi-modal neuroimaging evidence from hippocampus provide biomarkers for the progression of amnestic mild cognitive impairment? *Neurosci Bull.* 2015;31(1):128-140.
24. Mielke MM, Okonkwo OC, Oishi K, et al. Fornix integrity and hippocampal volume predict memory decline and progression to Alzheimer's disease. *Alzheimers Dement.* 2012;8(2):105-113.
25. Doi T, Blumen HM, Verghese J, et al. Gray matter volume and dual-task gait performance in mild cognitive impairment. *Brain Imaging Behav.* 2017;11(3):887-898.
26. Tripathi S, Verghese J, Blumen HM. Gray matter volume covariance networks associated with dual-task cost during walking-while-talking. *Hum Brain Mapp.* 2019;40(7):2229-2240.
27. Wang ML, Wei XE, Fu JL, et al. Subcortical nuclei in Alzheimer's disease: a volumetric and diffusion kurtosis imaging study. *Acta Radiol.* 2018:284185118758122.
28. Tian Q, Chastan N, Bair WN, Resnick SM, Ferrucci L, Studenski SA. The brain map of gait variability in aging, cognitive impairment and dementia-A systematic review. *Neurosci Biobehav Rev.* 2017;74(Pt A):149-162.
29. McKhann GM, Knopman DS, Chertkow H, et al. The diagnosis of dementia due to Alzheimer's disease: recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimers Dement.* 2011;7(3):263-269.
30. McKeith IG, Boeve BF, Dickson DW, et al. Diagnosis and management of dementia with Lewy bodies: Fourth consensus report of the DLB Consortium. *Neurology.* 2017;89(1):88-100.
31. Skrobot OA, O'Brien J, Black S, et al. The Vascular Impairment of Cognition Classification Consensus Study. *Alzheimers Dement.* 2017;13(6):624-633.
32. Albert MS, DeKosky ST, Dickson D, et al. The diagnosis of mild cognitive impairment due to Alzheimer's disease: recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimers Dement.* 2011;7(3):270-279.

33. Skrobot OA, Black SE, Chen C, et al. Progress toward standardized diagnosis of vascular cognitive impairment: Guidelines from the Vascular Impairment of Cognition Classification Consensus Study. *Alzheimers Dement.* 2018;14(3):280-292.
34. Brewer JB, Magda S, Airriess C, Smith ME. Fully-automated quantification of regional brain volumes for improved detection of focal atrophy in Alzheimer disease. *AJNR Am J Neuroradiol.* 2009;30(3):578-580.
35. Ochs AL, Ross DE, Zannoni MD, Abildskov TJ, Bigler ED, Alzheimer's Disease Neuroimaging I. Comparison of Automated Brain Volume Measures obtained with NeuroQuant and FreeSurfer. *J Neuroimaging.* 2015;25(5):721-727.
36. Kovacevic S, Rafii MS, Brewer JB, Alzheimer's Disease Neuroimaging I. High-throughput, fully automated volumetry for prediction of MMSE and CDR decline in mild cognitive impairment. *Alzheimer Dis Assoc Disord.* 2009;23(2):139-145.
37. Ries JD, Echternach JL, Nof L, Gagnon Blodgett M. Test-retest reliability and minimal detectable change scores for the timed "up & go" test, the six-minute walk test, and gait speed in people with Alzheimer disease. *Phys Ther.* 2009;89(6):569-579.
38. Hofheinz M, Schusterschitz C. Dual task interference in estimating the risk of falls and measuring change: a comparative, psychometric study of four measurements. *Clin Rehabil.* 2010;24(9):831-842.
39. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Phys Ther.* 2000;80(9):896-903.
40. Yang L, He C, Pang MY. Reliability and Validity of Dual-Task Mobility Assessments in People with Chronic Stroke. *PLoS One.* 2016;11(1):e0147833.
41. Kelly VE, Janke AA, Shumway-Cook A. Effects of instructed focus and task difficulty on concurrent walking and cognitive task performance in healthy young adults. *Exp Brain Res.* 2010;207(1-2):65-73.
42. McIsaac TL, Lamberg EM, Muratori LM. Building a framework for a dual task taxonomy. *Biomed Res Int.* 2015;2015:591475.
43. Yang L, Lam FMH, Liao LR, Huang MZ, He CQ, Pang MYC. Psychometric properties of dual-task balance and walking assessments for individuals with neurological conditions: A systematic review. *Gait & posture.* 2017;52:110-123.
44. Longhurst JK, Landers MR. A new way of measuring dual task cost: the construct validity of the comprehensive dual task cost equation in individuals with Parkinson's disease. Journal of Neurologic Physical Therapy; 2019; Washington, D.C.
45. Plummer P, Eskes G. Measuring treatment effects on dual-task performance: a framework for research and clinical practice. *Front Hum Neurosci.* 2015;9:225.
46. Fritz NE, Cheek FM, Nichols-Larsen DS. Motor-Cognitive Dual-Task Training in Persons With Neurologic Disorders: A Systematic Review. *J Neurol Phys Ther.* 2015;39(3):142-153.
47. Siu KC, Woollacott MH. Attentional demands of postural control: the ability to selectively allocate information-processing resources. *Gait Posture.* 2007;25(1):121-126.
48. Nasreddine ZS, Phillips NA, Bedirian V, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *J Am Geriatr Soc.* 2005;53(4):695-699.

