# EXAMINING THE RELATIONSHIPS AMONG COGNTIVE PROCESSING, PHYSICAL FUNCTION, AND DISABILITY IN OLDER ADULTS

**by**
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**A dissertation submitted to the faculty of The University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the School of Medicine (Program in Human Movement Science).**

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# ABSTRACT

**LORI A. SCHRODT: Examining the Relationships Among Cognitive Processing, Physical Function, and Disability in Older Adults**
**(Under the direction of Carol A. Giuliani)**

Age-related declines in cognitive processing are well documented and may contribute to limitations performing daily living tasks as people age. The purpose of this dissertation was to examine the relationships among cognitive processing, physical function, and disability in older adults. Three studies were organized into three distinct manuscripts. In this dissertation, we use the term *cognitive processing* to refer to performance on measures of attention and processing speed. The objective of the first study was to examine the direct and indirect effects of cognitive processing on physical function and disability. The second study examined: (1) the predictive relationship of cognitive processing to changes in physical function and disability, and (2) the association of change in cognitive processing to change in physical function and disability. The purpose of the third was to explore the relationship of cognitive processing to self-reported disability measured as dependence and measured as difficulty. The combined results of all three experiments confirmed that cognitive processing is associated with both concurrent and future levels of physical function and disability in older adults. The relationship between cognitive processing and disability is primarily mediated by physical function, such that poor cognitive processing is associated with lower levels of physical function and indirectly with higher levels of disability. Poor baseline cognitive processing is also predictive of decreased balance and disability one year later. The relationship of cognitive processing with disability appears to be most robust when

disability is defined as dependence.  These results illustrate the complex relationship of cognitive processing to physical function and disability in older adults.

To Andrew:

For your love and support.

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# LIST OF ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| ADL | Activities of daily living |
| BADL | Basic activities of daily living |
| CCRC | Continuing care retirement community |
| CES-D | Center for Epidemiologic Studies Depression Scale |
| CI | Confidence Interval |
| EPESE | Established Populations for Epidemiological Studies of the Elderly |
| FICSIT | Frailty and Injuries Cooperative Studies of Intervention Techniques |
| IADL | Instrumental activities of daily living |
| MMSE | Mini Mental State Exam |
| OARS | Older Americans Research and Service Center Instrument (IADL) |
| OR | Odds Ratio |
| PF | Physical Function |
| PF-10 | Physical Function sub-scale of the SF-36 |
| PPT | Physical performance test |
| SDMT | Symbol Digit Modalities Test |
| SE | Standard Error |
| SF-36 | Medical Outcomes Study Questionnaire- Short Form |
| SPMSQ | Short Portable Mental Status Questionnaire |
| TMT | Trail Making Test |
| TMTA | Trail Making Test Part A |
| TMTB | Trail Making Test Part B |
| WHAS | Women's Health and Aging Study |

| | |
|---|---|
| WS | Walking Speed |
| Z-COG | Composite Measure of Cognitive Processing |
| Z-SDMT | Symbol Digit Modalities Test Standard Score |
| Z-TMTB | Trail Making Test Part B Standard Score |
| ° | Degree |

# CHAPTER I

# INTRODUCTION

Independent and safe performance of daily living and mobility tasks requires the interaction of cognitive and physical functions. Presently, the relationships between specific aspects of cognitive and physical function and how they contribute to disability in older adults are not well understood. Gaining a better understanding of the relationships between specific aspects of cognition and physical function and how they contribute to everyday task performance is important for identifying impairments that may contribute to current or future functional limitations and disability. Furthermore knowledge of these relationships will provide guidance for developing prevention and rehabilitation programs.

Poor performance on general cognitive screening measures, such as the Mini Mental State Exam (MMSE)[1] and Short Portable Mental Status Questionnaire (SPMSQ),[2] is associated with physical function limitations in tasks such as walking and climbing stairs,[3,4] and with ADL and IADL disability in both cross-sectional and longitudinal research.[5-7] However, general cognitive measures such as the MMSE and SPMSQ are intended as screening tools to assess overall cognitive function and dementia. They do not adequately measure specific aspects of cognition, such as memory, attention, and processing speed. Although much concern is focused on memory decline in aging, other aspects of aging also may be important for physical function and daily task performance. Identifying decline in specific aspects of cognitive processing associated with physical function limitations and disability is critical for designing appropriate intervention programs effective for preserving independence among older adults for as long as possible.

Age-related declines in attention and processing speed are well documented and may contribute to limitations in performing daily living tasks as people age.[8-13] Older adults frequently demonstrate decreased performance with visual aspects of attention, such as visual scanning and selection of visual cues from the environment, that are important for performing daily tasks, such as walking and driving.[14,15] Slowed processing speed is theorized to contribute to the age-related impairments observed in other aspects of cognition, such as memory and problem solving.[16] Slowed processing speed may therefore impair an older individual's ability to organize and sequence both the cognitive and physical aspects of daily tasks and make decisions on how to adapt to changing environments or situations.

Cross-sectional research demonstrates stronger associations of attention and processing speed to physical function[17] and ADL and IADL performance[18] than other aspects of cognition, such as memory. Several studies provide evidence that poor performance on attention and processing speed measures is associated with poorer performance of physical function skills (such as balance and walking), ADL, IADL, and increased risk of falls.[17-23] However, the direct and indirect effects of attention and processing speed on physical function and disability and the prediction of future changes in physical function and disability based on attention and processing speed have not yet been examined.

The purpose of this dissertation was to address some of the gaps in the literature by examining the relationships among attention and processing speed, physical function, and disability. In this dissertation, we use the term *cognitive processing* to refer to performance on measures of attention and processing speed. Three studies were designed to explore these relationships. The first study (Chapter II) examined the direct and indirect effects of cognitive processing on physical function and disability. We also compared the magnitude of the mediating effects of two physical function measures on the relationship between cognitive processing and disability. The second study (Chapter III) examined the predictive relationship of cognitive processing to changes in physical function and disability at one-year follow-up. We also examined the association of change in cognitive processing to change in physical function and disability. In the third study (Chapter IV) we explored the relationship of cognitive processing to self-reported disability measured as difficulty and measured as dependence with daily tasks.

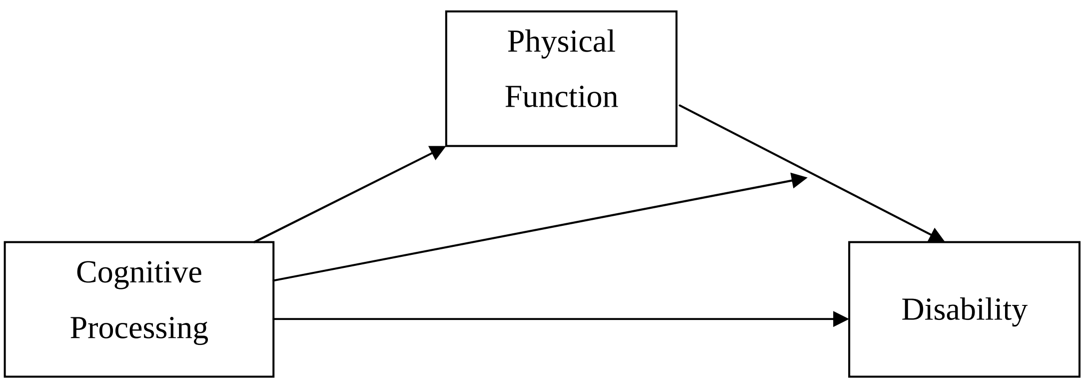
Examination of the complex relationships among cognitive processing, physical function, and disability provides a better understanding of how cognition contributes to everyday task performance in older adults. In particular, we examined the role of cognitive processing in future decline in physical function and increased disability with the expectation that this information will contribute to efforts to reduce disability in older adults.

## Thesis Summary

The central idea for the dissertation is that

*Cognitive processing is associated with both concurrent and future levels of physical function and disability in older adults.*

**THEORETICAL MODEL**




This model guides the theorized relationships among cognitive processing physical function, and disability.

To validate this assumption, the dissertation was organized into three studies.

## First Study

The objective of this study was to examine the direct and indirect effects of cognitive processing on physical function and disability.

Research Questions

1. Does cognitive processing demonstrate a direct effect on physical function?

*Hypothesis:* Cognitive processing demonstrates a direct effect on physical function.

2. Does cognitive processing demonstrate an indirect effect on disability mediated by physical function?

*Hypothesis:* Cognitive processing demonstrates an indirect effect on disability mediated by physical function.

2a. Is the magnitude of the indirect mediating effect of a comprehensive, multiple item physical function measure greater than that of a single-item physical function measure on the relationship between cognitive processing and disability?

*Hypothesis:* The magnitude of the indirect mediating effect of a comprehensive, multiple item physical function measure is greater than the indirect mediating effect of a single-item physical function measure.

3. Does cognitive processing demonstrate a direct effect on disability?

*Hypothesis:* Cognitive processing demonstrates a direct effect on disability.

4. Does cognitive processing modify the relationship between physical function and disability?

*Hypothesis:* Cognitive processing modifies the relationship between physical function and disability.

## Second Study

The objectives of this study were to examine: (1) the predictive relationship of cognitive processing to changes in physical function and disability one year later, and (2) the association of change in cognitive processing to change in physical function and disability over one year.

Research Questions

1. Does cognitive processing measured at baseline predict changes in physical function and disability after one year?

*Hypothesis:* Baseline cognitive processing predicts changes in physical function and disability after one year.

2. Is change in cognitive processing associated with changes in physical function, and disability after one year?

*Hypothesis:* Change in cognitive processing is associated with changes in physical function and disability after one year.

## Third Study

The purpose of this study was to explore the relationship of cognitive processing to self-reported disability measured as dependence and measured as difficulty.

Research Question

1. Is the association of cognitive processing to self-reported disability stronger when disability is measured as difficulty than when it is measured as dependence?

*Hypothesis:* Cognitive processing is more strongly associated with disability when disability is measured as difficulty than when it is measured as dependence.

The results of the three studies were organized into three manuscripts. The first manuscript (Chapter II) addresses the direct and indirect effects of cognitive processing on physical function and disability. The second manuscript (Chapter III) describes the predictive relationship of cognitive processing on changes in physical function and disability, and the association of change in cognitive processing to change in physical function and disability. The third manuscript (Chapter IV) explores the relationship of cognitive processing to self-reported disability defined as difficulty and defined as dependence. Chapter V provides a synthesis of the results of all three studies and discusses the research limitations.

**REFERENCES**


1. Folstein MF, Folstein SE, McHugh PR. Mini-Mental State: A practical method for grading the cognitive state of the patient for the clinician. *Journal of Psychiatric Research.* 1975;12:189-198.

2. Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficits in elderly patients. *J Am Geriatr Soc.* 1975;23:433-441.

3. Blaum CS, Ofstedal MB, Liang J. Low cognitive performance, comorbid disease, and task-specific disability: findings from a nationally representative survey. *J Gerontol: Med Sci.* 2002;57A(8):M523-M531.

4. Fried LP, Ettinger WH, Lind B, Newman AB, Gardin J. Physical disability in older adults: a physiological approach. Cardiovascular Health Study Research Group. *J Clin Epidemiol.* 1994;47(7):747-760.

5. Gill TM, Williams CS, Richardson ED, Tinetti ME. Impairments in physical performance and cognitive status as predisposing factors for functional dependence among nondisabled older persons. *J Gerontol: Med Sci.* 1996;51A(6):M283-M288.

6. Greiner PA, Snowden DA, Schmitt FA. The loss of independence in activities of daily living: the role of low normal cognitive function in elderly nuns. *Am J Public Health.* 1996;86(1):62-66.

7. Njegovan V, Man-Son-Hing M, Mitchell SL, Molnar. The hierarchy of functional loss associated with cognitive decline in older persons. *J Gerontol: Med Sci.* 2001;56A(10):M638-M643.

8. Salthouse TA. Aging and measures of processing speed. *Biol Psychol.* 2000;54:35-54.

9. Earles JL, Salthouse TA. Interrelations of age, health, and speed. *J Gerontol: Psychol Sci.* 1995;50B(1):P33-P41.

10. Allen PA, Weber TA, Madden DJ. Adult age differences in attention: filtering or selection? *J Gerontol: Psychol Sci.* 1994;49:213-222.

11. Jordan TC, Rabbitt PMA. Response times to stimuli of increasing complexity as a function of aging. *Br J Psychol.* 1977;68:189-201.

12. Rubichi S, Neri M, Nicoletti R. Age-related slowing of control processes: evidence from a response coordination task. *Cortex.* 1999;35(4):573-582.

13. Sliwinski M, Buschke H, Kuslansky G, Senior G, Scarisbrick D. Proportional slowing and addition speed in old and young adults. *Psychol Aging.* 1994;9(1):72-80.

14. Owsley C. Vision and driving in the elderly. *Optom Vis Sci.* 1994;71(12):727-735.

15. Owsley C, Burton-Danner K, Jackson GR. Aging and spatial localization during feature search. *Gerontology.* 2000;46(6):300-305.

16. Salthouse TA. The processing-speed theory of adult age differences in cognition. *Psychol Rev.* 1996;103(3):403-428.

17. Binder EF, Storandt M, Birge SJ. The relation between psychometric test performance and physical performance in older adults. *J Gerontol: Med Sci.* 1999;54A(8):M428-M432.

18. Carlson MC, Fried LP, Xue QL, Bandeen-Roche K, Zeger SL, Brandt J. Association between executive attention and physical functional performance in community-dwelling older women. *J Gerontol: Soc Sci.* 1999;54B(5):S262-S270.

19. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. *J Gerontol: Med Sci.* 1991;46(3):M69-M76.

20. Lord SR, Lloyd DG, Li SK. Sensori-motor function, gait parameters and falls in community-dwelling women. *Age Ageing.* 1996;25:292-299.

21. Nevitt MC, Cummings SR, Kidd S, Black D. Risk factors for recurrent non-syncopal falls: a prospective study. *JAMA.* 1989;261:2663-2668.

22. Rosano C, Simonsick EM, Harris TB, et al. Association between physical and cognitive function in health elderly: The Health, Aging and Body Composition Study. *Neuroepidemiology.* 2005;24:8-14.

23. Bell-McGinty S, Podell K, Franzen M, Baird AD, Williams MJ. Standard measures of executive function in predicting instrumental activities of daily living in older adults. *Int J Geriatr Psychiatry.* 2002;17:828-834.

# CHAPTER II

# FIRST MANUSCRIPT

Examining the relationships among cognitive processing, physical function, and disability in older adults

**Abstract**

**Background.** Prior research supports that cognitive processing is associated with level of independence in daily activities; however the complexities of this relationship are not well understood.

**Purpose.** To examine (1) the direct effects of cognitive processing on disability and the indirect effect mediated by physical function, and (2) if the relationship between physical function and disability is modified by cognitive processing.

**Method.** Volunteers (N=155) from a continuing care retirement community and church congregation (mean age 81.2 ± 5.7 years, 71% female) participated in a wellness assessment that included measures of cognitive processing, physical function, and disability. Cognitive processing, defined as performance on measures of attention and processing speed, was assessed with the Symbol Digit Modalities Test (SDMT) and the Trail Making Test Part B (TMTB). Raw SDMT and TMTB scores were transformed into z-scores to create a composite score of cognitive processing. Physical function was assessed with the Physical Performance Test (PPT), and walking speed (WS). The SF-36 Physical Function Sub-scale (PF-10) assessed disability. Linear regression models were estimated to examine the relationships among cognitive processing, physical function, and disability.

**Results.** Cognitive processing explained approximately 14% of the variance in PF-10 ($p \leq .001$), primarily though indirect effects. The indirect effect of cognitive processing on PF-10, mediated by PPT or WS, was significant ($p \leq .001$), but the direct effect of cognitive processing on PF-10 was not significant. The magnitude of the indirect effects of cognitive processing on disability were similar with the PPT or WS as the mediator. The relationship of PPT or walking speed to PF-10 was not modified by level of cognitive processing as indicated by a non-significant interaction.

**Conclusion.** The relationship between cognitive processing and disability is primarily mediated by physical function, illustrating the importance of cognitive processing on physical function and its indirect relationship to disability.

***Key words:*** *cognition, attention, processing speed, function, disability*

**INTRODUCTION**

As people age, cognitive function decreases and is associated with limitations in performing daily activities.[1-3] Although many older adults worry about memory loss, attention and processing speed also decline with advancing age and may contribute to limitations in physical function and daily living tasks.[1, 4-6] The complex relationships among various aspects of cognition, physical function, and disability are not well understood.

The cognitive processes of attention and processing speed are important for successful completion of both the cognitive and physical aspects of complex daily tasks. Attention and processing speed are reported to have stronger associations to physical function,[7] and activities of daily living (ADL) and instrumental activities of daily living (IADL)[8] than other aspects of cognition, such as memory. Attention and processing speed promote the cognitive organization, initiation, and sequencing of actions necessary for efficient information processing and performance of daily tasks; such as, finding objects on a crowded shelf, meal preparation, and walking.

Attention, especially visual aspects of attention such as visual scanning and selective attention, is particularly important for performing daily tasks that utilize external cues. For example, maintaining balance during walking requires an individual to select important information about the environment, such as the location of obstacles and movement of other persons, in order to adjust step placement and walking speed.

Processing speed, or the time it takes to process information about external and internal cues, plays a key role in the planning and execution of coordinated movements and is a critical component of balance responses. Fast processing speed is required for quick, compensatory adjustments needed to maintain balance in unstable conditions.

Salthouse proposed that slowed processing speed contributes to many of the age-related impairments observed in other aspects of cognition, such as working memory and problem solving.[4] In this way, slowed processing speed may impair an older individual's ability to organize and sequence daily tasks and make decisions on how to adapt to changing environments or situations. Impaired attention may also interfere with performance of daily tasks by reducing one's ability to scan the environment and utilize external cues. The relationship between processing speed and balance, a physical function skill, is especially important because sufficient balance is required for successful performance of independent mobility and dynamic daily activities, such as walking and reaching.

Nagi[9] proposed that impairments, theorized to result from disease, injury or developmental process, may increase the risk of functional limitations, which may consequently lead to disability. The extent to which physical function limitations and disability are associated with impairments in cognitive processing remains unclear.