49. Godi M, Franchignoni F, Caligari M, Giordano A, Turcato AM, Nardone A. Comparison of reliability, validity, and responsiveness of the mini-BESTest and Berg Balance Scale in patients with balance disorders. *Phys Ther.* 2013;93(2):158-167.
50. Wang CY, Hsieh CL, Olson SL, Wang CH, Sheu CF, Liang CC. Psychometric properties of the Berg Balance Scale in a community-dwelling elderly resident population in Taiwan. *J Formos Med Assoc.* 2006;105(12):992-1000.
51. Landers MR, Durand C, Powell DS, Dibble LE, Young DL. Development of a scale to assess avoidance behavior due to a fear of falling: the Fear of Falling Avoidance Behavior Questionnaire. *Phys Ther.* 2011;91(8):1253-1265.
52. Landers MR, Lopker M, Newman M. Reliability and validity of the modified Fear of Falling Avoidance Behavior Questionnaire in Parkinson’s disease. *Movement Disorders.* 2014;29:S177-178.
53. Peters DM, Fritz SL, Krotish DE. Assessing the reliability and validity of a shorter walk test compared with the 10-Meter Walk Test for measurements of gait speed in healthy, older adults. *J Geriatr Phys Ther.* 2013;36(1):24-30.
54. Marchetti G, Hodges M, Brown R, Krohn K. Test-retest reliability, external structure validity and responsiveness of gait parameters for older adult females walking at preferred and maximum velocity. *Journal of Geriatric Physical Therapy.* 2005;28(3):114.
55. Tappen RM, Roach KE, Buchner D, Barry C, Edelstein J. Reliability of physical performance measures in nursing home residents with Alzheimer's disease. *J Gerontol A Biol Sci Med Sci.* 1997;52(1):M52-55.
56. Bohannon RW, Shove ME, Barreca SR, Masters LM, Sigouin CS. Five-repetition sit-to-stand test performance by community-dwelling adults: A preliminary investigation of times, determinants, and relationship with self-reported physical performance. *Isokinet Exerc Sci.* 2007;15(2):77-81.
57. Fischer BL, Bacher R, Bendlin BB, et al. An Examination of Brain Abnormalities and Mobility in Individuals with Mild Cognitive Impairment and Alzheimer's Disease. *Front Aging Neurosci.* 2017;9:86.
58. Annweiler C, Beauchet O, Bartha R, et al. Motor cortex and gait in mild cognitive impairment: a magnetic resonance spectroscopy and volumetric imaging study. *Brain.* 2013;136(Pt 3):859-871.
59. Grahn JA, Parkinson JA, Owen AM. The cognitive functions of the caudate nucleus. *Progress in neurobiology.* 2008;86(3):141-155.
60. Yogev-Seligmann G, Hausdorff JM, Giladi N. Do we always prioritize balance when walking? Towards an integrated model of task prioritization. *Mov Disord.* 2012;27(6):765-770.
61. Rapp MA, Krampe RT, Baltes PB. Adaptive task prioritization in aging: selective resource allocation to postural control is preserved in Alzheimer disease. *Am J Geriatr Psychiatry.* 2006;14(1):52-61.
62. Mirelman A, Weiss A, Buchman AS, Bennett DA, Giladi N, Hausdorff JM. Association between performance on Timed Up and Go subtasks and mild cognitive impairment: further insights into the links between cognitive and motor function. *J Am Geriatr Soc.* 2014;62(4):673-678.

63. Morris R, Martini DN, Smulders K, et al. Cognitive associations with comprehensive gait and static balance measures in Parkinson's disease. *Parkinsonism & Related Disorders.*
64. Toots ATM, Taylor ME, Lord SR, Close JCT. Associations Between Gait Speed and Cognitive Domains in Older People with Cognitive Impairment. *Journal of Alzheimer's disease : JAD.* 2019;71(s1):S15-S21.
65. Li KZ, Lindenberger U, Freund AM, Baltes PB. Walking while memorizing: age-related differences in compensatory behavior. *Psychol Sci.* 2001;12(3):230-237.
66. Maclean LM, Brown LJE, Khadra H, Astell AJ. Observing prioritization effects on cognition and gait: The effect of increased cognitive load on cognitively healthy older adults' dual-task performance. *Gait Posture.* 2017;53:139-144.
67. Theill N, Martin M, Schumacher V, Bridenbaugh SA, Kressig RW. Simultaneously measuring gait and cognitive performance in cognitively healthy and cognitively impaired older adults: the Basel motor-cognition dual-task paradigm. *J Am Geriatr Soc.* 2011;59(6):1012-1018.
68. Corp DT, Youssef GJ, Clark RA, et al. Reduced motor cortex inhibition and a 'cognitive-first' prioritisation strategy for older adults during dual-tasking. *Exp Gerontol.* 2018;113:95-105.
69. Schaefer S, Schellenbach M, Lindenberger U, Woollacott M. Walking in high-risk settings: do older adults still prioritize gait when distracted by a cognitive task? *Exp Brain Res.* 2015;233(1):79-88.
70. Shumway-Cook A, Woollacott M, Kerns KA, Baldwin M. The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. *J Gerontol A Biol Sci Med Sci.* 1997;52(4):M232-240.
71. Bloem BR, Grimbergen YA, van Dijk JG, Munneke M. The "posture second" strategy: a review of wrong priorities in Parkinson's disease. *J Neurol Sci.* 2006;248(1-2):196-204.
72. Muir SW, Gopaul K, Montero Odasso MM. The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis. *Age Ageing.* 2012;41(3):299-308.
73. Taylor ME, Delbaere K, Mikolaizak AS, Lord SR, Close JC. Gait parameter risk factors for falls under simple and dual task conditions in cognitively impaired older people. *Gait Posture.* 2013;37(1):126-130.
74. McCulloch KL, Buxton E, Hackney J, Lowers S. Balance, attention, and dual-task performance during walking after brain injury: associations with falls history. *J Head Trauma Rehabil.* 2010;25(3):155-163.
75. Muir-Hunter SW, Wittwer JE. Dual-task testing to predict falls in community-dwelling older adults: a systematic review. *Physiotherapy.* 2016;102(1):29-40.
76. Huxhold O, Li SC, Schmiedek F, Lindenberger U. Dual-tasking postural control: aging and the effects of cognitive demand in conjunction with focus of attention. *Brain Res Bull.* 2006;69(3):294-305.

Figure 1. CONSORT flow diagram.