Recent studies suggest that declines in attention and processing speed are associated with poorer performance of balance, walking, ADL, and IADL, and with an increased risk of falls.[7, 8, 10-12] Because of the relationships of attention and processing speed to balance and other physical functions, and the well documented relationship of physical function to disability level,[13-16] it is possible that physical function, and particularly balance, may play a role in mediating the relationship of attention and processing speed to disability.

Few studies have examined the indirect mediating effects of physical function on the relationship of cognitive processing and disability. Van Schoor and colleagues[17] reported that grip strength, a physical impairment, and physical activity level, which is associated with physical function and disability status in older adults, mediated the relationship between immediate memory and recurrent falls. As with disability, falls often result from decreases in physical function.[18, 19] The authors suggest that the attention-demanding nature of the immediate memory test may have influenced the relationship between memory and recurrent falls. To our knowledge, the direct and indirect effects of attention and processing speed on physical function and disability have not been examined.

Complex daily living and mobility skills require the combination of physical and cognitive resources for independent function. Older adults with physical function limitations may need to rely more heavily on external cues and movement strategy adaptations to maximize independence in ADL and IADL. Reduced attention and processing speed capabilities may modify the relationship between physical function and disability by reducing one's ability to visually scan the environment, direct attention, and process external cues quickly; thus decreasing the utilization of effective compensation strategies. Further examination of the complex relationships among age related changes in attention and processing speed, physical function, and disability is important for identifying impairments that may contribute to loss of independence.

The purpose of this paper was to examine the relationships among the cognitive processes of attention and processing speed, physical function, and disability. We tested the hypotheses that attention and processing speed are associated with increased disability through both a direct effect and an indirect effect mediated by physical function, and that level of attention and processing speed modifies the relationship between physical function and disability in older adults.

## METHOD

### Study Design and Sample

This was a cross-sectional study using baseline data from the *Be Alive* project, a larger, ongoing longitudinal study promoting wellness and independence in older adults living in North Carolina. Participants in the *Be Alive* project were older adults living in the community or a continuing care retirement community (CCRC) who volunteered for on-site wellness assessments (N=195 at baseline) which consisted of a comprehensive battery of measures assessing cognitive and physical abilities. Individuals 50 years of age or older and able to walk independently with or without an assistive device were included in the *Be Alive Project*. Individuals with medical conditions precluding participation in physical performance testing, such as uncontrolled hypertension or severe joint pain, were excluded from testing. Prior to testing, a brief medical screen assessing health history, pain, medication use, and recent surgeries was administered by interview to identify participants with contraindications to performance testing. All participants signed an informed consent form approved by the UNC Chapel Hill School of Medicine Committee for the Protection of Human Subjects. Trained health professionals performed assessments in a single session lasting approximately 90 minutes.

Participants included in this secondary analysis were 155 individuals from the *Be Alive* project who were 65 years of age or older, scored above six on the Short Portable Mental Status Questionnaire,[20] and could clearly see the cognitive processing test items. The forty participants excluded from the original *Be Alive* project sample did not differ from the participants included in this study with respect to demographic characteristics and general health status.

## Data Collection Procedure

*Demographic and Health-Related Measures*

Participants in the study completed a series of self-report questionnaires to gather demographic and health-related information. The self-report questionnaires included medical history, the Katz Activities of Daily Living Scale[21] and the Older Americans Research and Service Center Instrument (OARS),[22] a measure of IADL ability. Because research suggests that depression may contribute to poor cognitive function and disability,[23, 24] we also administered the Center for Epidemiologic Studies Depression Scale[25] (CES-D) to identify participants who demonstrated depressive symptoms.

*Cognitive, Physical Function, and Disability Measures*

All timed performance measures were recorded to the nearest tenth of a second.

*Cognitive Processing: Attention and Processing Speed Measures*

We operationally defined cognitive processing as performance on measures of attention and processing speed, and selected these aspects of cognition because they are important to both the cognitive and physical aspects of daily tasks.[4, 7, 8] We selected the Symbol Digit Modalities Test and the Trail Making Test Part B to measure attention and processing speed based on their sensitivity to age-related impairments and psychometric properties. Participants were tested in a quiet room and wore corrective eyewear if necessary.

*(a)* S*ymbol Digit Modalities Test (SDMT):* The SDMT assesses visual aspects of attention, such as scanning and tracking, and processing speed.[26, 27] The test requires the conversion of meaningless geometric designs into oral or written number responses.[28] We chose the oral

version of the SDMT to reduce the influence of limited motor ability on test performance (e.g., participants with Parkinson's Disease or arthritis). Scores were calculated as the total number of items correct in 90 seconds.

*(b) Trail Making Test Part B (TMTB):* The TMTB assesses visual attention, processing speed, motor function, and mental flexibility.[26, 29] This paper-and-pencil test requires connecting circles in alternating numerical and alphabetical sequence (e.g., 1-A-2-B, etc.) as quickly as possible. Scores were recorded as the time required to complete the test, up to a maximum of 180 seconds. Participants unable to complete the test in the maximum allowed time were assigned scores of 180 seconds.

*Physical Function Measures*

The Physical Performance Test,[30] walking speed,[16] and timed 360° turn,[13] were used to assess physical function. These measures are performance based and can be administered to older adults with a wide range of ability levels.

*(a) Physical Performance Test (PPT):* The 7-item PPT was our primary measure of physical function because it assesses several aspects of upper and lower body function and mobility (writing, eating, lifting, dressing, bending, turning, and walking).[30] For all items on the PPT except the 360° turn, the time to complete each task was recorded using a stopwatch and then translated into scaled scores ranging from 0 (poor performance) to 4 (best performance). The 360° turn item was scored on a 0-4 scale based on step continuity and steadiness. The maximum possible score for the 7-item PPT is 28, representing the highest level of function.

*(b) Walking Speed (WS):* Walking speed is frequently used as a measure of physical function in older adults and is a good predictor of functional decline and disability in older adults.[13, 14,

[16, 31] Walking speed was our secondary measure of physical function because it assesses physical mobility compared to the more comprehensive functional assessment, the PPT. Self-selected walking speed was assessed using a 10-meter walk course allowing for acceleration and deceleration by including 1-meter zones at both ends. Participants started walking at the beginning of the acceleration zone and timing started when the participant's foot crossed the tape at the start of the 10-meter course, and stopped when the foot crossed the line at the end of the course. Two trials were completed and the average walking speed was calculated in meters/second.

*(c) Timed 360° Turn (360° turn):* The timed 360° turn was used to assess dynamic standing balance because it requires more complex sequencing than static measures of standing balance, such as tandem stance. The 360° turn is a single timed performance measure of balance[13] and is an item in several performance-based tests for older adults, including the PPT,[30] Berg Balance Scale,[32] and the Performance-Oriented Assessment of Mobility Problems.[33] Participants were instructed to stand behind a line on the floor facing the tester and then turn completely around in either direction. Participants performed two trials and the average turn time was used for analysis.

*Disability Measure*

*SF-36 Physical Function Sub-scale (PF-10):* The Medical Outcome Survey Short Form (SF-36) is a self-report measure of health status in 8 domains (general health, physical functioning, physical role, emotional role, social function, bodily pain, mental health, and vitality.[34] We selected the Physical Function sub-scale (PF-10) as our primary measure of disability because it specifically asks questions about ADL and other daily tasks (e.g.

carrying groceries, vacuuming, bathing, and dressing) and because it is a responsive measure of physical abilities in community dwelling older adults.[35] Participant responses for each sub-scale were converted to an index score ranging from 0 (worst health) to 100 (best health).[34]

*Statistical Analysis*

The data were analyzed using SPSS Version 12.0 (SPSS Inc.; Chicago, IL) and AMOS Version 4 (SmallWaters Corp.; Chicago, IL) statistical software. Univariate analyses of all variables were conducted to examine the data distribution, detect outliers, and characterize the sample. Because the SDMT scores and TMTB scores were moderately correlated ($r = -.63$, $p \leq .001$), we constructed a composite score. Raw scores on the SDMT and TMTB were transformed to standard *z*-scores using the sample means and standard deviations. The z-scores were then averaged to create a composite measure of cognitive processing (Z-COG) for each participant.

Ordinary least squares linear regression analyses were conducted to examine the relationships among cognitive processing, physical function, and disability. Separate linear regression models were estimated to examine the independent relationships among the cognitive processing measures (Z-COG, SDMT, and TMTB) and the physical function measures (PPT, 360° turn, and WS), and among the cognitive processing measures and the disability measure (PF-10). Separate linear regression models were also estimated to examine the independent relationships between the physical function measures and the disability measure. The latter analyses were conducted to examine the indirect effect of cognitive processing on disability mediated by physical function (Figure 2.1a). The Sobel test was used to determine whether the indirect effect of cognitive processing on disability was statistically significant ($p \leq .05$).[36]

For all models, residual analyses were conducted to confirm that the assumptions of linear regression analyses were met. Examination of the indirect effect of cognitive processing on disability using the 360° turn as a mediating physical function variable was not conducted because the 360° turn residuals were not normally distributed.

To compare the magnitudes of the indirect effects of the two physical function measures (PPT and WS), we examined the specific indirect effects using a multiple mediator model (Fig 2.1b). The specific indirect effects represented in the multiple mediator model are the paths from cognitive processing to disability through PPT ($a_1b_1$) and through WS ($a_2b_2$). We first used the Sobel test[36] to determine the significance ($p \leq .05$) of the specific indirect effects associated with PPT and WS in the multiple mediator model. Secondly, we calculated the 95% confidence interval around the difference between the two specific indirect effects ($a_1b_1 - a_2b_2$), using the standard error calculation method described by MacKinnon[37] and expanded by Preacher and Hayes.[38] The magnitude of the specific indirect effects of the PPT and WS were considered significantly different if the confidence interval around the difference excluded zero.

Multiple linear regression models were also estimated to examine the combined effect of cognitive processing, physical function, and the interaction of cognitive processing and physical function on disability (Figure 2.1c).

Finally, regression models that excluded specific sample sub-groups were estimated because of the potential influence of these sub-groups on the results. Regression models that excluded participants who demonstrated depressive symptoms (CES-D scores greater than

15,[25] N=11), impaired global cognition (SPMSQ scores less than 9,[20] N=9), or lived in the assisted living unit of the CCRC (N=18) were compared to regression models conducted with the entire sample.

**RESULTS**

Participant characteristics are presented in Tables 2.1 and 2.2. Most participants were female (71%), lived independently (91%), and had greater than a high school education (84%). On average, participants reported fewer than four medical conditions and prescription medications. Almost all participants were independent with ADL and 65% were independent with IADL.

Descriptive statistics for cognitive processing, physical function and disability measures are presented in Table 2.3. A floor effect for TMTB performance was noted in 27 participants who scored 180 seconds. There were no ceiling or floor effects for the SDMT, physical function or disability measures.

The associations among cognitive processing, physical function, and disability measures are presented in Table 2.4. Higher levels of cognitive processing were consistently associated with higher levels of physical function and lower levels of disability (Pearson correlation coefficient range .42 to .60). Similar correlations were demonstrated across all cognitive processing measures with each physical function and disability measure.

Results from the regression analyses conducted with entire sample and those that eliminated sample sub-groups were not different; therefore, all participants were included in the final analyses.

*Does cognitive processing demonstrate an indirect effect on disability mediated by physical function?*

The results of the regression analyses (Fig. 2.1a), examining direct and indirect effects of cognitive processing on PF-10, are presented in Tables 2.5 and 2.6. Because poorer scores on the TMTB are indicated by higher time scores and poorer scores on the PPT and PF-10 are indicated by lower scores, an inverse relationship is observed between the TMTB scores and the PPT and PF-10 scores. The total effect of cognitive processing on disability was significant ($p \leq .001$). Z-COG and the SDMT alone each accounted for 14% of the variance in disability, whereas the TMTB accounted for 10%. The indirect effects of cognitive processing on disability mediated by physical function (PPT and WS) were significant ($p \leq .001$). The direct effect of cognitive processing on disability was not significant. These results were similar across cognitive processing models.

The results of the regression analyses including both PPT and WS as mediators of the relationship between cognitive processing and PF-10 (Fig. 2.1b) are presented in Table 2.7. The indirect effects of cognitive processing on PF-10 were significant for mediation through WS for all cognitive processing measures ($p \leq .001$). Indirect effects mediated through PPT were significant only for the individual SDMT and TMTB measures ($p \leq .05$ and $p \leq .001$, respectively).

Comparison of the indirect effects of cognitive processing on PF-10, mediated by PPT and WS are presented in Table 2.8. The magnitude of mediation demonstrated by PPT and WS were not different when both physical function measures were included in the model. Both PPT and WS had similar mediating effects on the relationship between cognitive processing and PF-10 because the 95% CI of each of the contrasts included zero.

*Does cognitive processing modifying the relationship between physical function and disability?*

Tables 2.9 and 2.10 present the linear regression model coefficients examining the effect modification of cognitive processing on the relationship between physical function and disability.  Analyses revealed that the relationship between either PPT or walking speed and disability was not altered by level of cognitive processing as indicated by the non-significant interaction.

## DISCUSSION

These results support the hypothesis that the effects of cognitive processing on disability are mediated by physical function.  Through this indirect path, decreased cognitive processing is associated with increased disability.  These indirect effects were similar for the two measures of physical function, the PPT and walking speed.  The results of this study did not support a direct effect between cognitive processing and disability.  Levels of cognitive processing also did not modify the relationship between physical function and disability.

The results of this study are consistent with prior research describing associations among the cognitive processes of attention and processing speed, physical function, and disability.[7, 8, 39]  Binder et al[7] reported that processing speed (assessed by visual target cancellation tests and Trail Making Tests A & B) was associated with  physical function as measured by a modified version of the PPT.  Carlson et al[8] reported that a cognitive factor comprised of attention and processing speed measures, including the TMTB, was associated with ADL and IADL performance, although a greater percent of the variance in IADL was explained by the cognitive factor than for ADL. In addition, the TMTB alone was associated with IADL but not ADL performance.[8] Carlson and colleagues[8] assessed ADL using timed performance on three skills; walking four meters, climbing stairs, and donning a pair of pants. These tasks are similar to the self-report items on the PF-10 and consistent with our finding of no direct effect of cognitive processing on disability.

Our finding that physical function mediates the relationship between cognitive processing and disability is consistent with the hypothesis that attention and processing speed are important to the performance of physical functions, and balance in particular.[7, 40] Slowed processing speed is associated with delayed initiation and decreased accuracy of balance responses.[10] Poor performance on the SDMT and TMTB may be indicative of slowed processing, as well as a decreased ability to visually attend to and scan for environmental cues, such as surface properties and movement of other persons or objects, during daily activities. Delayed recognition and processing of these external cues may cause less efficient utilization of them for maintenance of balance during functional tasks. Because adequate balance abilities are important for safe and independent physical function, balance impairments may result in physical function limitations and subsequent disability.

van Schoor and colleagues[17] reported that immediate memory, processing speed, and MMSE scores were predictors of recurrent falls in adults aged 55 and older. However, immediate memory (abbreviated Auditory Verbal Learning Test[41]) was the only significant predictor after adjusting for age, depressive symptoms, and education. The authors hypothesized that the relationship between immediate memory and falls risk may be associated with reliance of immediate recall on the ability to attend to verbal presentation and oral recall of a word list. van Schoor and colleagues[17] state that insufficient attention, resulting in poorer immediate memory may indicate decreased attention to environmental cues during mobility tasks and contribute to an increased risk of falling. The authors also reported that the relationship between immediate memory and recurrent falls was mediated by grip strength, measures of physical function (walking and turning, chair stands, and tandem stance), and self-report of physical activity. Our results correspondingly demonstrate that physical function mediates the relationship between cognitive processing and disability.

The specific disability measures used in studying the relationships of cognitive processing to disability is an important discussion point. Owsley et al[42] and Bell-McGinty et al[39] used performance-based measures of disability (IADL) in demonstrating a relationship of choice reaction time[42] and TMTB[39] to disability. Carlson and colleagues[8] also used performance-based measures of ADL and IADL and reported a stronger relationship for measures of attention and processing speed , particularly TMTB, to IADL than to ADL. Our measure of disability, the PF-10, is a self-report of primarily mobility-related ADL tasks and does not include higher order IADL items that require greater cognitive planning and sequencing. The omission of IADL from the PF-10 may have contributed to our finding of no direct effect between cognitive processing and the PF-10. The self-report nature of the PF-10 may also limit its sensitivity to decline compared to performance-based measures. Owsley and McGwin[40] reported that visual attention was related to performance-based measures of balance and walking ability (Performance Oriented Mobility Assessment[33]), but not to self-report of mobility. Self-report measures may not adequately detect small changes in disability compared to performance-based measures due to limited response options and due to their reliance on the individual to detect decrements.

Comparison of the magnitude of the indirect mediating effects of PPT and walking speed demonstrated that both measures exhibited similar levels of mediation on the relationship of cognitive processing to disability. Although the PPT is a more comprehensive measure of physical function, and includes items such as sentence writing that require greater emphasis on cognition, there was no difference in the magnitude of mediation when compared to walking speed. The significant correlation between PPT and walking speed ($r = .69$) likely contributes to this finding.

Our finding that level of cognitive processing did not modify the relationship between physical function and disability may have been influenced by the relative high functioning of our sample. Older adults with greater limitations in physical function may require greater cognitive resources for problem solving and compensation of functional limitations than our participants did. In such individuals it is possible that the level of cognitive processing may influence the relationship between physical function limitations and disability. Further research should explore lower functioning older adults to examine the potential effect modification of cognitive processing on the relationship between physical function and disability.

These results add to the current literature by supporting important, but complex, relationships among cognitive processing, physical function, and disability in community dwelling older adults. These results demonstrate that the relationship between cognitive processing and disability is primarily mediated by physical function, suggesting that the combined effects of cognitive processing on physical function and physical function on disability be further researched.