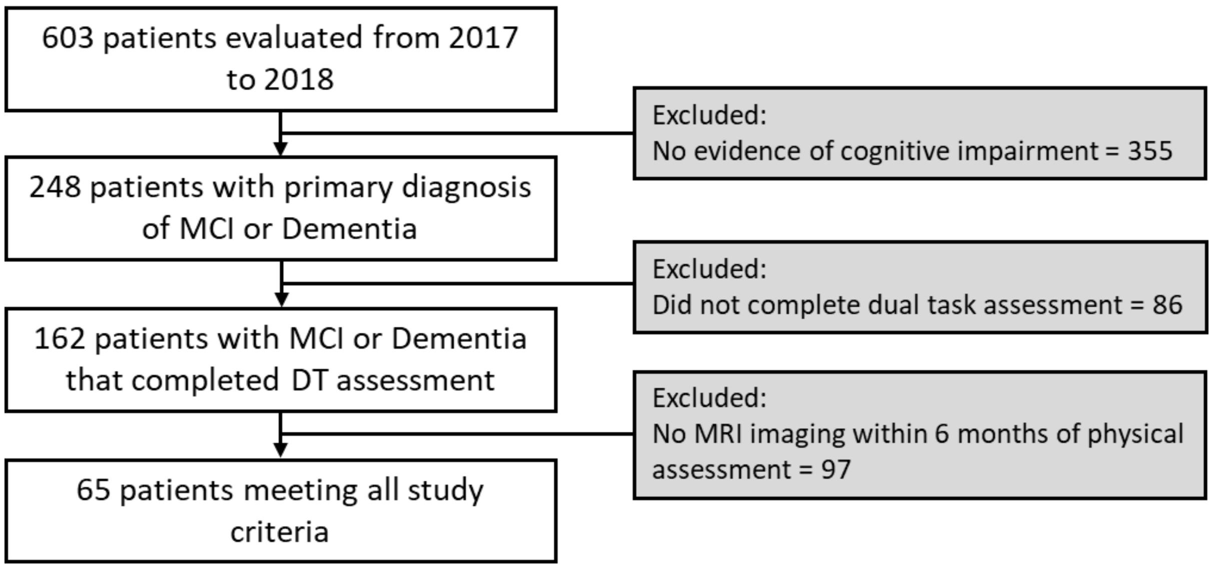

Figure 2. Heat map of Pearson correlation coefficients for motor relevant brain volumes and motor DTE[1], cognitive DTE, attention allocation index (mAAI), and combined DTE (cDTE).[2]

| | Motor DTE | Cognitive DTE | mAAI | cDTE |
|---|---|---|---|---|
| Caudate LH Vol % ICV | 0.105 | 0.190 | -0.166 | .287* |
| Caudate RH Vol % ICV | 0.146 | 0.242 | -0.210 | .344** |
| Caudate % ICV total | -0.104 | -0.016 | -0.031 | -0.081 |
| Putamen LH Vol % ICV | 0.081 | -0.011 | 0.026 | 0.023 |
| Putamen RH Vol % ICV | 0.043 | -0.087 | 0.093 | -0.071 |
| Pallidum LH Vol % ICV | 0.104 | -0.031 | 0.062 | 0.044 |
| Pallidum RH Vol % ICV | 0.232 | 0.009 | 0.052 | 0.112 |
| Putamen % ICV total | 0.227 | -0.248 | 0.296 | -0.247 |
| Pallidum % ICV total | 0.402 | 0.231 | -0.076 | 0.350 |
| Cerebellum LH Vol % ICV | 0.141 | -0.025 | 0.058 | 0.015 |
| Cerebellum RH Vol % ICV | 0.133 | 0.041 | -0.010 | 0.075 |
| Cerebellum Asymmetry Index | -0.080 | -0.015 | -0.005 | -0.024 |
| Cerebellar White Matter % ICV total | -0.265 | 0.258 | -0.334 | 0.138 |
| Cerebellar Gray Matter % ICV total | 0.418 | -0.028 | 0.170 | 0.146 |
| Brainstem % ICV total | 0.266 | 0.127 | -0.036 | 0.235 |
| Paracentral % ICV total | -0.078 | -0.324 | 0.286 | -0.377 |
| Primary Motor % ICV total | -0.020 | -0.010 | 0.021 | -0.043 |
| Parietal Lobes % ICV total | 0.029 | -0.177 | 0.182 | -0.197 |
| Primary Sensory % ICV total | 0.092 | -0.244 | 0.251 | -0.224 |
| Medial Parietal % ICV total | -0.029 | -0.187 | 0.184 | -0.234 |
| Superior Parietal % ICV total | 0.016 | -0.259 | 0.260 | -0.252 |
| Inferior Parietal % ICV total | 0.002 | -0.228 | 0.221 | -0.260 |

Significant at α=.05

>.25

.15 to .249

.05 to .149

-0.0499 to 0.0499

-.05 to -.149

-.15 to -.249

<-.25

Significant at α=.05

---

[1] Dual task effect

[2] Warm colors represent an inverse relationship between brain volume and DTE, meaning that smaller volumes are correlated with increased DTE. Cool colors represent a positive correlation between brain volume and DTE, meaning that smaller volumes are correlated with decreased DTE. A lower value mAAI represents motor prioritization, so a positive correlation (cool colors) means that smaller brain volumes are associated with motor prioritization.

Figure 3. Heat map of Pearson correlation coefficients for cognitive relevant brain volumes and motor DTE[3], cognitive DTE, attention allocation index (mAAI), and combined DTE (cDTE).[4]

| | Motor DTE | Cognitive DTE | mAAI | cDTE |
|---|---|---|---|---|
| Forebrain Parenchyma LH Vol % ICV | 0.064 | -0.083 | 0.102 | -0.060 |
| Forebrain Parenchyma RH Vol % ICV | -0.059 | -0.123 | 0.116 | -0.129 |
| Hippocampus LH Vol % ICV | 0.076 | -0.020 | 0.035 | 0.015 |
| Hippocampus RH Vol % ICV | 0.156 | 0.097 | -0.060 | 0.156 |
| Hippocampus % ICV total | -0.115 | -.474* | 0.395 | -.490* |
| Hippocampi Vol % ICV | 0.011 | -0.208 | 0.227 | -0.162 |
| Hippocampi Vol Normative % | -0.159 | -0.261 | 0.268 | -0.222 |
| Amygdala LH Vol % ICV | 0.046 | -0.047 | 0.058 | -0.030 |
| Amygdala RH Vol % ICV | 0.065 | -0.035 | 0.051 | -0.013 |
| Amygdala % ICV total | -0.026 | -0.443 | 0.394 | -0.415 |
| Temporal Lobes % ICV total | 0.141 | -0.188 | 0.231 | -0.157 |
| Transverse + Superior Temporal % ICV total | 0.087 | -0.234 | 0.266 | -0.241 |
| Posterior Superior Temporal Sulcus % ICV total | 0.048 | -0.179 | 0.186 | -0.201 |
| Middle Temporal % ICV total | 0.140 | -0.211 | 0.250 | -0.168 |
| Inferior Temporal % ICV total | -0.159 | -0.172 | 0.122 | -0.259 |
| Fusiform % ICV total | 0.003 | -0.243 | 0.245 | -0.270 |
| Parahippocampal % ICV total | -0.340 | -0.408 | 0.263 | -.561* |
| Entorhinal Cortex % ICV total | 0.219 | -0.383 | 0.420 | -0.280 |
| Temporal Pole % ICV total | 0.159 | -0.289 | 0.331 | -0.216 |
| Cingulate % ICV total | -0.174 | -0.419 | 0.326 | -.506* |
| Anterior Cingulate % ICV total | -0.205 | -0.381 | 0.279 | -.487* |
| Posterior Cingulate % ICV total | -0.194 | -0.359 | 0.269 | -0.439 |
| Isthmus Cingulate % ICV total | -0.004 | -0.404 | 0.379 | -0.402 |
| Lateral Orbitofrontal % ICV total | 0.378 | -0.375 | .463* | -0.192 |
| Medial Orbitofrontal % ICV total | 0.292 | -0.150 | 0.242 | -0.039 |
| Frontal Lobes % ICV total | 0.054 | -0.312 | 0.323 | -0.293 |
| Superior Frontal % ICV total | 0.103 | -.469* | .465* | -0.430 |
| Middle Frontal % ICV total | 0.074 | -0.101 | 0.132 | -0.108 |
| Inferior Frontal % ICV total | -0.145 | -0.374 | 0.323 | -0.364 |
| Nucleus accumbens % ICV Total | -0.049 | -0.081 | 0.056 | -0.168 |

| |
|---|
| Significant at α=.05 |
| >.25 |
| .15 to .249 |
| .05 to .149 |
| -0.0499 to 0.0499 |
| -.05 to -.149 |
| -.15 to -.249 |
| <-.25 |
| Significant at α=.05 |