Regression models including the individual cognitive processing measures demonstrated similar results compared to models including the composite score, suggesting that a single measure (TMTB or SDMT) may be sufficient when examining the relationship of attention and processing speed to physical function and disability. In light of these similarities and the problem of a floor effect with the TMTB score, we suggest that the SDMT alone may be adequate for examining the role of cognitive processing in physical function and disability in this population.

Despite the significant contributions of cognitive processing to disability, the overall percent of the variance in disability explained by cognitive processing is relatively small (approximately 14%). Factors other than cognitive processing remain important in trying to explain and understand disability. Additional factors may include other aspects of cognition, such as working memory and learning, as well as other contributors to physical function, such as strength and balance.

**Limitations**

This sample of older adults was predominantly independent with daily activities and had a relatively high educational level limiting generalizability of these results to a more diverse and frail group of older adults. The relatively low level of disability in this sample also limited our ability to explore specific daily tasks that may be difficulty for older adults with cognitive processing deficits.

We did not exclude participants with or control for medical conditions, such as hypertension, which can impair cognitive function,[43] therefore we cannot rule out that these conditions may have affected their cognitive processing beyond that of the aging process. In addition, by only excluding those who scored less than 6 on the SPMSQ[20] it is possible that a few persons with dementia were included in this sample.

Our included measures also posed certain limitations. The SDMT and TMTB emphasize the cognitive processes of attention and processing speed; however, they are not pure measures of such and require other cognitive skills, such as working memory and learning. Therefore, it is difficult to ascertain the precise contribution of attention and processing speed to physical function and disability. As mentioned previously the omission of higher-level IADL, such as medication and finance management, from the PF-10 may have influenced our results of no direct effect between cognitive processing and disability. Future research should further examine the combined effects of cognitive processing and physical function on performance of IADL.

## CONCLUSION

This study provides evidence that cognitive processing is associated with physical function and disability. However, the effects of cognitive processing on disability are primarily mediated by physical function. The mediation of this relationship by physical function illustrates the importance of cognitive ability in physical function and its indirect role in daily activities.

**REFERENCES**


1. Earles JL, Salthouse TA. Interrelations of age, health, and speed. *J Gerontol: Psychol Sci.* 1995;50B(1):P33-P41.

2. Gill TM, Williams CS, Richardson ED, Tinetti ME. Impairments in physical performance and cognitive status as predisposing factors for functional dependence among nondisabled older persons. *J Gerontol: Med Sci.* 1996;51A(6):M283-M288.

3. Njegovan V, Man-Son-Hing M, Mitchell SL, Molnar. The hierarchy of functional loss associated with cognitive decline in older persons. *J Gerontol: Med Sci.* 2001;56A(10):M638-M643.

4. Salthouse TA. The processing-speed theory of adult age differences in cognition. *Psychol Rev.* 1996;103(3):403-428.

5. Plude DJ, Doussard-Roosevelt JA. Aging, selective attention and feature integration. *Psychol Aging.* 1989;4:98-105.

6. Allen PA, Weber TA, Madden DJ. Adult age differences in attention: filtering or selection? *J Gerontol: Psychol Sci.* 1994;49:213-222.

7. Binder EF, Storandt M, Birge SJ. The relation between psychometric test performance and physical performance in older adults. *J Gerontol: Med Sci.* 1999;54A(8):M428-M432.

8. Carlson MC, Fried LP, Xue QL, Bandeen-Roche K, Zeger SL, Brandt J. Association between executive attention and physical functional performance in community-dwelling older women. *J Gerontol: Soc Sci.* 1999;54B(5):S262-S270.

9. Nagi SZ. An epidemiology of disability among adults in the United States. *Milbank Mem Fund Q.* 1976;54:439-467.

10. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. *J Gerontol: Med Sci.* 1991;46(3):M69-M76.

11. Lord SR, Lloyd DG, Li SK. Sensori-motor function, gait parameters and falls in community-dwelling women. *Age Ageing.* 1996;25:292-299.

12. Nevitt MC, Cummings SR, Hudes ES. Risk factors for injurious falls: a prospective study. *J Gerontol: Med Sci.* 1991;46(5):M164-M170.

13. Gill TM, Williams CS, Tinetti ME. Assessing risk for the onset of functional dependence among older adults: the role of physical performance. *J Am Geriatr Soc.* 1995;43:603-609.

14. Gill TM, Williams CS, Mendes de Leon CF, Tinetti ME. The role of change in physical performance in determining risk for dependence in Activities of Daily Living among nondisabled community-living elderly persons. *J Clin Epidemiol.* 1997;50(7):765-772.

15. Guralnik JM, Simonsick EM, Ferucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol: Med Sci.* 1994;49:M85-94.

16. Guralnik JM, Ferucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *New Engl J Med.* 1995;332:556-561.

17. van Schoor NM, Smit JH, Pluijm SM, Jonker C, Lips P. Different cognitive functions in relation to falls among older persons. Immediate memory as an independent risk factor for falls. *J Clin Epidemiol.* 2002;55(9):855-862.

18. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med.* 1988;319:1701-1707.

19. VanSwearingen JM, Paschal KA, Bonino P, Chen TW. Assessing recurrent fall risk of community-dwelling, frail older veterans using specific tests of mobility and the Physical Performance Test of Function. *J Gerontol: Med Sci.* 1998;53A(6):M457-M464.

20. Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficits in elderly patients. *J Am Geriatr Soc.* 1975;23:433-441.

21. Katz S, Ford A, Moskowitz R, Jackson B, Jaffe M. Studies of illness in the aged. The Index of ADL: a standardized measure of biological and psychological funtion. *JAMA.* 1963;185(12):914-919.

22. Fillenbaum GG. Screening the elderly. A brief instrumental activities of daily living measure. *J Am Geriatr Soc.* 1985;33(10):698-706.

23. Yaffe K, Blackwell T, Gore R, Sands L, Reus V, Browner WS. Depressive symptoms and cognitive decline in nondemented elderly women: A prospective study. *Arch Gen Psychiatry*. 1999;56:425-430.

24. Berkman LF, Berkman CS, Kasl S, et al. Depressive symptoms in relation to physical health and functioning in the elderly. *Am J Epidemiol.* 1986;124(3):372-388.

25. Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement.* 1977;1:385-401.

26. Spreen O, Strauss E. *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press; 1998.

27. Lezak MD. *Neuropsychological assessment*. New York: Oxford University Press; 1995.

28. Smith A. *Symbol Digit Modalities Test Manual*. Los Angeles, CA: Western Psychological Services; 1982.

29. Reitan RM, Wolfson D. *The Halstead-Reitan Neuropsychological Test Battery*. Tucson, AZ: Neuropsychology Press; 1985.

30. Reuben DB, Siu AL. An objective measure of physical function of elderly outpatients: the Physical Performance Test. *J Am Geriatr Soc.* 1990;38:1105-1112.

31. Onder G, Penninx B, Lapuerta P, et al. Change in physical performance over time in older women: The Women's Health and Aging Study. *J Gerontol: Med Sci.* 2002;57A(5):M289-M293.

32. Berg K, Dauphinee S, Williams JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. *Physiother Can.* 1989;41(6):304-311.

33. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc.* 1986;34:119-126.

34. McHorney CA, Ware JE, Lu JFR, Sherbourne CD. The MOS 36-Item Short Form Health Survey (SF-36): III. tests of data quality, scaling assumptions, and reliability across diverse patient groups. *Med Care.* 1994;32(1):40-66.

35. Wolinsky FD, Wan GJ, Tierney WM. Changes in the SF-36 in 12 months in a clinical sample of disadvantaged older adults. *Med Care.* 1998;36(11):1589-1598.

36. Sobel ME. Asymptotic intervals for indirect effects in structural equations models. In: (Ed.) SL, ed. *Sociological methodology*. San Francisco: Jossey-Bass; 1982:290-312.

37. MacKinnon DP. Contrasts in multiple mediator models. In: J.S. Rose LC, C.C. Pressson, & S.J. Sherman (Eds.), ed. *Multivariate applications in substance use research: New methods for new questions*. Mahwah, NJ: Erlbaum; 2000.

38. Preacher KJ, Hayes AF. Normal-theory and resampling tests of indirect effects in single and multiple mediator models. Manuscript in preparation.

39. Bell-McGinty S, Podell K, Franzen M, Baird AD, Williams MJ. Standard measures of executive function in predicting instrumental activities of daily living in older adults. *Int J Geriatr Psychiatry.* 2002;17:828-834.

40. Owsley C, McGwin G. Association between visual attention and mobility in older adults. *J Am Geriatr Soc.* 2004;52(11):1901-1906.

41. Rey A. *L'Examen clinique en psychologie*. Paris: Presse universitaire de France; 1964.

42. Owsley C, Sloane M, McGwin G, Ball K. Timed instrumental activities of daily living: Relationship to cognitive function and everyday performance assessments in older adults. *Gerontology.* 2002;48:254-265.

43. Kuo HK, Jones RN, Milberg WP, et al. Effect of blood pressure and diabetes mellitus on cognitive and physical functions in older adults: a longitudinal analysis of the advanced cognitive training for independent and vital elderly cohort. *J Am Geriatr Soc.* 2005;53(7):1154-1161.

Table 2.1. Participant demographic characteristics (N=155)

| **Participant characteristics** | **Mean (SD) or Percent Participants** |
|---|---|
| Age (years) | 81.2 (5.7) |
| Education (years) | 15.4 (2.5) |
| Number of medical diagnoses | 3.3 (2.0) |
| Number of prescription medications | 3.2 (2.5) |
| Body mass index | 24.1 (3.6) |
| Gender (female) | 71% |
| Married | 56% |
| Use assistive device | 26% |
| ADL function (Katz ADL Scale)[21] | |
| Independent in 5 ADL | 99% |
| IADL function (OARS)[22] | |
| Independent in 7 IADL | 65% |
| Dependent in 1 IADL | 23% |
| Depressive symptoms (CES-D >15)[25] | 7% |
| Intact cognitive function (SPMSQ scores 9-10)[20] | 95% |

*Notes:* OARS = Older Americans Research and Service Instrument, IADL Scale CES-D = Center for Epidemiologic Studies—Depression; SPMSQ = Short Portable Mental Status Questionnaire

Table 2.2. Medical conditions reported by participants

| | **N (%)** |
|---|---|
| Arthritis | 96 (61.9) |
| Hypertension | 66 (42.6) |
| Urinary dysfunction | 51 (32.9) |
| Cancer | 50 (32.3) |
| Osteoporosis | 43 (27.7) |
| Heart disease | 36 (23.2) |
| Fracture | 35 (22.6) |
| Pulmonary disease | 28 (18.1) |
| Dizziness | 23 (14.8) |
| Stroke | 12 (7.7) |
| Headache | 10 (6.5) |
| Diabetes | 6 (3.9) |

Table 2.3. Descriptive statistics for measures of cognitive processing, physical function, and disability.

| | Mean (SD) | Range |
|---|---|---|
| SDMT(number items correct) | 41.2 (13.0) | 9-87 |
| TMTB (seconds) | 125.0 (40.0) | 45.1-180.0 |
| PPT (total score) | 22.4 (3.4) | 11-28 |
| 360° turn (seconds) | 3.4 (1.5) | 1.3-11.4 |
| Walking speed (meters/second) | 1.1 (.3) | .5-1.7 |
| PF-10 (total score) | 62.5 (39.5) | 0-100 |

Table 2.4. Correlation matrix of associations among cognitive processing, physical function, and disability measures (Pearson r)

| | Z-COG | SDMT | TMTB |
|---|---|---|---|
| **Physical Function** | | | |
| PPT total score | .60 | .56 | -.53 |
| Timed 360° turn | -.46 | -.44 | .39 |
| Walking speed | .42 | .41 | -.34 |
| **Physical Disability** | | | |
| PF-10 | .37 | .36 | -.31 |

All correlation values significant at $p \leq .001$

Table 2.5. Unstandardized and standardized coefficients for the direct and indirect effects mediated by the Physical Performance Test (PPT) of cognitive processing (CP) on PF-10 scores

| **Effect (path)** | **Independent Variable** | | | | | |
|---|---|---|---|---|---|---|
| | **Z-COG** | | **SDMT** | | **TMTB** | |
| | **Unstandardized (SE)** | **Standardized** | **Unstandardized (SE)** | **Standardized** | **Unstandardized (SE)** | **Standardized** |
| Total effect | 10.405 (2.098)* | .372* | .707 (.147)* | .363* | -.196 (.049)* | .310* |
| Direct effects | | | | | | |
| CP—PPT (a) | 2.296 (.246)* | .603* | .149 (.018)* | .560* | -.046 (.006)* | -.529* |
| PPT—PF-10 (b) | 3.853 (.618)* | .525* | 3.799 (.595)* | .518* | 4.024 (.582)* | .548* |
| CP—PF-10 (c) | 1.559 (2.355) | .056 | .142 (.158) | .073 | -.012 (.050) | -.020 |
| Indirect effect | | | | | | |
| CP-PF-10 (ab) | 8.846 (1.713)* | .317* | .566 (.112)* | .290* | -.185 (.036)* | -.290* |
| Total effect explained by indirect effect | 85.0% | | 80.0% | | 94.4% | |

* p ≤ .001

Table 2.6. Unstandardized and standardized coefficients for the direct and indirect effects mediated by walking speed (WS) of cognitive processing (CP) on PF-10 scores

| **Effect (path)** | **Independent Variable** | | | | | |
|---|---|---|---|---|---|---|
| | **Z-COG** | | **SDMT** | | **TMTB** | |
| | **Unstandardized (SE)** | **Standardized** | **Unstandardized (SE)** | **Standardized** | **Unstandardized (SE)** | **Standardized** |
| Total effect | 10.405 (2.098)* | .372* | .707 (.147)* | .363* | -.196 (.049)* | .310* |
| Direct effects | | | | | | |
| CP—WS (a) | .118 (.021)* | .416* | .008 (.001)* | .411* | -.002 (.000)* | -.341* |
| WS—PF-10 (b) | 57.842 (6.770)* | .586* | 58.395 (6.766)* | .592* | 59.448 (6.565)* | .602* |
| CP—PF-10 (c) | 3.501 (1.919) | .125 | .222 (.134) | .113 | -.066 (.042) | -.105 |
| Indirect effect | | | | | | |
| CP—PF-10 (ab) | 6.825 (1.461)* | .244* | .467 (.080)* | .243* | -.119 (.013)* | -.205* |
| Total effect explained by indirect effect | 65.6% | | 66.1% | | 60.7% | |

* p ≤ .001

Table 2.7. Unstandardized coefficients for the direct and indirect effects mediated by the Physical Performance Test (PPT) and walking speed (WS) of cognitive processing (CP) on PF-10 scores

| **Effect (path)** | **Independent Variable** | | | | | |
|---|---|---|---|---|---|---|
| | **Z-COG** | | **SDMT** | | **TMTB** | |
| | **Unstandardized (SE)** | ***p*** | **Unstandardized (SE)** | ***p*** | **Unstandardized (SE)** | ***p*** |
| Total effect | 10.405 (2.098) | .001 | .707 (.147) | .001 | -.196 (.049) | .001 |
| Direct effects | | | | | | |
| CP—PPT ($a_1$) | 2.296 (.245) | .001 | .149 (.018) | .001 | -.046 (.006) | .001 |
| CP—WS ($a_2$) | .119 (.021) | .001 | .008 (.001) | .001 | -.002 (.001) | .001 |
| CP—PF-10 (c) | 1.575 (2.120) | .458 | .103 (.142) | .469 | -.025 (.045) | .579 |
| PPT—PF-10 ($b_1$) | 1.330 (.706) | .060 | 1.377 (.681) | .043 | 1.412 (.690) | .041 |
| WS—PF-10 ($b_2$) | 48.573 (8.368) | .001 | 48.269 (8.380) | .001 | 48.798 (8.383) | .001 |
| Indirect effects | | | | | | |
| CP—PPT—PF-10 ($a_1b_1$) | 3.054 (.166) | .065 | .205 (.105) | .049 | -.065 (.033) | .001 |
| CP—WS—PF-10 ($a_2b_2$) | 5.780 (1.436) | .001 | .386 (.083) | .001 | -.098 (.030) | .001 |

Table 2.8. Contrast between the indirect effects of cognitive processing (CP) on PF-10 via the Physical Performance Test (PPT) and via walking speed (WS)

| **Independent Variable** | **Contrast between PPT and WS (SE)** | **95% CI** |
|---|---|---|
| Z-COG | -2.726 (2.509) | -7.644 - 2.192 |
| SDMT | -.181 (.161) | -.497 - .135 |
| TMTB | .033 (.051) | -.068 - .133 |

Table 2.9. Unstandardized and standardized coefficients for effect modification of cognitive processing (CP) on the relationship between PPT and PF-10 scores

| Effect | Independent Variable | | | | | |
|---|---|---|---|---|---|---|
| | Z-COG | | SDMT | | TMTB | |
| | Unstandardized (SE) | Standardized | Unstandardized (SE) | Standardized | Unstandardized (SE) | Standardized |
| CP | -1.558 (13.579) | -.056 | .278 (.928) | .143 | .199 (.321) | .315 |
| PPT | 3.941 (.727)$^{*}$ | .537$^{*}$ | 3.986 (1.392)$^{*}$ | .543$^{*}$ | 5.355 (2.080)$^{\dagger}$ | .729$^{\dagger}$ |
| CP*PPT | .132 (.568) | .106 | -.006 (.039) | -.087 | -.009 (.013) | -.288 |
| Constant | -21.429 (16.939) | | -28.099 (30.712) | | -53.316 (50.766) | |

$^{*}$ $p \leq .005$

$^{\dagger}$ $p \leq .020$

Table 2.10. Unstandardized and standardized coefficients for effect modification of cognitive processing (CP) on the relationship between walking speed (WS) and PF-10 scores