[3] Dual task effect

[4] Warm colors represent an inverse relationship between brain volume and DTE, meaning that smaller volumes are correlated with increased DTE. Cool colors represent a positive correlation between brain volume and DTE, meaning that smaller volumes are correlated with decreased DTE. A lower value mAAI represents motor prioritization, so a positive correlation (cool colors) means that smaller brain volumes are associated with motor prioritization.

Figure 4. Heat map of Pearson correlation coefficients for whole brain volumes and motor DTE[5], cognitive DTE, attention allocation index (mAAI), and combined DTE (cDTE).[6]

| | Motor DTE | Cognitive DTE | mAAI | cDTE |
|---|---|---|---|---|
| Cortical Gray Matter LH Vol % ICV | -0.082 | -0.186 | 0.171 | -0.192 |
| Cortical Gray Matter RH Vol % ICV | -0.184 | -0.231 | 0.195 | -.254* |
| Cortical Gray % ICV total | 0.075 | -0.275 | 0.291 | -0.256 |
| Whole brain Vol % ICV | -0.014 | -0.152 | 0.143 | -0.201 |
| Whole brain Vol Normative % | -0.037 | 0.047 | -0.053 | -0.024 |
| Cerebral white % ICV total | 0.191 | -0.255 | 0.309 | -0.158 |

| |
|---|
| Significant at α=.05 |
| >.25 |
| .15 to .249 |
| .05 to .149 |
| -0.0499 to 0.0499 |
| -.05 to -.149 |
| -.15 to -.249 |
| <-.25 |
| Significant at α=.05 |

[5] Dual task effect

[6] Warm colors represent an inverse relationship between brain volume and DTE, meaning that smaller volumes are correlated with increased DTE. Cool colors represent a positive correlation between brain volume and DTE, meaning that smaller volumes are correlated with decreased DTE. A lower value mAAI represents motor prioritization, so a positive correlation (cool colors) means that smaller brain volumes are associated with motor prioritization.

Figure 5. Heat map of Pearson correlation coefficients for measures of gait and balance and motor DTE[7], cognitive DTE, attention allocation index (mAAI), and combined DTE (cDTE).[8]

| | Motor DTE | Cognitive DTE | mAAI | cDTE |
|---|---|---|---|---|
| Falls in prior year | 0.003 | 0.000 | 0.004 | -0.002 |
| Falls in prior 30 days | -0.033 | 0.029 | -0.044 | -0.007 |
| Fall injuries in prior year | 0.037 | 0.084 | -0.068 | 0.084 |
| Berg Balance Scale | -0.077 | -0.219 | 0.155 | -0.215 |
| MBT Anticipatory | -0.061 | -0.047 | 0.000 | -0.037 |
| MBT Reactive | -0.045 | -0.191 | 0.132 | -0.186 |
| MBT Sensory Organization | 0.077 | -0.239 | 0.257 | -0.120 |
| MBT Dynamic Gait | 0.006 | -0.407 | 0.371 | -0.266 |
| MBT Total | 0.032 | -0.264 | 0.246 | -0.171 |
| Ten-meter walk test | -0.105 | -0.239 | 0.167 | -0.214 |
| Ten-meter walk test - Fast | -0.058 | -0.194 | 0.136 | -0.170 |
| Six-minute walk test | -0.161 | -0.321 | 0.249 | -0.336 |
| Five times sit to stand | 0.092 | 0.225 | -0.165 | 0.186 |
| Time Up and Go | 0.030 | 0.423 | -0.383 | 0.314 |
| FFABQ | -0.075 | 0.177 | -0.203 | 0.081 |

Significant at α=.05
>.25
.15 to .249
.05 to .149
-.0499 to .0499
-.05 to -.149
-.15 to -.249
<-.25
Significant at α=.05

[7] Dual task effect

[8] Since a higher value on some gait and balance measures means better performance and a lower value on others means better performance, we have coded the proper relationship with the color rather than the positive or negative values in the table. Cool colors indicate that increased DTE is associated with worse gait/balance performance, while warm colors indicate the opposite correlation. A lower value mAAI represents motor prioritization, so a positive correlation (cool colors) means that worse gait/balance performance is associated with motor prioritization.

Figure 6. Heat map comparing strength of relationship on measures of gait and balance measures among motor DTE[9], cognitive DTE, and combined DTE (cDTE).[10]

| | motor DTE | Cognitive DTE | cDTC |
|---|---|---|---|
| Berg Balance Scale | -0.077 | -0.219 | -0.215 |
| MBT Anticipatory | -0.045 | -0.191 | -0.186 |
| MBT Reactive | 0.077 | -0.239 | -0.120 |
| MBT Sensory Organization | 0.006 | -0.407 | -0.266 |
| MBT Dynamic Gait | 0.032 | -0.264 | -0.171 |
| MBT Total | 0.092 | 0.225 | 0.186 |
| Ten-meter walk test | -0.105 | -0.239 | -0.214 |
| Ten-meter walk test - Fast | -0.058 | -0.194 | -0.170 |
| Six-minute walk test | -0.161 | -0.321 | -0.336 |
| Five times sit to stand | 0.092 | 0.225 | 0.186 |
| Time Up and Go | 0.030 | 0.423 | 0.314 |
| FFABQ | -0.075 | 0.177 | 0.081 |

Strongest relationship

Weakest relationship

[9] Dual task effect

[10] Darker colors indicate a stronger relationship between gait/balance performance and the different measure of dual task performance, as determined by Pearson correlation coefficients.

Table 1. Means, proportions and standard deviations for demographics, dual task effect battery, and measures of cognition, balance, gait, and strength and endurance.

| | n | Mean or Proportion |
|---|---|---|
| **DEMOGRAPHICS** | | |
| Age (years) | 65 | 76.37 ± 8.83 |
| Sex | | |
| Male | 35 | 53.8% |
| Female | 30 | 46.2% |
| Race | | |
| White | 51 | 78.5% |
| Black | 4 | 6.2% |
| Asian | 4 | 6.2% |
| Pacific Islander | 1 | 1.5% |
| Multiracial | 5 | 7.7% |
| Ethnicity | | Hispanic=4<br>Non-Hispanic=61 |
| Years since first cognitive symptom | 61 | 5.20 ± 3.65 |
| Falls reported in prior year | 58 | 4.26 ± 12.63 |
| Falls reported in prior 30 days | 46 | 1.15 ± 4.57 |
| Falls injuries reported in prior year | 50 | .44 ± .91 |
| **DUAL TASK EFFECT BATTERY** | | |
| Motor Dual Task Effect | 65 | 44.40 ± 42.52 |
| Cognitive Dual Task Effect | 65 | 114.96 ± 179.79 |
| Attention Allocation Index | 65 | -70.35 ± 175.97 |
| Combined Dual Task Effect | 65 | 226.56 ± 330.44 |
| **COGNITION** | | |
| Montreal Cognitive Assessment (scale points) | 58 | 19.98 ± 5.81 |
| **BALANCE** | | |
| Berg Balance Scale (scale points) | 16 | 42.50 ± 11.31 |
| MBT – overall (scale points) | 57 | 18.79 ± 5.97 |
| MBT Anticipatory | 57 | 3.98 ± .78 |
| MBT Reactive | 57 | 3.76 ± 1.36 |
| MBT Sensory Organization | 57 | 5.15 ± 1.10 |
| MBT Dynamic Gait | 57 | 6.07 ± 1.77 |
| Fear of Falling Avoidance Beliefs Questionnaire (scale points) | 24 | 16.17 ± 12.25 |
| **GAIT** | | |
| Ten-meter walk test (meters/second) | 42 | 1.00 ± .49 |
| Ten-meter walk test – Fast (meters/second) | 40 | 1.47 ± .78 |
| **STRENGTH AND ENDURANCE** | | |
| Five times sit to stand (seconds) | 59 | 15.79 ± 7.05 |
| Six-minute walk test (meters) | 35 | 325.01 ± 125.37 |

**CURRICULUM VITAE**

Caitlin Moreland, SPT
University of Nevada, Las Vegas
4505 S Maryland Pkwy, Las Vegas, NV, 89154
Caitlin.moreland9@gmail.com

**Education**

DPT University of Nevada, Las Vegas- Las Vegas, Nevada 2017-2020 Physical Therapy
BS University of Nevada, Reno- Reno, Nevada 2014-2017 Community Health Sciences

**Licensure**

Nevada State Board of Physical Therapy Examiners - Pending 2020

**Certifications**

- CPR Certified under American Heart Association (until May 2020)
- HIPAA Training Certified (as of September 2017)
- Blood-borne Pathogens Training Certified (as of September 2017)

**Employment/Work Experience**

| | |
|---|---|
| Jan 2020 - March 2020 | **Student Physical Therapist** - Advanced Healthcare of Reno<br>961 Kuenzli St. Reno, NV 89502 |
| Sept 2019 - Dec 2019 | **Student Physical Therapist** - St. Luke's Rehab Hospital<br>600 Robbins Rd. Boise, ID 83702 |
| July 2019 - Sept 2019 | **Student Physical Therapist** - Great Basin Physical Therapy<br>1701 County Rd. #B Minden, NV 89423 |
| Aug 2018 - May 2019 | **Graduate Assistant** – UNLV Physical Therapy Department<br>4505 S Maryland Pkwy, Las Vegas, NV 89154 |
| June 2018 - Aug 2018 | **Student Physical Therapist** - Reno Sport & Spine<br>15 McCabe Drive, Reno, NV 89511 |
| Oct 2011 - May 2017 | **Physical Therapy Technician** - Moreland Physical Therapy<br>2225 N. McCarren Blvd, Sparks, Nevada 89441 |

**Publications**

- Longhurst JK, Wise MA, Krist DJ, **Moreland CA**, Basterrechea JA, Landers MR. Brain volumes and dual-task performance correlates among individuals with cognitive impairment: a retrospective analysis. *Journal of Neural Transmission*. 2020, in print. DOI: 10.1007/s00702-020-02199-7
    - Poster Presentation at Combined Sections Meeting 2020

**Membership in Professional Organizations**

- American Physical Therapy Association (2017-present)

**Service**

- Volunteer at Rock Steady Boxing- Assisted adults with Parkinson's Disease in their workout routine (2018)
- Cupping Study Participant-UNLV Kinesiology Masters' student study (2017)
- Three Square Food Bank- Prepared lunches for children in need of food assistance (2017)
- Volunteer Pediatric Physical Therapy Aide-Washoe County School District (2016-2017)
- Advantage Program Youth Soccer Coach-Reno, NV (2015-2016)
- Anatomy Lab Dissection Assistant- University of Nevada, Reno (2015)
- Therapeutic Horseback Riding Assistant-Kids N' Horses (2015)

**Honors and Awards**

- Millennium Scholarship- University of Nevada, Reno (2014-2017)
- UNLV Access Grant 2018-2019
- UNLVPT Scholarship 2018-2019
- UNLVPT Scholarship 2019-2020
- UNLVPT Rural Health Scholarship 2019

**Continuing Education Attended (last 2 years)**

- February 13th-15th 2020: Combined Sections Meeting 2020
- January 24th-26th, 2019: Combined Sections Meeting 2019
- Monday, September 24th, 2018: Dr. David Holmes, DC, CSCS, DACBSP, "Principles of Functional Soft Tissue Examination"
- Monday, February 12th, 2018: Donna Costa, DHS, OTR/L, FAOTA, "Managing Stress in College Students with the Koru Mindfulness Programs"
- Monday, October 23rd, 2017: Manual Therapy Club – "Sacroiliac Joint Dysfunction, Evidence for Myofascial Release, and the Anterior Innominate Manipulation."
- Tuesday, October 3rd, 2017: Michael Tabo, DPT, VA Medical Center, "Federal physical therapy"
- Thursday, September 21st, 2017: Dr. Mahesh Kuthuru – "Pain, Medicine, and You."
- Tuesday, September 12th, 2017: NPTA – "Traumatic Brain Injury and NeuroRestorative"

Morgan Wise, SPT
Department of Physical Therapy, University of Nevada, Las Vegas
4505 Maryland Parkway, Las Vegas, Nevada 89154
Morganwise.dpt@gmail.com

**Education**

| | | |
|---|---|---|
| DPT | University of Nevada, Las Vegas – Las Vegas, Nevada<br>Physical Therapy | 2017-2020 |
| BA | University of Nevada, Reno – Reno, Nevada<br>Kinesiology | 2013-2017 |