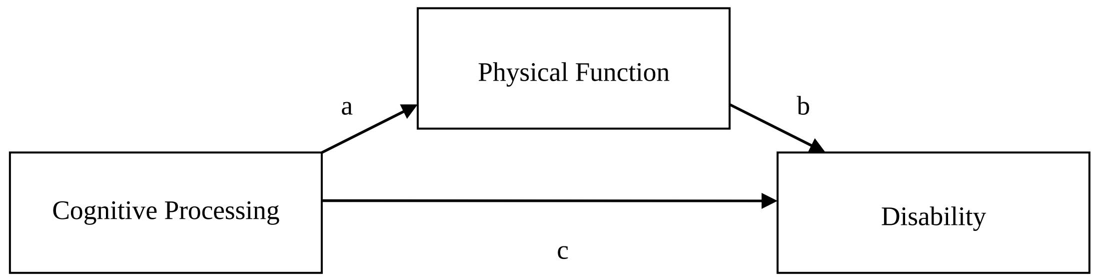
| Effect | Independent Variable | | | | | |
|---|---|---|---|---|---|---|
| | Z-COG | | SDMT | | TMTB | |
| | Unstandardized (SE) | Standardized | Unstandardized (SE) | Standardized | Unstandardized (SE) | Standardized |
| CP | 4.432 (7.876) | .158 | .349 (.527) | .178 | -.056 (.186) | -.089 |
| WS | 57.683 (6.917)$^{*}$ | .585$^{*}$ | 62.798 (18.918)$^{*}$ | .636$^{*}$ | 60.613 (21.696)$^{\dagger}$ | .614$^{\dagger}$ |
| CP*WS | -.815 (6.685) | -.034 | -.114 (.456) | -.094 | -.009 (.156) | -.017 |
| Constant | 2.201 (8.080) | | -12.572 (20.531) | | 7.020 (26.740) | |

$^{*}$ $p \leq .005$

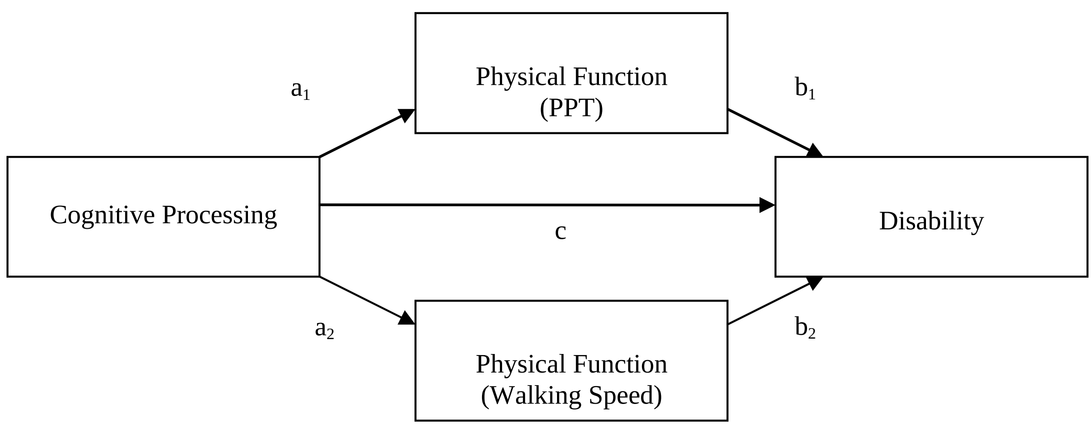
$^{\dagger}$ $p \leq .010$

Figure 2.1: Conceptual Models

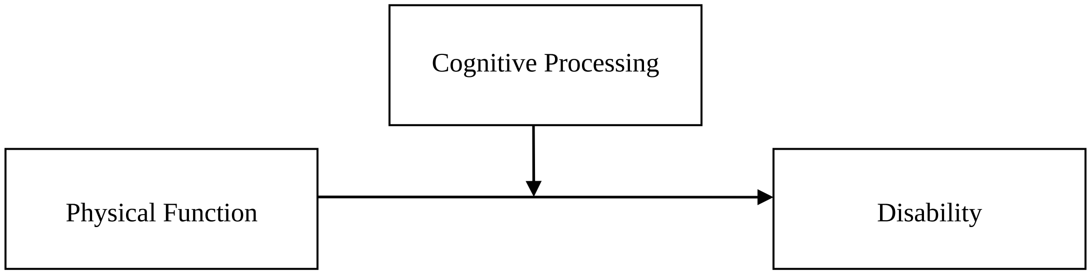
a. Direct and indirect effects of cognitive processing on physical function and disability via a single physical function measure




b. Direct and indirect effects of cognitive processing on physical function and disability via two physical function measures



c. Effect modification of cognitive processing on the relationship between physical function and disability



# CHAPTER III

## SECOND MANUSCRIPT

Examination of the relationship of cognitive processing to future declines in physical function and increased disability in older adults

**Abstract**

**Background.** Cross-sectional research supports an important relationship between cognitive processing and independent function. However, much remains unknown about the relationship of cognitive processing to future declines in independent function among older adults.

**Purpose.** To examine in older adults: (1) the predictive relationship of cognitive processing to changes in physical function and disability one year later, and (2) the association of change in cognitive processing to change in physical function and disability over one year.

**Methods.** Volunteers (N=62) from a continuing care retirement community and church congregation (mean age 80.7 ± 5.0 years at baseline, 68% female) participated in a wellness assessment that included measures of cognitive processing, physical function, and disability. Cognitive processing, defined as performance on measures of attention and processing speed, were assessed with the Symbol Digit Modalities Test (SDMT) and the Trail Making Test Part B (TMTB). Raw SDMT and TMTB scores were transformed into z-scores to create a composite score of cognitive processing (Z-COG), our primary measure of cognitive processing. Physical function was assessed with the 360° turn, the Physical Performance Test (PPT), and walking speed. The SF-36 Physical Function Sub-scale (PF-10) and OARS Instrumental Activities of Daily Living Scale (OARS) measured mobility and IADL disability. Participants with meaningful decline in any physical function or disability measure or requiring an increased level of care over one year were identified as having decreased independent function. Linear regression and logistic regression analyses were conducted to examine the relationship between baseline cognitive processing and change in physical function and disability; and between change in cognitive processing and change in physical function and disability.

**Results.** Poorer Z-COG scores at baseline were associated with a one year decline in 360° turn ($R^2$=.12, p $\leq$ .01) and that one-year decline in TMTB was also associated with decline in 360° turn ($R^2$=.072, p$\leq$ .05). No linear relationship was observed for baseline cognitive processing to change in PPT, walking speed, or PF-10. Logistic regression analyses demonstrated that poorer Z-COG scores at baseline were predictive of decline in PF-10 (OR=2.846, 95% confidence interval [CI] 1.291-6.271) and OARS scores (OR=2.593, 95%CI 1.187-5.665). Poorer TMTB scores also demonstrated significant associations for decline in PF-10 (OR= 1.028, 95% CI 1.009-1.047) and OARS (OR=1.026, 95% CI 1.008-1.045). Z-COG, SDMT, and TMTB demonstrated significant associations for decreased independent function (OR ranged from 1.026 to 3.052).

**Conclusions.** Cognitive processing is associated with one-year change in balance and disability. Poorer performance on measures of attention and processing speed are associated with declines in balance and increased risk for mobility and IADL disability.

***Key words:*** *cognition, attention, processing speed, balance, function, disability*

## INTRODUCTION

Independence in physical function, activities of daily living (ADL), and instrumental activities of daily living (IADL) allows older adults to remain living in the community rather than moving to an assisted living facility or nursing home. Physical function tasks such as walking and climbing stairs and ADL and IADL, such as bathing, preparing a meal, and shopping require adequate cognitive abilities to organize, initiate and properly sequence these complex tasks. Numerous studies support that declines in general cognitive function are associated with declines in physical function and ADL/IADL disability in older adults. adults.[1-3]

Cognitive measures such as the Mini Mental State Exam[4] (MMSE) and Short Portable Mental Status Questionnaire[5] (SPMSQ) are intended as screening tools for general cognitive function and dementia. Poor performance on the MMSE, is associated with physical function limitations in tasks such as walking and climbing stairs,[6, 7] and with ADL and IADL disability in both cross-sectional and longitudinal research.[8-10] Community dwelling older adults demonstrating cognitive dysfunction on general screening measures have twice the risk of developing disability in three years compared to older adults without cognitive dysfunction.[2, 8] There is also evidence that older adults who score in the low-normal range on the MMSE (scores of 24-27) are at increased risk for future disability and institutionalization compared to individuals with high-normal scores.[8, 9]

Although general cognitive measures such as the MMSE and SPMSQ may be good screening tools for cognitive function and dementia, they do not adequately measure specific aspects of cognition, such as memory, attention, and processing speed. Identifying decline in specific cognitive processes associated with physical function limitations and ADL/IADL disability is critical for designing appropriate intervention programs effective for preserving independence among older adults for as long as possible.

ADL and IADL, such as dressing and meal preparation, are complex tasks that require organization and sequencing of multiple steps. Two cognitive processes important to information processing and successful completion of these complex tasks are attention and processing speed. Both processes contribute to cognitive organization, initiation, and sequencing of actions necessary for efficient information processing and performance of daily tasks; such as, finding objects on a crowded shelf, meal preparation, and walking. Attention, especially visual aspects of attention, such as visual scanning and selective attention, is particularly important for performing daily tasks that utilize external cues. For example, maintaining balance during walking requires an individual to select important information about the environment, such as the location of obstacles and movement of other persons, in order to adjust step placement and walking speed. Processing speed, or the time it takes to process information about external and internal cues, plays a key role in the planning and execution of coordinated movements and is a critical component of balance responses, with faster processing speed required for quick , compensatory adjustments needed to maintain balance in unstable situations.

Although older adults tend to worry about memory loss, attention and processing speed also decline with advancing age, and may contribute to limitations in physical function and daily living tasks.[11-15] As task complexity increases older adults demonstrate more difficulty in performing physical tasks compared to young adults.[16, 17] Salthouse proposed that slowed processing speed contributes to the age-related impairments observed in other aspects of cognition, such as working memory and problem solving.[12] In this way, slowed processing speed may impair an older individual's ability to organize and sequence daily tasks and make decisions on how to adapt to changing environments or situations. Impaired attention may also interfere with performance of daily tasks by reducing one's ability to scan the environment and utilize external cues. The relationship between processing speed and balance, a physical function skill, is particularly important because sufficient balance is required for successful performance of independent mobility and dynamic daily activities, such as walking and reaching.

Cross-sectional research demonstrates stronger associations of attention and processing speed to physical function[18] and ADL and IADL performance[19] than other aspects of cognition, such as memory. Numerous studies demonstrate that poor performance on attention and processing speed measures is associated with poorer performance of physical function skills (such as balance and walking), ADL, IADL, and increased falls.[18-23] Rosano and colleagues[22] reported stronger associations between physical function and attention and processing speed (Digit Symbol Substitution Test[24]) than between physical function and general cognition (Teng-modified Mini-Mental Status Exam[25]). To the best of our knowledge, the relationship between the cognitive processes of attention and processing speed and future declines in physical function or increased disability in community dwelling older adults has not been reported.

The purpose of this paper was to examine the longitudinal relationship of attention and processing speed, defined here as cognitive processing, to changes in physical function and disability over one year in older adults. We tested the hypotheses that cognitive processing performance at baseline is predictive of changes in physical function and disability, and that changes in cognitive processing are also associated with changes in physical function and disability.

## METHOD

### Study Design and Sample

This was a longitudinal study using data from the baseline and one year follow-up assessments of the *Be Alive* project, a larger, ongoing longitudinal study promoting wellness and independence in older adults living in North Carolina. Participants in the *Be Alive* project were older adults living in the community or in a continuing care retirement community (CCRC) who volunteered for on-site wellness assessments (N=195 at baseline), which consisted of a comprehensive battery of measures assessing cognitive and physical abilities. Individuals 50 years of age or older and able to walk independently with or without an assistive device were included in the *Be Alive* project. Individuals with medical conditions precluding participation in physical performance testing, such as uncontrolled hypertension or severe joint pain, were excluded from testing. Prior to testing, a brief medical screen assessing health history, pain, medication use, and recent surgeries was administered by interview to identify individuals with contraindications to performance testing. All participants signed an informed consent form approved by the UNC Chapel Hill School of Medicine Committee for the Protection of Human Subjects. Trained health professionals performed assessments in a single session lasting approximately 90 minutes.

Participants of the *Be Alive* project who were 65 years of age or older, scored above six on the Short Portable Mental Status Questionnaire (SPMSQ),[5] could clearly see the cognitive test items, and completed the physical function and disability measures described below, were eligible for inclusion in this study. At baseline, 137 of the *Be Alive* participants (N=195) met these criteria. Sixty-four of these participants returned for follow-up testing at one year. Eight of the 64 participants who participated in both testing sessions were excluded from these analyses; four due to visual impairment, one because their SPMSQ score was less than six, and three who had missing data at follow-up. We chose to include six participants from baseline who declined in functional status and transferred to a higher level of care within the CCRC (assisted living or skilled nursing care) during the study period, but who were not tested at one year. Thus, a sample of 62 participants was included in these longitudinal analyses. Participants of this study were defined as individuals who met the inclusion criteria, completed baseline testing and for whom one year follow-up data were available.

Sixty-seven of the 137 participants who were eligible for this study at baseline did not return at one year and were not identified as having transferred to a higher level of care. We identified through phone calls and CCRC staff that two died during the study period and twelve did not return for reasons unrelated to their health (e.g. travel, schedule conflicts, moved). We were unable to determine specific reasons why the remaining participants did not return for testing at one year. Non-participants were defined as individuals who met the inclusion criteria at baseline, but did not return for follow-up.

## Data Collection Procedure

### *Demographic and Health-Related Measures*

Participants in the study completed a series of self-report questionnaires to gather demographic and health-related information. The self-report questionnaires included medical history and the Katz Activities of Daily Living Scale.[26] Because prior research suggests depression may contribute to poor cognitive function and disability,[27, 28] we also administered the Center for Epidemiologic Studies Depression Scale (CES-D)[29] to identify participants who demonstrated depressive symptoms.

*Cognitive Processing: Attention and Processing Speed Measures*

We operationally defined cognitive processing as performance on measures of attention and processing speed, and selected these aspects of cognition because they are important to both the cognitive and physical aspects of daily tasks.[12, 18, 19] We selected the Symbol Digit Modalities Test and the Trail Making Test Part B to measure attention and processing speed based on their sensitivity to age-related impairments and psychometric properties. Participants were tested in a quiet room and wore corrective eyewear if necessary.

*(a) Symbol Digit Modalities Test (SDMT):* The SDMT assesses visual aspects of attention, such as scanning and tracking, and processing speed.[30, 31] The test requires the conversion of meaningless geometric designs into oral or written number responses.[32] We chose the oral version of the SDMT to reduce the influence of limited motor ability on test performance (e.g., participants with arthritis or Parkinson's Disease). Scores were calculated as the total number of items correct in 90 seconds.

*(b) Trail Making Test Part B (TMTB):* The TMTB assesses visual attention, processing speed, motor function, and mental flexibility.[30, 33] This paper-and-pencil test requires connecting circles in alternating numerical and alphabetical sequence (e.g., 1-A-2-B, etc.) as quickly as possible. Scores were recorded as the time required to complete the test, up to a

maximum of 180 seconds. Participants unable to complete the test in the maximum allowed time were assigned scores of 180 seconds.

*Physical Function Measures*

The Physical Performance Test,[34] walking speed,[35] and timed 360° turn[36] were used to assess physical function. These measures are performance based and can be administered to older adults with a wide range of ability levels. Prior research also supports an association between poor performance or decline on these measures of physical function and increased risk of future disability.[35-37]

*(a) Physical Performance Test (PPT):* The 7-item PPT was our primary measure of physical function because it assesses several aspects of upper and lower body function and mobility (writing, eating, lifting, dressing, bending, turning, and walking).[34] For all items on the PPT except the 360° turn, the time to complete each task was recorded using a stopwatch and then translated into scaled scores ranging from 0 (poor performance) to 4 (best performance). The 360° turn item was also scored on a 0-4 scale based on step continuity and steadiness. The maximum possible score for the 7-item PPT is 28, representing the highest level of function.

*(b) Walking Speed (WS):* Walking speed is frequently used to measure of physical function in older adults and is a significant predictor of functional decline and disability.[35, 36, 38, 39] We chose walking speed as a secondary measure of physical function because it assesses physical mobility compared to the more comprehensive functional assessment of the PPT. Self-selected walking speed was assessed using a 10-meter walk course allowing for acceleration and deceleration by including 1-meter zones at both ends. Participants started walking at the beginning of the acceleration zone and timing started when the participant's

foot crossed the tape at the start of the 10-meter course, and stopped when the foot crossed the line at the end of the course. Two trials were completed and the average walking speed was calculated in meters/second.

*(c) Timed 360° Turn (360° Turn):* The timed 360° turn was used to assess dynamic standing balance because the ability to turn without losing one's balance is important for safe and independent function, and because it requires more complex sequencing than static measures of standing balance. Turning 360° is a single timed performance measure of balance[36] and is also included, as either a timed or scored item, in several performance-based tests for older adults, including the PPT,[34] Berg Balance Scale,[40] and the Performance-Oriented Assessment of Mobility Problems.[41] Participants were instructed to stand behind a line on the floor facing the tester and then turn completely around in either direction. Participants performed two trials and the average turn time was used for analysis.

*Disability Measures*

We operationally defined disability as new or worsening of perceived disability for mobility tasks and IADL over one year. Mobility tasks, such as rising from a chair and walking, enable one to move around their environment and are required for independence in daily living. We selected two measures, the SF-36 Physical Function Sub-scale and the Older Americans Research and Service Center Instrument, to assess disability because of their focus on mobility tasks and IADL needed for independent living.

*(a) SF-36 Physical Function Sub-scale (PF-10):* The Medical Outcome Survey Short Form (SF-36) is a self-report measure of health status in 8 domains (general health, physical functioning, physical role, emotional role, social function, bodily pain, mental health, and

vitality.[42] We selected the Physical Function sub-scale of the SF-36 (PF-10) as our primary measure of disability because it specifically asks questions about ADL and other daily tasks (e.g., carrying groceries, vacuuming, walking, and bathing) and because it is a responsive measure of physical ability in community dwelling older adults.[43] Participant responses for each sub-scale were converted to an index score ranging from 0 (worst health) to 100 (best health).[44]

*(b) Older Americans Research and Service Center Instrument (OARS):* The OARS is a self-report measure of IADL independence on seven tasks (ability to use the telephone, get to places out of walking distance, shop for groceries or clothes, prepare meals, perform housework, take medications, and handle money).[45] We included the OARS as a secondary measure of disability because of its focus on IADL and because a number of participants reported increased dependence on this scale at follow-up. The OARS is scored according to how much help individuals report needing to complete each task. Individual item scores range from 0 (dependent) to 2 (completely independent) and were summed to create a total score (range 0-14).