**Licensure**

Nevada State Board of Physical Therapy Examiners (Pending 2020)

**Certifications**

- McKenzie Certification Part A (February 2019)
- CITI Training (May 2018)
- PT CPI Web Training (May 2018)
- Health-Care Provider CPR Certified (April 2018)
- HIPAA Training Certified (September 2017)
- Blood-borne Pathogens Training Certified (September 2017)

**Clinical Experience**

January 2020 – March 2020: **Physical Therapy Student** – Independence Rehab, Issaquah Nursing and Rehabilitation, 805 Front St S, Issaquah, WA 98027
September 2019 – December 2019: **Physical Therapy Student** – Renown Regional Medical Center, 1155 Mill St, Reno, NV 89502
July 2019 – September 2019: **Physical Therapy Student** – Lake Burien Physical Therapy, 15811 Ambaum Blvd SW #140, Burien, WA 98166
June 2018. – August 2018: **Physical Therapy Student**– ATI Physical Therapy, Desert Valley, 1701 N Green Valley Pkwy, Suite 8, Henderson, NV 89074

**Work Experience**

December 2015 – May 2017: **Physical Therapy Technician** – Reno Sport and Spine Institute, 15 McCabe Drive, Reno, Nevada, 89511
June 2015 – January 2016: **Physical Therapy Technician** — Barbieri Manual Physical Therapy, 1495 Ridgeview Drive, Suite 120, Reno, Nevada 89519

**Current Research Activity**

- "Brain volumes and dual-task performance correlates among individuals with cognitive impairment: a retrospective analysis" Landers M PT, DPT, PhD, OCS, Longhurst J PT, DPT, NCS, **Wise M SPT**, Moreland C SPT, Krist D SPT, Basterrechea J SPT

**Publications**

- Longhurst JK, Wise MA, Krist DJ, Moreland CA, Basterrechea JA, Landers MR. Brain volumes and dual-task performance correlates among individuals with cognitive impairment: a retrospective analysis. *Journal of Neural Transmission*. 2020, in print. DOI: 10.1007/s00702-020-02199-7

**Membership in Professional Organizations**

- APTA Student Assembly Core Ambassador for State of Nevada (August 2018 to present)
- Member American Physical Therapy Association (2017 to present)
- APTA Nevada Chapter (2017 to present)
- Member of Golden Key Honors Society (2014-2017)

**Service and Volunteer**

- Teddy Bear Kits for Kids ATI, Albuquerque, New Mexico, November 1st, 2019
- Burien Wellness Fair, Burien, Washington August 17th, 2019
- Nevada National Advocacy Dinner, Las Vegas, Nevada, July 9th, 2019
- Attendee of NV SB355 Hearing, May 10th, 2019
- Rock Steady Boxing, Las Vegas, Nevada, October 28th, 2018 – January 2019
- Muscular Dystrophy Association Walk, Las Vegas, Nevada, September 22nd, 2018
- Amputee Gait Workshop, Las Vegas, Nevada, September 15th, 2019
- ACL Prevention Screen Spanish Spring High School Junior Varsity/Varsity Soccer, Reno, Nevada, August 16th, 2018
- UNLVPT Student Interview Day, January 26th, 2018
- UNLVPT Student Interview Day, January 19th, 2018
- Three Square Volunteer, Las Vegas, Nevada, November 14th, 2017

**Honors and Awards**

- UNLVPT Scholarship 2019-2020
- UNLV Access Grant 2018-2019
- UNLVPT Scholarship 2018-2019
- Cum Laude upon graduation from University of Nevada, Reno (2017)

**Professional Growth and Continuing Education**

- November 1st, 2019 — APTA NSC 2019 – Albuquerque, New Mexico, "Pursuing Travel Therapy to Optimize Your Finances after Graduation" Whitney Elissa Eakin PT DPT
- November 1st, 2019 — APTA NSC 2019 – Albuquerque, New Mexico, "Everything You Didn't Know about Being a New Grad" Bryn Hager PT DPT
- October 22nd 2019 — Renown Medical Center, Traumatic Injury Presentation, Dr. Peter Althausen, MD, Reno, Nevada
- February 8th-9th — McKenzie Part A Certification, Las Vegas, Nevada

- November 29th, 2018 — 49th Mary McMillian Lecture: “Wisdom and Courage: Doing the Right Thing” By Laurie Hack, PT, DPT, PhD, MBA, FAPTA, Las Vegas, Nevada
- November 16th, 2018 — “Well Aligned, Soft Landings: A Cure for Running Injuries?” Dr. Irene Davis, PhD, PT, FACSM, FAPTA, FASB, Distinguished Lecture Series, Las Vegas, Nevada
- November 15th, 2018 — “Footwear Matters: Let’s Think Differently about the Foot” Dr. Irene Davis, PhD, PT, FACSM, FAPTA, FASB, Distinguished Lecture Series, Las Vegas, Nevada
- October 13th, 2018 – APTA-NSC 2018 - Providence, Rhode Island, “PT Plus Nutrition: The Perfect Combo to Help You Stand Out,” Joseph Tatta, PT, DPT, CNS
- October 13th, 2018 – APTA-NSC 2018 - Providence, Rhode Island, “Cancer Rehabilitation: What Every PT and PTA Needs to Know,” Stephen Wechsler, PT, DPT
- October 12th, 2018 – APTA-NSC 2018 - Providence, Rhode Island, “Building a Sports Specialty Practice from the Ground Up,” Carol Ferkovic Mack, DPT
- October 12th, 2018 – APTA-NSC 2018 - Providence, Rhode Island, “Bridging the Gap Between Orthopedic and Neurologic Rehabilitation,” Lindsay Walston, PT
- September 24th, 2018 – Sports Didactic – “Principles of Functional Soft Tissue Examination,” Dr. David Holmes DC, CSCS, DACBSP
- September 6th, 2018 – “Why Your DPT is Worthless and What You Can Do to Change It,” Beren Shah, PT, DPT and Rob Robb, PT, DPT
- April 18th, 2018 — “Pain Neuroscience in the Clinic” Adriaan Lowe, PT, PhD, Las Vegas, Nevada
- April 12th, 2018 – Online Seminar, “Pelvic Health: Implications for Orthopedic Therapists,” Evidence In Motion, Jennifer Stone, PT, DPT, OCS, PHC
- March 12, 2018 – Nevada Physical Therapy Monthly Meeting – “Pressure Management,” Skylar Post, AT
- American Physical Therapy Association Combined Sections Meeting, New Orleans, LA, February 22nd -24th 2018 – 1.8 CEU
    - “New Horizons for Children with SMA: Implication for PT Care,” Patterson K PT, MS, PCS, Krosschell K PT, DPT, MA, PCS, Carry T PT
    - “Understanding and Managing Pain in Neurodegenerative Diseases,” February 22nd, 2018, APTA-CSM 2018 – New Orleans
    - “Shoulder Pathomechanics in the Throwing Athlete – Causes, Surgery, Outcomes and Rehab,” Dr. Andrews, Dr. K Wilk, Dr. M Reinold, APTA-CSM 2018 – New Orleans
    - “Science Meets Practice: Clinical Decision Making for Examination, Surgery, Rehabilitation and Return to Sport for Patients with Shoulder Instability,” APTA-CSM 2018 – New Orleans

- “Neuromuscular Training after ACLT to Decrease ACL Re-Injuries and Risk in Females,” APTA-CSM 2018 – New Orleans
  - “Training Smarter and Harder: Improve Performance, Reduce Risk, Improve Return,” February 22nd, 2018, APTA-CSM 2018 – New Orleans
  - “Dual-task Gait Training: If, Who, When, How,” February 22nd, 2018, APTA-CSM 2018 – New Orleans
- February 13th, 2018 – UNLVPT Spanish Club attendance
- February 12th, 2018 – “Managing Stress in College Students with the Koru Mindfulness Program,” Donna Cost DHS, OTR/L. FAOTA
- November 27th, 2017 – “Early Mobility in the ICU,” Courtney Lee. K Haia, Las Vegas, Nevada
- November 16th, 2017 – “Incorporating Wellness Service into PT Clinic,” Mitch Smith PT, DPT, CWC, COS-C, Las Vegas, Nevada
- November 14th, 2017 – Nevada Physical Therapy Monthly Meeting – “Freezing of Gait in Parkinson’s Disease” – Jason Longhurst PT, DPT, NCS, MSC, CDP (tuned in online)
- November 14th, 2017 – UNLVPT Spanish Club attendance
- November 13th, 2017 – Presentation for UNLVPT Faculty, candidate Dr. Branch, Las, Vegas, Nevada
- October 27th, 2017 – “Disruption and Opportunity in Health Delivery: Go Hard or Go Home,” Dr. Sharon Dunn, APTA President, Las Vegas, Nevada
- October 26th, 2017 – “APTA: Pursuing Our Transformation Vision,” Dr. Sharon Dunn, APTA President, Las Vegas, Nevada
- September 23rd, 2017 – Nevada Physical Therapy Annual Meeting, featured speaker APTA Board Member Shelia Nicholson Las Vegas, Nevada
- September 12, 2017 – Nevada Physical Therapy Association Meeting – “Traumatic Brain Injury,” Julie Dendy, PT, Las Vegas, Nevada
  - September 11th, 2017 – Mindfulness/Yoga Workshop, Carolina Villar-Mendez, Las Vegas, Nevada
- June 16th, 2017 – “Animal Rehabilitation/Canine Physical Therapy,” Kelly Straub, Las Vegas, Nevada
- June 13th, 2017 – Interior Ankle Brace Seminar, Troy Watson MD, Henderson Nevada

Jon Basterrechea, SPT
Department of Physical Therapy, University of Nevada, Las Vegas
4505 Maryland Parkway, Las Vegas, Nevada 89154
Jonbast3@gmail.com

**Education**

| | | |
|---|---|---|
| DPT | University of Nevada, Las Vegas – Las Vegas, Nevada | 2017-2020 Physical Therapy |
| BS | University of Nevada, Reno – Reno, Nevada | 2011-2015 Biology |

**Licensure**

Nevada State Board of Physical Therapy Examiners (Pending 2020)

**Certifications**

- Hawkgrips Level 1 IASTM Certification (September 2018)
- CITI Program Human Subjects Research Certified (May 2018-May 2021)
- CITI Program Responsible Conduct of Research Certified (May 2018)
- American Heart Association, BLS for Healthcare Providers (May 2016-May 2018)
- HIPAA Training Certified (September 2017)
- Blood-borne Pathogens Training Certified (September 2017)

**Employment / Clinical Experience**

- January 2020 - March 2020 — **Student Physical Therapist** – Renown Regional Medical Center Double R, 10085 Double R Blvd, Suite 205, Reno, NV 89521
- September 2019 - December 2019 — **Student Physical Therapist** - VA Sierra Nevada, 975 Kirman Ave., Department of Physical Therapy, Reno, NV 89502
- July 2019 - September 2019 — **Student Physical Therapist** - St Mary's Regional Medical Center, 235 W 6th St Reno, NV 89503
- June 2018 - July 2018 — **Student Physical Therapist** - Select Physical Therapy, 821 N Nellis Blvd #130, Las Vegas, NV 89110
- July 2016 - May 2017 — **Physical Therapy/Wellness Technician** – Five Star Premier Residences of Reno, 3201 Plumas St, Reno, NV 89509

**Membership in Professional Organizations**

- Member American Physical Therapy Association (2017 to present)
- Member Nevada Physical Therapy Association (2017 to present)

- Member Orthopedic Section of the American Physical Therapy Association (2017 to present)

**Service / Volunteer Activity**

- Volunteer at UNLV-PT Interview day (January 2018)
- Volunteer at Nevada Health Link Holiday Health Fair (December 2017)

**Publications**

- Longhurst JK, Wise MA, Krist DJ, Moreland CA, Basterrechea JA, Landers MR. Brain volumes and dual-task performance correlates among individuals with cognitive impairment: a retrospective analysis. *Journal of Neural Transmission*. 2020, in print. DOI: 10.1007/s00702-020-02199-7

**Continuing Education Attended**

- American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020
    - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: Mobilizing an Enterprise: The Development of a Comprehensive Rehabilitation-Led Safe Patient Handling and Mobility Program
    - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: Movement System-Based Treatment Approach for the Hip Joint
    - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: Making the Transition: Physical Therapy for People With Advancing Multiple Sclerosis
    - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: What Assessment and Intervention Strategies Are Essential for Great Foot and Ankle Care?
    - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: Pushing the Envelope on Exercise: Physical Therapy and Medical Management of the Active Patient With Arthritis
    - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: Muscle Degeneration of the Rotator Cuff: Scientific Advances to Guide Surgery and Rehabilitation
    - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: Dysfunction of the Lumbo-Pelvic-Hip Complex in Human vs. Canine Clients
    - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: Academy of Orthopaedic Physical Therapy Platform 7