**Statistical Analysis**

The data were analyzed using SPSS Version 12.0 statistical software (SPSS Inc.; Chicago, IL). Univariate analyses of all variables were conducted to examine the data distribution, detect outliers, and characterize the sample. Because baseline SDMT and TMTB scores were moderately correlated ($r = -.69$, $p \leq .001$), we constructed a composite score. Raw scores on the SDMT and TMTB were transformed to standard *z*-scores using the sample means and standard deviations. The z-scores were then averaged to create a composite measure to represent cognitive processing (Z-COG) for each participant.

To assess for non-response bias, participant (N=62) and non-participant (N=77) demographic, health status, and performance scores were compared using t-test or chi-square statistics.

Paired t-test or McNemar chi-squared analyses were used to compare baseline and one year demographic and health status characteristics of the sample for this study. Paired t-test analyses were also used to examine differences in the mean scores for cognitive processing, physical function, and disability at baseline and at one year follow-up. All t-test and chi-square statistics were adjusted for multiple tests using the Bonferroni Procedure. Differences in the mean composite Z-COG measure at baseline and one year follow-up was not calculated because of inconsistent patterns of change between SDMT and TMTB ($r = -.07$, $p > .05$).

Ordinary least squares linear regression analyses were conducted to examine the relationships between baseline cognitive processing and change in physical function measures; and between baseline cognitive processing and change in disability measures. Separate linear regression models were estimated to examine the independent relationships between each of the cognitive processing measures (Z-COG, SDMT, TMTB) and change in each of the physical function measures (PPT, 360° turn, and walking speed), and between each of the cognitive processing measures and change in our primary measure of disability (PF-10). Non-normal residual distribution for change in OARS scores precluded examination of this disability measure using linear regression analyses. Ordinary least squares linear regression analyses were also conducted to examine the relationships between raw score changes in cognitive processing (SDMT and TMTB) from baseline to one year and changes in physical function and disability measures from baseline to one year.

Because group averages of continuous measures can sometimes mask significant individual changes, we dichotomized our dependent variables based on previous literature values of meaningful decline and conducted logistic regression analyses. For PPT we dichotomized change scores using the criterion of three points.[46] Participants whose PPT performance declined by three or more points from baseline to one year were classified as "declined"; otherwise participants were classified as "no change or improved". Similarly, participants who declined by 2.3 seconds on the 360° turn,[39] 0.2 m/s for walking speed,[47] 10 points on the PF-10,[47] and 1 point on the OARS[36] were classified as "declined" and others were classified as "no change or improved".

Because the numbers of participants who declined in the 360° turn, PPT, and walking speed were small (Table 3.4), logistic regression analyses were only conducted using the PF–10 and OARS measures. Logistic regression analyses examined the relationships between baseline cognitive processing and disability, and also between change in cognitive processing and disability one year later. To allow consistent interpretation of logistic regression models, baseline Z-COG and SDMT scores, and TMTB change scores were multiplied by negative one to create transformed scores such that higher scores represented poorer performance. Baseline Z-COG, SDMT, and TMTB and one year change in SDMT and TMTB were entered into logistic regression analyses as continuous variables. Therefore, the odds ratios presented are the effects for a one point reduction in performance on each measure. Baseline SDMT and TMTB performance expressed as z-scores (Z-SDMT and Z-TMTB) were included to allow comparison to the odds ratios of the Z-COG scores.

Because we were also concerned with individuals who experienced any decline in independent functioning we conducted logistic regression analyses to examine the relationship of baseline cognitive processing to decline on any one or more of the physical function or disability measures, or transfer to a higher level of care over one year. This collective group was identified as participants with decreased independent function. Participants who declined by the criteria above for PPT, 360° turn, walking speed, PF-10, or OARS, or who required a higher level of care were categorized as having decreased independent function.

Separate logistic regression analyses were conducted for each dependent variable (PF-10, OARS, decreased independent function) using both baseline cognitive processing and change in cognitive processing as the independent variables.

We also conducted the same linear and logistic regression analyses excluding specific sample sub-groups because of the potential influence of these sub-groups on the results. Linear and logistic regression models that excluded participants who demonstrated depressive symptoms (CESD scores greater than 15,[29] N=3), impaired general cognition (SPMSQ scores less than 9, N=5),[5] or lived in the assisted living unit of the CCRC (N=2) were compared to regression models conducted with the entire sample. Chi-square tests and a significance level of .05 were used to assess logistic regression model fit.

# RESULTS

## Participant Characteristics

Participant characteristics at baseline were compared between individuals who were included in these longitudinal analyses and those who were lost to attrition (non-participants) at one year (Table 3.1). Participants in this study were not different from non-participants with regards to demographic characteristics, general health, cognitive processing, or ADL independence. Participants did demonstrate better balance and walking speed than non-participants and also reported greater independence on the PF-10 than non-participants.

Demographic and descriptive characteristics of the participants who completed both baseline and one year testing are presented in Table 3.2. At one year most of the participants were still independent with ADL (98%), lived in the community (91%), and retained good overall cognitive skills on the SPMSQ (95%). However, ten participants (17.5%) reported dependence in one or more IADL at one year compared to baseline. Additionally, six (10%) participants who completed baseline testing transferred to a higher level of care within study period and did not return for follow-up testing.

### *Performance Change Over One Year*

Descriptive data and group mean change statistics for cognitive processing, physical function, and disability measures are presented in Table 3.3. Participants demonstrated inconsistent patterns of change on the SDMT and TMTB. As a group, participants performed better on the TMTB at one year (faster time for completion) compared to baseline; however, no change in SDMT performance was observed. Mean 360° turn time was slower and group mean PPT scores were significantly higher at one year.  No mean differences were observed for walking speed or PF-10.

The number of participants demonstrating clinically meaningful decline on physical function or disability measures is presented in Table 3.4.  Few participants demonstrated decline in physical function at one year.  However, self-reported increase in disability measured by the PF-10 and OARS was noted by fifteen (27%) and fourteen (25%) participants respectively.  Thirty-one participants demonstrated decreased independent function as defined above.

*Does cognitive processing measured at baseline predict change in physical function and disability after one year?*

The results of the linear regression analyses examining the relationship between baseline cognitive processing and one year change in physical function and disability are presented in Table 3.5.  Poorer cognitive processing scores (lower Z-COG and SDMT scores and increased TMTB time) were significantly associated with decline in 360° turn performance one year later.  No relationship was observed between baseline cognitive processing and change in PPT, walking speed, or PF-10.

Goodness of fit statistics, regression coefficients, and odds ratios for logistic regression models examining the relationship of baseline cognitive processing to disability and decreased independent function are presented in Tables 3.6 and 3.7.  Chi-square analysis of fit demonstrated good fit ($p \leq .05$) for all models except for the relationship between SDMT and the disability measures.

Poorer cognitive processing as measured by Z-COG was associated with both a decline in PF-10 or OARS scores and decreased independent function ($p \leq .05$). Examination of the relationships between the individual cognitive processing measures and disability demonstrated that poorer TMTB scores at baseline were significantly associated with decline in PF-10 or OARS scores ($p \leq .05$). Poorer scores on both the TMTB and SDMT at baseline were associated with decreased independent function at one year ($p \leq .05$).

*Is change in cognitive processing associated with changes in physical function and disability after one year?*

The results of linear regression analyses examining the relationships of change in SDMT and TMTB to change in physical function and disability measures are presented in Table 3.8. Slowing in TMTB performance was significantly, but weakly, associated with decline in 360° turn performance over one year ($p \leq .045$). Change in TMTB was not associated with change in PPT, walking speed, or PF-10. SDMT change was not associated with change in any measures of physical function or the PF-10.

Logistic regression models examining the relationship between change in cognitive processing and disability or decreased independent function at one year did not exhibit good fit ($p \geq .05$, Table 3.9). Change in cognitive processing was not associated with disability or decreased independent function at one year (Table 3.10).

*Influence of sample sub-groups on the relationships between cognitive processing and changes in physical function and disability*

Separate linear regression analyses that excluded participants with depressive symptoms (N=3) altered the significance for two of the relationships reported above. When participants with depressive symptoms were excluded, the linear relationships between baseline SDMT performance and change in 360° turn, and between change in TMTB performance and change in 360° turn were no longer significant ($p > .05$). Other linear regression analyses excluding participants with depressive symptoms were not different from those of the entire sample. Results from the linear and logistic regression analyses that excluded participants with impaired general cognition and those that lived in the assisted living unit of the CCRC were not different from the analyses for the entire sample presented above.

## DISCUSSION

This study examined how baseline cognitive processing and change in cognitive processing is associated with changes in physical function and disability in a sample of community dwelling older adults. The results support the hypotheses that cognitive processing is associated with independent function, and more specifically, to changes in balance and disability. Poorer cognitive processing at baseline was associated with decreased balance and independent function, and increased disability at one year. Declines in cognitive processing over one year were also significantly, but weakly associated with decreased balance performance, but not other physical function measures or disability.

Poorer cognitive processing at baseline was associated with increased disability, as measured by changes in both the PF-10 and OARS, one year later. Because the PF-10 emphasizes mobility-related daily living tasks and the OARS emphasizes IADL that rely more heavily on cognitive skills these results support an important role for cognitive processing in both types of complex daily activities.

Although prior research demonstrates an association between processing speed and mortality,[48, 49] research examining the role of cognitive processing on future disability is lacking. The results of this study are consistent with longitudinal studies demonstrating increased disability in older adults with poorer scores on general cognitive measures (e.g. MMSE),[8, 10] as well as with cross-sectional research documenting associations between various attention and processing speed measures and disability. In two prior reports, the TMTB was associated with timed performance of IADL[19] and The Independent Living Scales,[50] a performance and self-report measure of IADL ability.[23]

In this study, level of cognitive processing at baseline and one-year change in cognitive processes were associated with declines in balance, an aspect of physical function. Poorer cognitive processing was associated with decreased balance performance at one year. The association between change in cognitive processing and change in balance performance over one year was weak, but significant, and is consistent with previous research demonstrating that slower processing speed is associated with disruption in the production and sequencing of timely balance responses.[20] Because balance is a critical component of other physical functions and daily living tasks, it is possible that balance mediates the relationship of cognitive processing to other physical functions and daily living tasks.

According to the Nagi Model of Disablement[51] if balance decrements persist, declines in other physical functions and daily living tasks will follow.

Prior cross-sectional research supports an association between cognitive processing and other measures of physical function. Rosano et al[22] reported that scores on the Digit Symbol Substitution Test[24] (a written test similar to the SDMT used in this study) were associated with performance of walking speed and balance (measured by a series of static standing positions). Similarly, Binder and colleagues[18] reported that scores on visual target cancellation tests and the Trail Making Tests A & B were associated with performance on a modified Physical Performance Test. Binder and colleagues[18] hypothesized that balance impairments related to slowed processing speed may contribute to declines in physical function among older adults. The association between cognitive processing and change in balance in this study may lend support to the hypothesis that balance performance mediates the relationship between cognitive processing and functional ability. Although the influence of a small number of participants with depressive symptoms may have confounded our results regarding the relationship between cognitive processing and balance, it must be recognized that older adults often experience depressive symptoms[27, 28] in conjunction with cognitive and physical declines in their usual daily lives. Inclusion of participants with depressive symptoms may offer a more realistic view of the interactions that influence performance of daily activities among older adults.

Participants in this study demonstrated relatively stable levels of physical function over one year, with few experiencing meaningful decline. Approximately 80% of participants demonstrated some level of decline in balance based on simple raw change scores; however, only three participants demonstrated a clinically meaningful decline. The

PPT, walking speed, and PF-10 may not be sensitive to small balance decrements, limiting our ability to detect a linear relationship between level of cognitive processing and change in these measures. It is also possible that these older adults were able to compensate during other functional tasks for small declines in balance; for example, by widening their base of support, which may not be reflected in their scores. In addition, our follow-up interval of one year may not have been long enough to detect the effects of balance decline on the other measures.

Practice effects can mask decreases in performance and limit examination of the effects of decline on other outcomes.[52, 53] It is possible that performance on the cognitive processing measures at follow-up was influenced by prior test experience, particularly for the TMTB, for which improvement in group mean score was observed. This may have limited identification of participants who experienced decline in cognitive processing and examination of the relationship of change in cognitive processing to physical function and disability.

These results add to the current literature supporting associations of cognitive processing to decreased independent function, balance, and disability in older adults over time. Although, there was some inconsistency across the cognitive processing measures, these results do support that poor performance on measures of attention and processing speed is associated with increased risk of future disability. Identifying these specific aspects of cognition to be associated with future decline in daily living tasks is important for screening older adults at risk for future disability and for developing more directed interventions.

## Limitations

Potential limitations of this study include our sample and the follow-up interval of one year. Because only 41% of the original baseline participants returned for one year follow-up it is possible that our longitudinal results are biased. This convenience sample consisted of older adults who had high educational levels and who were relatively independent in functioning, thus limiting generalizability of these results to a more diverse and frail group of older adults. In addition, by only excluding those who scored less than 6 on the SPMSQ[5] it is possible that a few persons with dementia were included in this sample. Our analysis was also limited by the small number of participants who demonstrated decline on the selected measures over one year. Despite declines in raw change scores by a number of participants, we were unable to examine risk of decline in physical function because few participants demonstrated meaningful decline. Future research using a longer follow-up interval or a more frail group of older adults may be necessary to more fully examine this relationship.

## CONCLUSION

This study provides evidence that baseline cognitive processing is associated with decreased independent function one year later. More specifically, poorer performance on baseline measures of attention and processing speed were associated with declines in balance and increased risk for disability in mobility and IADL daily living tasks. The association of cognitive processing with changes in balance lends support to the hypothesis that the relationship of cognitive processing to performance of physical functions and daily living tasks may be partially mediated by balance. However, additional research is needed to further examine specific amounts and rate of change in cognitive processing that may be associated with decline in physical functions and performance of daily living tasks.

**REFERENCES**


1. Scherr PA, Albert MS, Funkenstein HH, et al. Correlates of cognitive function in an elderly community population. *Am J Epidemiol.* 1988;128:1084-1101.

2. Moritz DJ, Kasl SV, Berkman LF. Cognitive functioning and the incidence of limitations in activities of daily living in an elderly community sample. *Am J Epidemiol.* 1995;141:41-49.

3. Gill TM, Williams CS, Richardson ED, Berkman LF, Tinetti ME. A predictive model for ADL dependence in community-dwelling older adults based on a reduced set of cognitive status items. *J Am Geriatr Soc.* 1997;45:441-445.

4. Folstein MF, Folstein SE, McHugh PR. Mini-Mental State: A practical method for grading the cognitive state of the patient for the clinician. *Journal of Psychiatric Research.* 1975;12:189-198.

5. Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficits in elderly patients. *J Am Geriatr Soc.* 1975;23:433-441.

6. Blaum CS, Ofstedal MB, Liang J. Low cognitive performance, comorbid disease, and task-specific disability: findings from a nationally representative survey. *J Gerontol: Med Sci.* 2002;57A(8):M523-M531.

7. Fried LP, Ettinger WH, Lind B, Newman AB, Gardin J. Physical disability in older adults: a physiological approach. Cardiovascular Health Study Research Group. *J Clin Epidemiol.* 1994;47(7):747-760.

8. Gill TM, Williams CS, Richardson ED, Tinetti ME. Impairments in physical performance and cognitive status as predisposing factors for functional dependence among nondisabled older persons. *J Gerontol: Med Sci.* 1996;51A(6):M283-M288.

9. Greiner PA, Snowden DA, Schmitt FA. The loss of independence in activities of daily living: the role of low normal cognitive function in elderly nuns. *Am J Public Health.* 1996;86(1):62-66.

10. Njegovan V, Man-Son-Hing M, Mitchell SL, Molnar. The hierarchy of functional loss associated with cognitive decline in older persons. *J Gerontol: Med Sci.* 2001;56A(10):M638-M643.

11. Earles JL, Salthouse TA. Interrelations of age, health, and speed. *J Gerontol: Psychol Sci.* 1995;50B(1):P33-P41.

12. Salthouse TA. The processing-speed theory of adult age differences in cognition. *Psychol Rev.* 1996;103(3):403-428.

13. Plude DJ, Doussard-Roosevelt JA. Aging, selective attention and feature integration. *Psychol Aging.* 1989;4:98-105.

14. Allen PA, Weber TA, Madden DJ. Adult age differences in attention: filtering or selection? *J Gerontol: Psychol Sci.* 1994;49:213-222.

15. Jordan TC, Rabbitt PMA. Response times to stimuli of increasing complexity as a function of aging. *Br J Psychol.* 1977;68:189-201.

16. Light KE, Spirduso WW. Effects of adult aging on the movement complexity factor of response programming. *J Gerontol.* 1990;45:107-109.

17. Madden DJ, Pierce TW, Allen PA. Adult age differences in the use of distractor homogeneity during visual search. *Psychol Aging.* 1996;11(3):454-474.

18. Binder EF, Storandt M, Birge SJ. The relation between psychometric test performance and physical performance in older adults. *J Gerontol: Med Sci.* 1999;54A(8):M428-M432.

19. Carlson MC, Fried LP, Xue QL, Bandeen-Roche K, Zeger SL, Brandt J. Association between executive attention and physical functional performance in community-dwelling older women. *J Gerontol: Soc Sci.* 1999;54B(5):S262-S270.

20. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. *J Gerontol: Med Sci.* 1991;46(3):M69-M76.

21. Nevitt MC, Cummings SR, Hudes ES. Risk factors for injurious falls: a prospective study. *J Gerontol: Med Sci.* 1991;46(5):M164-M170.