  - American Physical Therapy Association, Combined Sections Meeting, Denver, CO, February 12-15, 2020: Can the Power of Language Be More Important Than Our Hands?
- McKenzie Method of Mechanical Diagnosis and Therapy, Part A: Lumbar Spine, Las Vegas, NV, February 8-10, 2019
- Hawkgrips Level 1 IASTM Certification, Las Vegas, NV, September 8, 2018
- American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 22-24, 2018
  - American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 24, 2018: Why the Overhead Athlete Should Never Skip Leg Day
  - American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 24, 2018: Muscle Alterations in Various Conditions of Aging: Implications for Rehab
  - American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 23, 2018: Neuromuscular Training After ACLR to Decrease ACL Reinjuries and Risk in Young Female Athletes
  - American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 23, 2018: Shoulder Pathomechanics in the Throwing Athlete: Causes, Surgery, Outcomes, and Rehab
  - American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 23, 2018: Science Meets Practice: Innovative Changes with Treating Shoulder Instabilities
  - American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 22, 2018: Academic Preparation for a Career in Sports Physical Therapy
  - American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 22, 2018: Movement, Pain, and Aquatic Therapy
  - American Physical Therapy Association, Combined Sections Meeting, New Orleans, LA, February 22, 2018: Responding to Emergencies: When the PT Is the Most Medical Professional

Daniel Krist, SPT
Department of Physical Therapy, University of Nevada, Las Vegas
4505 Maryland Parkway, Las Vegas, Nevada 89154
Danielkrist01@gmail.com

## Education

| | | | |
|---|---|---|---|
| DPT | University of Nevada, Las Vegas<br>Las Vegas, NV | 2017-2020 | Physical Therapy |
| BS | California Polytechnic State University<br>San Luis Obispo, CA | 2006-2010 | Biology |

## Licensure

Oregon State Board of Physical Therapy (Pending April 2020)

## Certifications

- OTAGO Exercise Program: Falls Prevention Training Certification (March 2019)
- STEADI Exercise Program Training Certification (February 2019)
- HawkGrips IASTM Practitioner Level I (Sept 2018)
- CITI Responsible Research Conduct Training Certified (May 2018)
- American Heart Association CPR Certified (April 2018)
- HIPAA Training Certified (September 2017)
- Blood-borne Pathogens Training Certified (September 2017)

## Employment

| | |
|---|---|
| Sept 2018 – May 2019 | **Graduate Research Assistant** – University of Nevada Las Vegas Physical Therapy Department, 4505 S Maryland Pkwy, Las Vegas, NV 89154 |
| Dec 2014 – Feb 2017 | **Physical Therapy Aide** – Cambria Physical Therapy, 1266 Tamson St #101, Cambria, CA 93428 |

## Clinical Experience

| | |
|---|---|
| Jan 2020 – March 2020 | **Student Physical Therapist** – Centennial Hills Hospital, 6900 N. Durango Drive, Physical Therapy Department, Las Vegas, Nevada, NV 89149 |
| Sept 2019 – Dec 2019 | **Student Physical Therapist** – Comprehensive Therapy Centers, 3602 E Sunset Rd, Suite 100, Las Vegas, NV 89120 |
| July 2019 – Sept 2019 | **Student Physical Therapist** – MountainView Hospital Acute Rehabilitation, 3100 N Tenaya Way, Department of Physical Therapy, Las Vegas, NV 89128 |
| June 2018 – Aug 2018 | **Student Physical Therapist** – Donatelli Physical Therapy and Sports, 7229 W Sahara Ave, Las Vegas, NV 8117 |

## Current Research Activity

- Longhurst JK, Wise MA, Krist DJ, Moreland CA, Basterrechea JA, Landers MR. Brain volumes and dual-task performance correlates among individuals with cognitive impairment: a retrospective analysis. *Journal of Neural Transmission*. 2020, in print. DOI: 10.1007/s00702-020-02199-7

**Membership in Professional Organizations**

- Member American Physical Therapy Association, Orthopedic Section (2018 to present)
- Member American Physical Therapy Association (2017 to present)
- Member Nevada Physical Therapy Association (2017 to present)

**Service**

- Volunteer, trail building - Mt. Charleston, NV – May 18, 2019
- Volunteer, UNLVPT Community Fall Screening – Sept 29, 2018
- Volunteer, UNLVPT/Kinesiology Interdisciplinary Simulation Lab – April 23, 2018
- Volunteer, UNLVPT Interview day – Jan 19, 2018
- Volunteer, Amputee Coalition of Southern Nevada Meeting – Las Vegas, NV – December 2, 2017

**Honors and Awards**

- UNLVPT Scholarship 2019
- UNLV Graduate Student Access Grant 2019
- UNLV Graduate Student Access Grant 2018

**Continuing Education Attended (last 2 years)**

- UNLVPT Brown Bag Lecture - "Evidence for Electrotherapy for Strengthening" - Las Vegas, NV, March 28th, 2019 – 1 hour
- UNLVPT Distinguished Lecture Series – Las Vegas, NV November 15th & 16th, 2018
    - "Footwear Matters: Let's Think About the Foot" - Dr. Irene Davis -1.5 hours
    - "Well Aligned, Soft Landings: A Cure For Running Injuries?" - Dr. Irene Davis - 2.5 hours
- HawkGrips IASTM Fundamentals: Level I – Las Vegas, NV, Sept 8th, 2018 – 8 hours
- UNLVPT Brown Bag Lecture – "Why Your DPT is Worthless and What You Can Do About It" – Las Vegas, NV, Sept 6th, 2018 – 1 hour
- "Pain Neuroscience in the Clinic" – Adriaan Louw, PT, PhD - Las Vegas, NV, April 18, 2018 – 6 hours
- UNLVPT Brown Bag Lecture - "Runners Dystonia: the Mystery Movement Disorder" – Las Vegas, NV, March 12th, 2018 – 1 hour
- American Physical Therapy Association Combined Sections Meeting, New Orleans, LA, Feb 22-24, 2018 – 14 hrs
    - Thursday, February 22, 2018: "Sports Medicine Secrets: Motor Control in the Overhead Athlete"
    - Thursday, February 22, 2018: "Dry Needling for Tendinopathy?"

- Thursday, February 22, 2018: “Applying the Movement System Diagnosis to Neurodegenerative Diseases”
- Friday, February 23, 2018: “Pitfalls of Post-Concussion Syndrome”
- Friday. February 23, 2018: “Task Specific Movement Training: A Novel Treatment Approach for Chronic Lower-Extremity Pain”
- Friday, February 23, 2018: “No Fear: Treating the Stroke Patient in the Neurological ICU with Confidence”
- Saturday, February 24, 2018: “Video-Enhanced Movement Analysis and Training: The Clinical Reasoning Process”