22. Rosano C, Simonsick EM, Harris TB, et al. Association between physical and cognitive function in health elderly: The Health, Aging and Body Composition Study. *Neuroepidemiology.* 2005;24:8-14.

23. Bell-McGinty S, Podell K, Franzen M, Baird AD, Williams MJ. Standard measures of executive function in predicting instrumental activities of daily living in older adults. *Int J Geriatr Psychiatry.* 2002;17:828-834.

24. Wechsler D. *The Wechsler Adult Intelligence Scale-Revised*. New York: The Psychological Corporation; 1981.

25. Teng EL, Chue HC. The modified mini-mental state (3MS) examination. *J Clin Psychiatr.* 1987;48:314-318.

26. Katz S, Ford A, Moskowitz R, Jackson B, Jaffe M. Studies of illness in the aged. The Index of ADL: a standardized measure of biological and psychological funtion. *JAMA.* 1963;185(12):914-919.

27. Berkman LF, Berkman CS, Kasl S, et al. Depressive symptoms in relation to physical health and functioning in the elderly. *Am J Epidemiol.* 1986;124(3):372-388.

28. Yaffe K, Blackwell T, Gore R, Sands L, Reus V, Browner WS. Depressive symptoms and cognitive decline in nondemented elderly women: A prospective study. *Arch Gen Psychiatry.* 1999;56:425-430.

29. Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement.* 1977;1:385-401.

30. Spreen O, Strauss E. *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press; 1998.

31. Lezak MD. *Neuropsychological assessment*. New York: Oxford University Press; 1995.

32. Smith A. *Symbol Digit Modalities Test Manual*. Los Angeles, CA: Western Psychological Services; 1982.

33. Reitan RM, Wolfson D. *The Halstead-Reitan Neuropsychological Test Battery*. Tucson, AZ: Neuropsychology Press; 1985.

34. Reuben DB, Siu AL. An objective measure of physical function of elderly outpatients: the Physical Performance Test. *J Am Geriatr Soc.* 1990;38:1105-1112.

35. Guralnik JM, Ferucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *New Engl J Med.* 1995;332:556-561.

36. Gill TM, Williams CS, Tinetti ME. Assessing risk for the onset of functional dependence among older adults: the role of physical performance. *J Am Geriatr Soc.* 1995;43:603-609.

37. Reuben DB, Rubenstein LV, Hirsch SH, Hays RD. Value of functional status as a predictor of mortality: results of a prospective study. *Am J Med.* 1992;93:663-669.

38. Onder G, Penninx B, Lapuerta P, et al. Change in physical performance over time in older women: The Women's Health and Aging Study. *J Gerontol: Med Sci.* 2002;57A(5):M289-M293.

39. Gill TM, Williams CS, Mendes de Leon CF, Tinetti ME. The role of change in physical performance in determining risk for dependence in Activities of Daily Living among nondisabled community-living elderly persons. *J Clin Epidemiol.* 1997;50(7):765-772.

40. Berg K, Dauphinee S, Williams JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. *Physiother Can.* 1989;41(6):304-311.

41. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc.* 1986;34:119-126.

42. McHorney CA. Measuring and monitoring general health status in elderly persons: practical and methodological issues in using the SF-36 Health Survey. *Gerontologist.* 1996;36(5):571-583.

43. Wolinsky FD, Wan GJ, Tierney WM. Changes in the SF-36 in 12 months in a clinical sample of disadvantaged older adults. *Med Care.* 1998;36(11):1589-1598.

44. McHorney CA, Ware JE, Lu JFR, Sherbourne CD. The MOS 36-Item Short Form Health Survey (SF-36): III. tests of data quality, scaling assumptions, and reliability across diverse patient groups. *Med Care.* 1994;32(1):40-66.

45. Fillenbaum GG. Screening the elderly. A brief instrumental activities of daily living measure. *J Am Geriatr Soc.* 1985;33(10):698-706.

46. Kernan WN, Viscoli CM, Brass LM, Gill TM, Sarrel PM, Horwitz RI. Decline in physical performance among women with a recent transient ischemic attack or ischemic stroke: opportunities for functional preservation a report of the Women's Estrogen Stroke Trial. *Stroke.* 2005;36(3):630-634.

47. Studenski S, Perera S, Wallace D, et al. Physical performance measures in the clinical setting. *J Am Geriatr Soc.* 2003;51(3):314-322.

48. Smits CH, Deeg DJ, Kriegsman DM, Schmand B. Cognitive functioning and health as determinants of mortality in an older population. *Am J Epidemiol.* 1999;150(9):978-986.

49. Metter EJ, Schrager M, Ferrucci L, Talbot LA. Evaluation of movement speed and reaction time as predictors of all-cause mortality in men. *J Gerontol A Biol Sci Med Sci.* 2005;60(7):840-846.

50. Loeb PA. *The Independent Living Scales*. San Antonio, Texas: The Psychological Corporation; 1996.

51. Nagi SZ. An epidemiology of disability among adults in the United States. *Milbank Mem Fund Q.* 1976;54:439-467.

52. Wilson RS, Beckett LA, Barnes LL, et al. Individual differences in rates of change in cognitive abilities of older persons. *Psychol and Aging.* 2002;17(2):179-193.

53. Mitrushina M, Satz P. Effect of repeated administration of a neuropsychological battery in the elderly. *J Clin Psychol.* 1991;47(6):790-801.

Table 3.1: Baseline demographic characteristics, performance scores, and medical conditions for participants and non-participants.

| **Characteristics** | **Participants N=62 Mean (SD) or Percent** | **Non-participants N=67 Mean (SD) or Percent** | ***p level*** |
|---|---|---|---|
| | | | *t-test*[*] |
| Age (years) | 80.7 (5.0) | 81.3 (6.2) | .553 |
| Education (years) | 15.6 (2.7) | 15.3 (2.5) | .498 |
| Medical conditions (number) | 3.3 (2.1) | 3.5 (2.0) | .503 |
| Prescription medications (number) | 2.9 (2.0) | 3.6 (2.8) | .102 |
| SDMT (number items correct) | 42.5 (12.6) | 41.6 (13.8) | .700 |
| TMTB (seconds) | 118.7 (38.7) | 128.4 (36.9) | .149 |
| 360° turn (seconds) | 2.9 (0.9) | 3.5 (1.4) | **.003** |
| PPT (total score) | 23.3 (2.6) | 21.6 (4.0) | .006 |
| Walking speed (meters/second) | 1.2 (.3) | 1.1 (.3) | **.005** |
| PF-10 (total score) | 75.8 (21.8) | 58.8 (26.1) | **.000** |
| | | | *Chi-square*[†] |
| Gender (percent female) | 67.9 | 72.6 | .558 |
| Community dwelling | 96.7 | 89.2 | .101 |
| Use assistive device | 21.8 | 32.9 | .168 |
| Depressive symptoms (CES-D > 15)[29] | 5.4 | 6.8 | .728 |
| ADL function (Katz ADL Scale)[26] Independent in 5 ADL | 100.0 | 98.6 | .384 |
| IADL function (OARS)[45] Independent in 7 IADL | 78.2 | 57.5 | .014 |
| Intact cognitive function (SPMSQ scores 9-10)[5] | 94.5 | 97.3 | .433 |
| **Reported Medical Conditions** | | | |
| Arthritis | 60.7 | 64.4 | .669 |
| Hypertension | 35.7 | 42.5 | .437 |
| Urinary Dysfunction | 33.9 | 32.9 | .990 |
| Cancer | 26.8 | 37.0 | .220 |
| Osteoporosis | 26.8 | 31.5 | .560 |
| Heart Disease | 23.2 | 30.1 | .381 |
| Dizziness | 17.9 | 14.5 | .590 |
| Fracture | 17.6 | 30.1 | .176 |
| Stroke | 1.8 | 12.3 | .026 |

[*] Significance level, $p \leq .005$ (Bonferroni adjustment for 10 tests)
[†] Significance level, $p \leq .003$ (Bonferroni adjustment for 16 tests)
*Note: OARS = Older Americans Research and Service Instrument CES-D = Center for Epidemiologic Studies—Depression; SPMSQ = Short Portable Mental Status Questionnaire*

Table 3.2. Baseline and one year follow-up participant characteristics (N=56)

| **Participant characteristics** | **Baseline Mean (SD) or Percent** | **One Year Follow-Up Mean (SD) or Percent** | ***p level*** |
|---|---|---|---|
| Age (years) | 80.5 (4.8) | 81.9 (5.0) | n/a |
| Education (years) | 15.6 (2.7) | n/a | n/a |
| Gender (percent female) | 66.1 | n/a | n/a |
| | | | *Paired t-test*[*] |
| Medical conditions (number) | 3.2 (2.1) | 2.8 (1.9) | .451 |
| Prescription medications (number) | 2.9 (2.1) | 2.7 (2.1) | .055 |
| | | | *McNemar chi-square*[†] |
| Community dwelling | 93.5 | 91.1 | .250 |
| Use assistive device | 21.8 | 20.0 | 1.000 |
| Depressive symptoms (CES-D > 15)[29] | 5.4 | 5.4 | 1.000 |
| ADL function (Katz ADL Scale)[26] Independent in 5 ADL | 100.0 | 98.2 | 1.000 |
| IADL function (OARS)[45] Independent in 7 IADL | 80.0 | 62.5 | .049 |
| Intact cognitive function (SPMSQ scores 9-10)[5] | 96.4 | 94.6 | 1.000 |
| **Reported Medical Conditions** | | | |
| Arthritis | 58.9 | 42.9 | .012 |
| Hypertension | 35.7 | 42.9 | .289 |
| Urinary dysfunction | 32.1 | 32.1 | 1.000 |
| Cancer | 28.6 | 23.2 | .375 |
| Osteoporosis | 26.8 | 28.6 | 1.000 |
| Fracture | 19.6 | 19.6 | 1.000 |
| Heart disease | 21.4 | 17.9 | .687 |
| Dizziness | 17.9 | 17.9 | 1.000 |

[*] Significance level, $p \leq .025$ (Bonferroni adjustment for 2 tests)

[†] Significance level, $p \leq .004$ (Bonferroni adjustment for 14 tests)

*Note: OARS = Older Americans Research and Service Instrument CES-D = Center for Epidemiologic Studies—Depression; SPMSQ = Short Portable Mental Status Questionnaire*

Table 3.3. Descriptive statistics for cognitive processing, physical function, and disability at baseline and one year (N=56).

| Measure (scoring method) | Baseline Mean (SD) | One Year Mean (SD) | Mean Change (SD) | *p level* |
|---|---|---|---|---|
| SDMT (number items correct) | 43.2 (11.7) | 42.4 (10.0) | .8 (7.8) | .464 |
| TMTB (seconds) | 117.5 (37.8) | 99.7 (36.7) | 17.8 (28.3) | **.001** |
| 360° turn (seconds) | 2.9 (.8) | 3.5 (1.2) | -.6 (.8) | **.001** |
| PPT (total score) | 23.5 (2.2) | 24.4 (2.8) | -.9 (2.2) | **.003** |
| Walking speed (meters/second) | 1.2 (.2) | 1.2 (.3) | 0.0 (.2) | .383 |
| PF-10 (total score) | 76.9 (21.3) | 73.9 (24.9) | 3.0 (13.3) | .098 |

*Significance level, $p \leq .008$ (Bonferroni adjustment for 6 tests)

Table 3.4. Participants demonstrating clinically meaningful decline on physical function and disability outcome measures at one year.

| Outcome measure ▪ criteria for meaningful decline | Number with performance decline at one year |
|---|---|
| 360° Turn ▪ 2.3 seconds[39] | 3 |
| PPT ▪ 3 points[46] | 4 |
| Walking speed ▪ .2 meters/second[47] | 5 |
| PF-10 ▪ 10 points[47] | 15 |
| OARS ▪ 1 point[45] | 14 |
| Decreased Independent Function ▪ Decline in any physical function or disability measure as defined above, or increased level of care | 31 |

Table 3.5. Linear regression results examining relationships between baseline cognitive processing and change in physical function and disability over one year (N=56).

| **Physical Function and Disability Change** | **Z-COG** | | | **SDMT** | | | **TMTB** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Coefficient (SE)** | **$R^2$** | ***p*** | **Coefficient (SE)** | **$R^2$** | ***p*** | **Coefficient (SE)** | **$R^2$** | ***p*** |
| 360° turn | .336 (.126) | .116 | **.010** | .022 (.009) | .097 | **.020** | -.007 (.003) | .096 | **.020** |
| PPT | -.093 (.351) | .001 | .791 | -.007 (.025) | .001 | .787 | .002 (.008) | .001 | .832 |
| Walking speed | -.046 (.025) | .063 | .065 | -.003 (.002) | .047 | .112 | .001 (.001) | .057 | .079 |
| PF-10 | -2.638 (2.107) | .028 | .216 | -.142 (.153) | .016 | .357 | .063 (.047) | .032 | .186 |

*Note: Change scores indicating poorer performance at one year compared to baseline are negative for 360° turn and positive for PPT, walking speed and PF-10.*

Table 3.6. Goodness of fit for logistic regression models examining relationships of baseline cognitive processing to disability and decreased independent function.

| **Cognitive Processing** | **Disability N=56** | | | | **Decreased Independent Function N=62** | |
|---|---|---|---|---|---|---|
| | **PF-10** | | **OARS IADL** | | | |
| | **Chi-square** | ***p*** | **Chi-square** | ***p*** | **Chi-square** | ***p*** |
| Z-COG | 7.718 | **.005** | 6.357 | **.012** | 12.577 | **.000** |
| SDMT | 3.392 | .066 | 2.438 | .118 | 8.584 | **.003** |
| TMTB | 10.302 | **.001** | 9.127 | **.003** | 12.749 | **.000** |

*Note: Goodness of fit statistics for Z-SMDT and Z-TMTB are identical to those for the raw SDMT and TMTB scores*

Table 3.7. Logistic regression coefficients and odds ratios examining relationship of baseline cognitive processing to disability and decreased independent function at one year.

| **Cognitive Processing** | **Disability N=56** | | | | | | **Decreased Independent Function N=62** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **PF-10** | | | **OARS IADL** | | | | | |
| | **Coefficient (SE)** | **OR (95% CI)** | ***p*** | **Coefficient (SE)** | **OR (95% CI)** | ***p*** | **Coefficient (SE)** | **OR (95% CI)** | ***p*** |
| Z-COG | 1.046 (.403) | 2.846 (1.291-6.271) | **.009** | .953 (.399) | 2.593 (1.187-5.665) | **.017** | 1.116 (.354) | 3.052 (1.523-6.113) | **.002** |
| SDMT | .049 (.028) | 1.050 (.995-1.109) | .075 | .042 (.028) | 1.043 (.988-1.101) | .127 | .064 (.024) | 1.066 (1.017-1.117) | **.008** |
| TMTB | .027 (.009) | 1.028 (1.009-1.047) | **.003** | .026 (.009) | 1.026 (1.008-1.045) | **.005** | .026 (.008) | 1.026 (1.010-1.043) | **.001** |
| Z-SDMT | .635 (.358) | 1.888 (.937-3.804) | .075 | .542 (.356) | 1.720 (.856-3.453) | .127 | .824 (.311) | 2.279 (1.240-4.191) | **.008** |
| Z-TMTB | 1.096 (.372) | 2.992 (1.444-6.198) | **.003** | 1.039 (.370) | 2.825 (1.368-5.835) | **.005** | 1.030 (.322) | 2.802 (1.491-5.268) | **.001** |

Table 3.8. Linear regression results examining relationships between change in cognitive processing and change in physical function and disability one year later (N=56).

| **Physical Function and Disability Change** | **Change SDMT** | | | **Change TMTB** | | |
|---|---|---|---|---|---|---|
| | **Coefficient (SE)** | **$R^2$** | ***p*** | **Coefficient (SE)** | **$R^2$** | ***p*** |
| 360° turn | -.011 (.014) | .010 | .468 | .008 (.004) | .072 | **.045** |
| PPT | .003 (.038) | .000 | .935 | -.001 (.010) | .000 | .900 |
| Walking speed | -.003 (.003) | .019 | .312 | .000 (.001) | .006 | .573 |
| PF-10 | -.123 (.231) | .005 | .598 | .001 (.064) | .000 | .986 |

*Note: Change scores indicating poorer performance at one year compared to baseline are negative for TMTB and 360° turn, and positive for SDMT, PPT, walking speed and PF-10.*

Table 3. 9. Goodness of fit for logistic regression models examining relationships of change in cognitive processing to disability and decreased independent function at one year (N=56).

| **Cognitive Processing** | **Disability** | | | | **Decreased Independent Function** | |
|---|---|---|---|---|---|---|
| | **PF-10** | | **OARS IADL** | | | |
| | **Chi-square** | ***p*** | **Chi-square** | ***p*** | **Chi-square** | ***p*** |
| SDMT | .807 | .369 | .012 | .914 | 1.551 | .213 |
| TMTB | .237 | .626 | 2.400 | .121 | .280 | .597 |

Table 3.10. Logistic regression coefficients and odds ratios examining relationships between change in cognitive processing and disability over one year (N=56).

| **Cognitive Processing** | **Disability** | | | | | | **Decreased Independent Function** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **PF-10** | | | **OARS IADL** | | | | | |
| | **Coefficient (SE)** | **OR (95% CI)** | ***p*** | **Coefficient (SE)** | **OR (95% CI)** | ***p*** | **Coefficient (SE)** | **OR (95% CI)** | ***p*** |
| SDMT | -.037 (.042) | .964 (.887-1.047) | .383 | -.004 (.040) | .996 (.920-1.077) | .914 | -.045 (.038) | .956 (.887-1.029) | .231 |
| TMTB | -.005 (.011) | .995 (.974-1.016) | .628 | -.018 (.012) | .982 (.960-1.006) | .136 | -.005 (.010) | .995 (.976-1.014) | .599 |

# CHAPTER IV

## THIRD MANUSCRIPT

## Examination of the relationship of cognitive processing to difficulty and dependence disability

**Abstract**

**Background.** Declines in cognitive processing are associated with disability and may be more apparent as one experiences difficulty with daily tasks than once one develops dependence on others to complete daily tasks.

**Purpose:** To explore the relationship of the cognitive processing to self reported disability measured as dependence and measured as difficulty.

**Methods.** Volunteers (N=72) from a continuing care retirement community and church congregation (mean age 81.6 ± 5.6 years, 69% female) participated in a wellness assessment that included measures of cognitive processing and disability. Cognitive processing, defined as performance on measures of attention and processing speed, were assessed with the Symbol Digit Modalities Test (SDMT) and the Trail Making Test Part B (TMTB). Raw SDMT and TMTB scores were transformed into z-scores and the mean used to create a composite measure as our primary measure of cognitive processing (Z-COG). Difficulty and dependence with daily tasks were assessed by self-report of performance on eleven mobility tasks and instrumental activities of daily living (IADL). Logistic regression analyses were conducted to examine the relationship of cognitive processing (Z-COG, SDMT, and TMTB) to difficulty disability and dependence disability and to examine the relationship of cognitive processing to IADL disability and mobility disability (dichotomized as no disability or disability on one or more tasks).

**Results.** Poorer cognitive processing scores (Z-COG, SDMT, and TMTB) were significantly associated with dependence disability (OR ranged from 1.08 to 2.48) and more specifically with IADL dependence (OR ranged from 1.03 to 3.86). Logistic regression models examining the association of cognitive processing to difficulty disability (IADL and mobility) and mobility dependence did not demonstrate adequate fit.

**Conclusions.** Poorer cognitive processing ability is associated with self-reported dependence in IADL.

***Key words:*** cognition, attention, processing speed, disability

## INTRODUCTION

Independence in daily activities allows older adults to remain living in the community rather than move into an assisted living facility or nursing home. Independence in daily activities such as walking, preparing a meal, driving, and shopping requires both physical and cognitive abilities. Numerous studies demonstrate that decline in general cognitive function is associated with dependence in activities of daily living (ADL) and instrumental activities of daily living (IADL) in older adults.[1-4] IADL require higher levels of cognitive processing than ADL and as general cognitive function declines, dependence in IADL typically occurs before dependence in ADL.[5] Poor performance on general cognitive screening measures, such as the Mini Mental Status Exam[6] (MMSE) and Short Portable Mental Status Questionnaire[7] (SPMSQ), is also associated with disability and institutionalization.[4,8-9]

General cognitive measures such as the MMSE and SPMSQ are intended as screening tools for general cognitive function and dementia. They do not adequately measure specific aspects of cognition, such as memory, attention, and processing speed. Identifying decline in specific aspects of cognition associated with disability in daily activities is critical for designing effective intervention programs to preserve independence among older adults.

Two cognitive processes important to performing complex tasks, such as ADL and IADL, are attention and processing speed. Both promote the cognitive organization, initiation, and sequencing of actions necessary for efficient information processing and performance of daily tasks; such as, finding objects in a crowded cupboard, preparing meals, and walking. Processing speed, or the time it takes to process information from external and internal sensory cues, plays a key role in the planning and execution of coordinated movement.

Age-related declines in attention and processing speed are well documented.[10-13] Prior research demonstrates stronger associations of attention and processing speed to IADL in older adults than other aspects of cognition, such as memory.[14] Older adults frequently exhibit deficits with visual aspects of attention, such as visual scanning and selecting appropriate visual cues from the environment, that are important for performing daily tasks, such as walking and driving.[15,16] Slowed processing speed is also theorized to contribute to other age-related cognitive impairments such as memory and problem solving.[17] Numerous studies provide evidence that poor performance on measures of attention and processing speed is associated with poorer performance of daily tasks and increased falls.[14,18-22]

Disability outcomes typically measure disability as either self-reported dependence or difficulty with ADL or IADL. Measuring disability as dependence assesses whether an individual needs assistance to perform a task; whereas, measuring disability as difficulty assesses whether one experiences difficulty when performing a task. Estimates of disability defined as difficulty demonstrate a 1.2 to 5 times greater prevalence rate for disability than when it is defined as dependence.[23] Also, except in cases of acute adverse events, individuals experience difficulty with a task before they require assistance.[24]

Because of the important associations between cognition and independent living activities it is important to examine the relationship of attention and processing speed to disability defined as difficulty and as dependence. Decline in attention and processing speed capabilities may first become apparent as difficulty performing daily tasks occurs. It is also possible that dependence disability may be more related to physical limitations such as pain or weakness than cognitive processing deficits. Furthermore, attention and processing speed may be more related to complex IADL than simpler mobility tasks such as walking. A review of the literature revealed no previous studies of the relationship of attention and processing speed to difficulty and dependence disability.

The purpose of this paper was to explore the relationship of attention and processing speed, defined here as cognitive processing, to self reported disability measured by dependence and measured by difficulty with daily tasks. We tested the hypothesis that cognitive processing is more strongly associated with disability measured by difficulty than measured by dependence. We also hypothesized that cognitive processing is more strongly associated with IADL disability than with mobility disability.

## METHOD

### Study Design and Sample

This was a cross-sectional study using data from the *Be Alive* project, a larger, ongoing longitudinal study promoting wellness and independence in older adults living in North Carolina. Participants in the *Be Alive* project were community dwelling individuals and continuing care retirement community (CCRC) residents who volunteered in on-site wellness assessments (N=195 at baseline), which consisted of a comprehensive battery of measures assessing cognitive and physical abilities. Individuals 50 years of age or older and able to walk independently with or without an assistive device were included in the *Be Alive* project. Individuals with medical conditions precluding participation in physical performance testing such as uncontrolled hypertension or severe joint pain were excluded from testing. Prior to testing, a brief medical screen assessing health history, pain, medication use, and recent surgeries was administered to identify individuals with contraindications to performance testing. All participants signed a consent form approved by the UNC Chapel Hill School of Medicine Committee for the Protection of Human Subjects. Trained health professionals performed assessments in a single session lasting approximately 90 minutes.

Cross sectional data collected at the *Be Alive* project one year follow up was used for these analyses. Participants included 72 individuals who were 65 years of age or older, scored above six on the Short Portable Mental Status Questionnaire,[7] could clearly see the cognitive test items, and completed an additional questionnaire regarding difficulty and dependence in daily tasks.

## Data Collection Procedure

### *Demographic and Health-Related Measures*

Participants in the study completed a series of self-report questionnaires to gather demographic and health-related information. The self-report questionnaires included medical history, the Katz ADL Scale,[25] and the Older Americans Research and Service Center Instrument (OARS),[26] a measure of IADL ability. Because research suggests that depression may contribute to poor cognitive function and disability,[27-28] we also administered the Center for Epidemiologic Studies Depression Scale (CES-D)[29] to identify participants who demonstrated depressive symptoms.

### *Cognitive Processing: Attention and Processing Speed Measures*

We operationally defined cognitive processing as performance on measures of attention and processing speed, and selected these aspects of cognition because they are important to both the cognitive and physical aspects of daily tasks.[14,17,30] We selected the Symbol Digit Modalities Test and the Trail Making Test Part B to measure attention and processing speed based on their sensitivity to age-related impairments and psychometric properties. Participants were tested in a quiet room and wore corrective eyewear if necessary.

*(a) Symbol Digit Modalities Test (SDMT):* The SDMT assesses visual aspects of attention, such as scanning and tracking, and processing speed.[31-32] The test requires the conversion of meaningless geometric designs into oral or written number responses.[33] We chose the oral version of the SDMT to reduce the influence of limited motor ability on test performance (e.g., participants with Parkinson's Disease or arthritis). Scores were calculated as the total number of items correct in 90 seconds.

*(b) Trail Making Test Part B (TMTB):* The TMTB assesses visual attention, processing speed, motor function, and mental flexibility.[31,34] This paper-and-pencil test requires connecting circles in alternating numerical and alphabetical sequence (e.g., 1-A-2-B, etc.) as quickly as possible. Scores were recorded as the time required to complete the test, up to a maximum of 180 seconds. Participants unable to complete the test in the maximum allowed time were assigned scores of 180 seconds.

*Disability Measure: Difficulty and Dependence Questionnaire*

The Difficulty and Dependence Questionnaire was modified from the disability questionnaire utilized in the Women's Health and Aging Study[35] (WHAS). We chose eleven tasks from the WHAS and modified the response choices and scoring to assess difficulty and dependence with each task. We chose these eleven tasks because they emphasize higher level mobility tasks and complex IADL. Mobility tasks, such as rising from a chair and walking, are required for independence in daily living, and prior research provides evidence that decline in mobility performance is associated with decreases in attention.[30,36-37] Complex IADL, such as shopping and meal preparation, appear more sensitive than ADL (e.g. dressing and grooming) to declines in several aspects of cognition.[3,5,14]

In this study, participants were first asked about their level of difficulty in performing eleven tasks (Table 4.1). The questionnaire administration process was streamlined and response options modified from the WHAS to address difficulty and dependence. Difficulty question response options were; none, a little, some, or a lot. Each item was scored individually on a 1-4 scale, with 1 representing responses of "none" and 4 representing "a lot". To address dependence, participants were then asked if they needed help from another person to perform each of these same tasks. Dependence question response options were; no, yes, and unable to do the task. Each item was scored on a 1-3 scale, for no, yes, and unable responses, respectively. If participants reported they did not perform a particular task for reasons unrelated to their health, it was not scored for either the difficulty or dependence questions. Individual item scores for the difficulty questions were summed and then divided by the number of items each participant reported they performed to create a difficulty scale score. A dependence scale score was similarly created.

**Statistical Analysis**

The data were analyzed using SPSS Version 12.0 statistical software (SPSS Inc.; Chicago, IL). Univariate analyses of all variables were conducted to examine the data distribution, detect outliers, and characterize the sample. Because baseline SDMT and TMTB scores were moderately correlated ($r = -.75$, $p \leq .001$), we constructed a composite score. Raw scores on the SDMT and TMTB were transformed to standard *z*-scores using the sample means and standard deviations. The z-scores were then averaged to create a composite measure to represent cognitive processing (Z-COG) for each participant.

Because we were also concerned with disability in any daily living task, we dichotomized our dependent variables based on difficulty and dependence on one or more of the eleven items and conducted logistic regression analyses. Participants who reported no difficulty or dependence in any of the tasks were classified as “not disabled” for each scale. Participants who reported difficulty or dependence in one or more of the tasks were classified as “disabled” for each scale (difficulty and dependence).

Because cognitive processing may be differentially associated with mobility tasks and IADL, we also examined the relationship of cognitive processing to mobility tasks and IADL for both the difficulty and dependence scales. We categorized ten of the eleven items as either an IADL or a mobility task in accordance with the WHAS categorizations.[35] Although the WHAS categorized the remaining task, lifting, as an upper extremity task; because the example of lifting a bag of groceries is provided on the questionnaire, we categorized lifting as an IADL. Two dependent variables were created for both the difficulty and dependence scale representing disability in one or more IADL, and one or more mobility tasks.

Separate logistic regression analyses were conducted for each dependent variable (difficulty scale (all items), dependence scale (all items), IADL difficulty, IADL dependence, mobility difficulty, and mobility dependence). We also conducted the same logistic regression analyses excluding specific sample sub-groups because of the potential influence of these sub-groups on the results. Logistic regression models that excluded participants who demonstrated depressive symptoms (CESD scores greater than 15,[29] N=1), impaired general cognition (SPMSQ scores less than 9,[7] N=3), or lived in the assisted living unit of the CCRC (N=6) were compared to regression models conducted with the entire sample. Chi-square tests and a significance level of .05 were used to assess logistic regression model fit.

To allow consistent interpretation of logistic regression models, Z-COG and SDMT scores were multiplied by negative one to create transformed scores such that higher scores represented poorer performance. All measures of cognitive processing were entered into logistic regression analyses as continuous variables. Therefore, the odds ratios presented are the effects for one point reduction in performance on each measure. SDMT and TMTB performance expressed as z-scores (Z-SDMT and Z-TMTB) were included to allow comparison of the odds ratios between Z-COG and scores on the individual measures.

**RESULTS**

Participant characteristics are presented in Tables 4.2 and 4.3. Most participants were female (69%), lived independently (90%), and had greater than a high school education (73%). On average, participants reported fewer than three medical conditions and prescription medications. Almost all participants were independent with ADL and 65% were independent with IADL.

Descriptive statistics for cognitive processing and the difficulty and dependence scales are presented in Table 4.4 and Figures 4.1a and 4.1b. Individual item responses and the number of tasks participants reported disability in are presented in Tables 4.5 and 4.6. Greater than 94% of participants indicated that they performed ten of the eleven tasks on the questionnaire. Only 36 (50%) participants reported performing heavy housework. Two times as many participants reported difficulty disability compared to dependence disability

(Table 7).  The percentages of participants reporting disability by item are shown in Figure 4.2.  Between 25-29% of participants reported having difficulty walking up ten steps, walking a quarter of a mile, and lifting.  The two tasks participants most frequently reported dependence in were heavy housework (19.4%) and lifting (9.7%).

*Is the association of cognitive processing to self-reported disability stronger when disability is measured as difficulty than when it is measured as dependence?*

Results from the logistic regression analyses conducted with the entire sample and those that eliminated sample sub-groups were not different; therefore, all participants were included in the final analyses.

Goodness of fit statistics, regression coefficients, and odds ratios for logistic regression models examining the relationship of cognitive processing to difficulty and dependence disability are presented in Tables 4.8 and 4.9.  Chi-square analysis of fit demonstrated good fit ($p \leq .05$) for all dependence models, but not for difficulty models. Poorer scores for cognitive processing, as measured by all three measures (Z-COG, SDMT, and TMTB), were associated with dependence disability ($p \leq .05$).  The three measures of cognitive processing appear comparable in their association with dependence disability.

Goodness of fit statistics, regression coefficients, and odds ratios for logistic regression models examining the relationship of cognitive processing with dependence in mobility tasks and IADL are presented in Tables 4.10 and 4.11.  Chi-square analysis of fit demonstrated good fit ($p \leq .05$) for all IADL models, but not for mobility task models. Poorer scores for cognitive processing, as indicated by Z-COG, SDMT, and TMTB, were associated with dependence in performance of IADL.  Chi-square analysis of fit for logistic regression models for the relationship of cognitive processing to mobility task and IADL difficulty did not demonstrate a good fit ($p > .05$).

## DISCUSSION

The results of this study do not support the hypothesis that the association of cognitive processing to disability is stronger when disability is defined as difficulty than when it is defined as dependence. Our results do provide evidence that cognitive processing is associated with dependence disability. More specifically, cognitive processing is associated with IADL dependence. The poor fit of logistic regression models examining the association of cognitive processing to difficulty and mobility dependence disability precluded interpretation of these relationships.

Consistent with prior research, our results demonstrated that twice as many participants reported difficulty with daily tasks than reported dependence.[23] However, cognitive processing was only associated with dependence in daily tasks and it appears that this relationship may be largely due to the association of cognitive processing to IADL. These results support prior studies documenting that cognitive processing play a key role in the performance of complex, multi-step IADL. Processing speed (choice reaction time)[38] and TMTB[22] performance were significantly associated with performance-based measures of IADL. Similarly, Carlson et al[14] reported that TMTB scores were associated with timed performance of three complex IADL (locking door, dialing phone, plugging into outlet).

Adequate performance of mobility tasks is often needed for independence in IADL. For example, shopping requires sufficient ability to walk throughout a store in addition to sufficient cognitive processing to plan and sequence the steps necessary to complete the task, such as finding items in the store and managing payment. We were unable to conclude if cognitive processing was associated with mobility task disability in this study; however prior research supports a relationship between cognitive processing and mobility tasks. Rosano and colleagues[37] reported that poorer performance on the Digit Symbol Substitution Test[39] (a timed, written test similar to the SDMT used in this study) was significantly related to slower walking speed performance. In the Rosano et al[37] study, the measure of walking ability was performance-based and timed. The self-report nature of our measure may not have been sensitive enough to detect decreases in mobility because it focused on presence of difficulty and dependence and not on modification of task performance, such as slowing or using an alternate movement strategy. Task performance modification may not result in difficulty or dependence in mobility tasks and thus may not have been reflected in responses to our questionnaire. It is also possible that other factors, such as physical strength or balance, have a stronger relationship to mobility tasks than cognitive processing.

The ability of the participants to conceptualize difficulty disability may have contributed to the poor model fit for these analyses. During administration of the questionnaire some participants appeared to have a limited ability to understand what was meant by difficulty; whereas, they appeared to easily understand the issue of dependence. It may also be possible that a certain threshold of decline in cognitive processing is needed to influence daily task difficulty and these participants were performing at too high a level to establish a relationship between the two.

## Limitations

Potential limitations of this study include our sample and selected measures. This sample of older adults was predominantly highly educated and independent functioning thus limiting generalizability of these results to a more diverse and frail group of older adults. The relatively low prevalence of disability in this sample also limited our ability to examine the association of cognitive processing to specific daily tasks. The SDMT and TMTB assess the cognitive processes of attention and processing speed; however, they are not pure measures of such and also require other aspects of cognition, such as working memory and learning.

## CONCLUSION

This study provides evidence that cognitive processing is associated with self-reported dependence in IADL. Although decreases in cognitive processing are related to increased IADL dependence, adaptive task modifications that may result may not be perceived by older adults as difficulty with daily tasks. Further investigation into identifying disability based on perceived (self-reported) difficulty is warranted and crucial to research focused on identifying preclinical disability and frailty.

## REFERENCES


1. Gill TM, Williams CS, Tinetti ME. Assessing risk for the onset of functional dependence among older adults: the role of physical performance. *J Am Geriatr Soc.* 1995;43:603-609.

2. Gill TM, Williams CS, Richardson ED, Berkman LF, Tinetti ME. A predictive model for ADL dependence in community-dwelling older adults based on a reduced set of cognitive status items. *J Am Geriatr Soc.* 1997;45:441-445.

3. Scherr PA, Albert MS, Funkenstein HH, et al. Correlates of cognitive function in an elderly community population. *Am J Epidemiol.* 1988;128:1084-1101.

4. Moritz DJ, Kasl SV, Berkman LF. Cognitive functioning and the incidence of limitations in activities of daily living in an elderly community sample. *Am J Epidemiol.* 1995;141:41-49.

5. Njegovan V, Man-Son-Hing M, Mitchell SL, Molnar. The hierarchy of functional loss associated with cognitive decline in older persons. *J Gerontol: Med Sci.* 2001;56A(10):M638-M643.

6. Folstein MF, Folstein SE, McHugh PR. Mini-Mental State: A practical method for grading the cognitive state of the patient for the clinician. *Journal of Psychiatric Research.* 1975;12:189-198.

7. Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficits in elderly patients. *J Am Geriatr Soc.* 1975;23:433-441.

8. Gill TM, Williams CS, Richardson ED, Tinetti ME. Impairments in physical performance and cognitive status as predisposing factors for functional dependence among nondisabled older persons. *J Gerontol: Med Sci.* 1996;51A(6):M283-M288.

9. Greiner PA, Snowden DA, Schmitt FA. The loss of independence in activities of daily living: the role of low normal cognitive function in elderly nuns. *Am J Public Health.* 1996;86(1):62-66.

10. Earles JL, Salthouse TA. Interrelations of age, health, and speed. *J Gerontol: Psychol Sci.* 1995;50B(1):P33-P41.

11. Salthouse TA. Aging and measures of processing speed. *Biol Psychol.* 2000;54:35-54.

12. Allen PA, Weber TA, Madden DJ. Adult age differences in attention: filtering or selection? *J Gerontol: Psychol Sci.* 1994;49:213-222.

13. Jordan TC, Rabbitt PMA. Response times to stimuli of increasing complexity as a function of aging. *Br J Psychol.* 1977;68:189-201.

14. Carlson MC, Fried LP, Xue QL, Bandeen-Roche K, Zeger SL, Brandt J. Association between executive attention and physical functional performance in community-dwelling older women. *J Gerontol: Soc Sci.* 1999;54B(5):S262-S270.

15. Owsley C. Vision and driving in the elderly. *Optom Vis Sci.* 1994;71(12):727-735.

16. Owsley C, Burton-Danner K, Jackson GR. Aging and spatial localization during feature search. *Gerontology.* 2000;46(6):300-305.

17. Salthouse TA. The processing-speed theory of adult age differences in cognition. *Psychol Rev.* 1996;103(3):403-428.

18. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. *J Gerontol: Med Sci.* 1991;46(3):M69-M76.

19. Lord SR, Lloyd DG, Li SK. Sensori-motor function, gait parameters and falls in community-dwelling women. *Age Ageing.* 1996;25:292-299.

20. Nevitt MC, Cummings SR, Kidd S, Black D. Risk factors for recurrent non-syncopal falls: a prospective study. *JAMA.* 1989;261:2663-2668.

21. Nevitt MC, Cummings SR, Hudes ES. Risk factors for injurious falls: a prospective study. *J Gerontol: Med Sci.* 1991;46(5):M164-M170.

22. Bell-McGinty S, Podell K, Franzen M, Baird AD, Williams MJ. Standard measures of executive function in predicting instrumental activities of daily living in older adults. *Int J Geriatr Psychiatry.* 2002;17:828-834.

23. Jette AM. How measurement techniques influence estimates of disability in older populations. *Soc Sci Med.* 1994;38(7):937-942.

24. Gill TM, Robison JT, Tinetti ME. Difficulty and dependence: two components of the disability continuum among community-living older persons. *Ann Intern Med.* 1998;128(2):96-101.

25. Katz S, Ford A, Moskowitz R, Jackson B, Jaffe M. Studies of illness in the aged. The Index of ADL: a standardized measure of biological and psychological funtion. *JAMA.* 1963;185(12):914-919.

26. Fillenbaum GG. Screening the elderly. A brief instrumental activities of daily living measure. *J Am Geriatr Soc.* 1985;33(10):698-706.

27. Berkman LF, Berkman CS, Kasl S, et al. Depressive symptoms in relation to physical health and functioning in the elderly. *Am J Epidemiol.* 1986;124(3):372-388.

28. Yaffe K, Blackwell T, Gore R, Sands L, Reus V, Browner WS. Depressive symptoms and cognitive decline in nondemented elderly women: A prospective study. *Arch Gen Psychiatry*. 1999;56:425-430.

29. Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement.* 1977;1:385-401.

30. Binder EF, Storandt M, Birge SJ. The relation between psychometric test performance and physical performance in older adults. *J Gerontol: Med Sci.* 1999;54A(8):M428-M432.

31. Spreen O, Strauss E. *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press; 1998.

32. Lezak MD. *Neuropsychological assessment*. New York: Oxford University Press; 1995.

33. Smith A. *Symbol Digit Modalities Test Manual*. Los Angeles, CA: Western Psychological Services; 1982.

34. Reitan RM, Wolfson D. *The Halstead-Reitan Neuropsychological Test Battery*. Tucson, AZ: Neuropsychology Press; 1985.

35. Guralnik JM, Fried LP, Simonsick EM, Kasper JD, Lafferty ME. *The Women's Health and Aging Study: Health and social characteristics of older women with disability (NIH Publication No. 95-4009)*. Bethesda, MD: National Institute on Aging; 1995.

36. Persad CC, Giordani B, Chen HC, et al. Neuropsychological predictors of complex obstacle avoidance in healthy older adults. *J Gerontol Psych Sci.* 1995;50B(5):P272-277.

37. Rosano C, Simonsick EM, Harris TB, et al. Association between physical and cognitive function in health elderly: The Health, Aging and Body Composition Study. *Neuroepidemiology.* 2005;24:8-14.

38. Owsley C, Sloane M, McGwin G, Ball K. Timed instrumental activities of daily living: Relationship to cognitive function and everyday performance assessments in older adults. *Gerontology.* 2002;48:254-265.

39. Wechsler D. *The Wechsler Adult Intelligence Scale-Revised*. New York: The Psychological Corporation; 1981.

Table 4.1. Items included on the difficulty and dependence scales. Participants responded to levels of difficulty and dependence for each activity.

| |
|---|
| ***Difficulty Question***<br>By yourself, that is, without help from another person or special equipment (such as a cane, walker or other device), how much difficulty do you have __? |
| ***Dependence Question***<br>Do you need help from another person to perform the following activities? |
| ***Mobility Tasks***<br>1. Walking up 10 steps without resting<br>2. Walking for a quarter of a mile, that is, about 2 or 3 blocks<br>3. Walking across a small room<br>***IADL Tasks***<br>4. Doing heavy housework, such as washing windows, walls or floors<br>5. Doing light housework, such as doing dishes, straightening up, or light cleaning<br>6. Lifting or carrying something as heavy as 10 pounds, for example, a bag of groceries<br>7. Shopping for personal items, such as toiletries or medicine<br>8. Preparing your own meals<br>9. Managing your money, for example, paying bills or keep track of a bank account<br>10. Using the telephone<br>11. Taking medications |

Table 4.2. Participant demographic characteristics (N=72).

| **Participant characteristics** | **Mean (SD) or Percent Participants** |
|---|---|
| Age (years) | 81.6 (5.6) |
| Education (years) | 15.6 (2.8) |
| Number of medical diagnoses | 2.7 (1.9) |
| Number of prescription medications | 2.9 (2.2) |
| Body mass index | 24.0 (2.9) |
| Gender (percent female) | 69.4% |
| Married | 63.9% |
| Live alone | 27.8% |
| Live independently | 90.3% |
| Use assistive device | 20.8% |
| ADL function (Katz ADL Scale)[25]<br>Independent in 5 ADL | <br>98.6% |
| IADL function (OARS)[26]<br>Independent in 7 IADL<br>Dependent in 1 IADL | <br>65.3%<br>25.0% |
| Depressive symptoms (CES-D >15)[29] | 1.4% |
| Intact cognitive function (SPMSQ scores 9-10)[7] | 95.8% |

*Notes:* OARS = Older Americans Research and Service Instrument CES-D = Center for Epidemiologic Studies—Depression; SPMSQ = Short Portable Mental Status Questionnaire

Table 4.3. Medical conditions reported by participants.

| | Number (%) |
|---|---|
| Arthritis | 45.8% |
| Hypertension | 43.1% |
| Osteoporosis | 30.6% |
| Urinary dysfunction | 29.2% |
| Cancer | 22.2% |
| Heart disease | 18.1% |
| Fracture | 18.1% |
| Dizziness | 15.3% |

Table 4.4. Descriptive statistics for measures of cognitive processes, difficulty and dependence disability.

| | Mean (SD) | Range |
|---|---|---|
| SDMT (number items correct) | 41.7 (10.2) | 17 - 60 |
| TMTB (seconds) | 103.6 (37.0) | 43.0 – 180.0 |
| Difficulty scale (score) | 1.2 (.4) | 1.0 – 2.6 |
| Dependence scale (score) | 1.1 (.1) | 1.0 – 1.9 |

Table 4.5. Frequency reports of difficulty and dependence disability.

| Task | Number who reported doing task | Difficulty Scale Amount of difficulty | | | | Dependence Scale Ability to do task | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | None | A little | Some | A lot | Independent | Need assistance | Unable | Don't do task for reasons unrelated to health |
| Steps | 71 | 51 | 11 | 7 | 2 | 69 | 2 | 0 | 1 |
| Walk blocks | 71 | 50 | 11 | 6 | 4 | 69 | 2 | 0 | 1 |
| Walk across room | 72 | 71 | 1 | 0 | 0 | 72 | 0 | 0 | 0 |
| Heavy Housework | 36 | 26 | 5 | 2 | 3 | 29 | 5 | 2 | 35 |
| Light Housework | 72 | 67 | 2 | 3 | 0 | 72 | 0 | 0 | 0 |
| Lifting | 72 | 54 | 9 | 5 | 4 | 65 | 7 | 0 | 0 |
| Shopping | 72 | 66 | 4 | 1 | 1 | 72 | 0 | 0 | 0 |
| Preparing meals | 68 | 65 | 3 | 0 | 0 | 68 | 0 | 0 | 4 |
| Managing finances | 70 | 63 | 3 | 2 | 2 | 67 | 3 | 0 | 2 |
| Using telephone | 72 | 68 | 1 | 3 | 0 | 71 | 1 | 0 | 0 |
| Taking medications | 71 | 67 | 4 | 0 | 0 | 67 | 4 | 0 | 1 |

Table 4.6. Frequency reports of disability by number of tasks.

| Disability | Number of participants |
|---|---|
| **Difficulty (number of tasks)** | |
| ▪ 0 | 39 |
| ▪ 1 | 8 |
| ▪ 2 | 6 |
| ▪ 3 | 7 |
| ▪ 4 | 6 |
| ▪ 5 | 4 |
| ▪ 6 | 0 |
| ▪ 7 | 2 |
| **Dependence (number of tasks)** | |
| ▪ 0 | 53 |
| ▪ 1 | 11 |
| ▪ 2 | 7 |
| ▪ 3 | 1 |

Table 4.7. Participants reporting disability on one or more items defined as difficulty or dependence.

| | Number (%) |
|---|---|
| Difficulty (all tasks) | 33 (45.8) |
| ▪ Mobility tasks | 28 (38.9) |
| ▪ IADL tasks | 24 (33.3) |
| Dependence (all tasks) | 16 (22.2) |
| ▪ Mobility tasks | 10 (13.9) |
| ▪ IADL tasks | 11 (15.3) |

Table 4.8. Goodness of fit for logistic regression models examining relationships between cognitive processing and disability defined as difficulty and dependence.

| Cognitive Processing | Difficulty | | Dependence | |
|---|---|---|---|---|
| | $X^2$ | *p* | $X^2$ | *p* |
| Z-COG | .893 | .345 | 8.266 | .004 |
| SDMT | .854 | .356 | 6.772 | .009 |
| TMTB | .714 | .398 | 7.649 | .006 |

*Note: Goodness of fit statistics for Z-SMDT and Z-TMTB are identical to those for the raw SDMT and TMTB scores*

$X^2$=Chi-square statistic

Table 4.9. Logistic regression coefficients and odds ratios examining relationships between cognitive processing and disability defined as difficulty and dependence.

| Cognitive Processing | Difficulty | | | Dependence | | |
|---|---|---|---|---|---|---|
| | Coefficient (SE) | OR (95% CI) | *p* | Coefficient (SE) | OR (95% CI) | *p* |
| Z-COG | .242 (.258) | 1.274 (.768-2.112) | .348 | .907 (.336) | 2.477 (1.283-4.781) | .007 |
| SDMT | .022 (.024) | 1.022 (.976-1.071) | .359 | .076 (.031) | 1.079 (1.016-1.145) | .014 |
| TMTB | .005 (.006) | 1.005 (.993-1.018) | .400 | .022 (.008) | 1.022 (1.006-1.038) | .008 |
| Z-SDMT | .222 (.242) | 1.249 (.777-2.005) | .359 | .771 (.313) | 2.162 (1.170-3.995) | .014 |
| Z-TMTB | .202 (.240) | 1.224 (.764-1.961) | .400 | .800 (.304) | 2.226 (1.228-4.035) | .008 |

Table 4.10. Goodness of fit for logistic regression models examining relationships between cognitive processing and mobility task and IADL dependence.

| Cognitive Processing | Mobility | | IADL | |
|---|---|---|---|---|
| | $X^2$ | *p* | $X^2$ | *p* |
| Z-COG | 1.229 | .268 | 12.541 | .000 |
| SDMT | 1.015 | .314 | 9.192 | .002 |
| TMTB | 1.139 | .286 | 12.623 | .000 |

*Note: Goodness of fit statistics for Z-SMDT and Z-TMTB are identical to those for the raw SDMT and TMTB scores*

$X^2$=Chi-square statistic

Table 4.11. Logistic regression coefficients and odds ratios examining relationships between cognitive processing and mobility task and IADL dependence.

| Cognitive Processing | Mobility | | | IADL | | |
|---|---|---|---|---|---|---|
| | Coefficient (SE) | OR (95% CI) | *p* | Coefficient (SE) | OR (95% CI) | *p* |
| Z-COG | .400 (.361) | 1.492 (.736-3.025) | .268 | 1.350 (.434) | 3.856 (1.648-9.022) | .002 |
| SDMT | .034 (.033) | 1.034 (.969-1.104) | .315 | .105 (.038) | 1.110 (1.031-1.196) | .006 |
| TMTB | .010 (.009) | 1.010 (.992-1.028) | .283 | .033 (.010) | 1.034 (1.013-1.055) | .002 |
| Z-SDMT | .343 (.341) | 1.409 (.722-2.750) | .315 | 1.066 (.388) | 2.905 (1.359-6.210) | .006 |
| Z-TMTB | .357 (.333) | 1.429 (.744-2.743) | .283 | 1.229 (.387) | 3.418 (1.600-7.303) | .002 |

Figure 4.1a.  Distribution of SDMT scores.

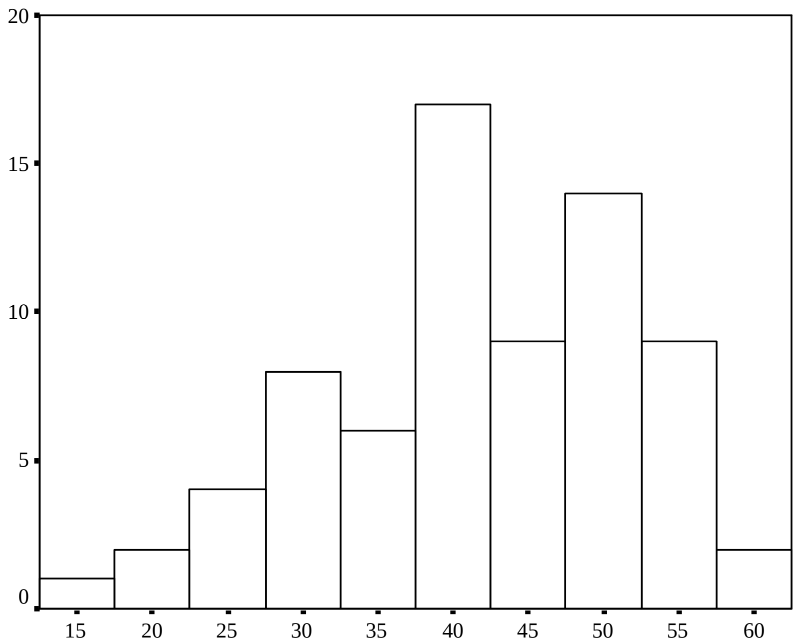



Figure 4.1b. Distribution of TMTB scores.

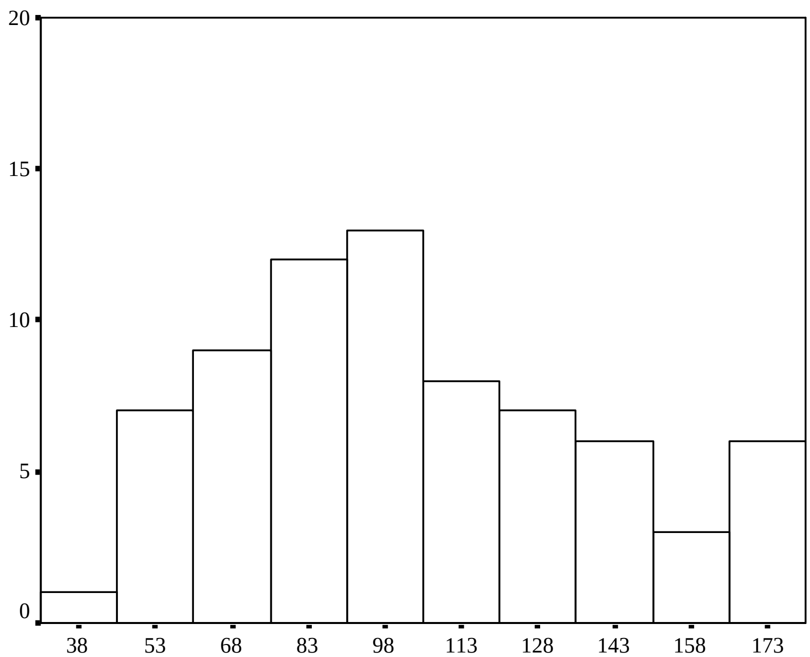
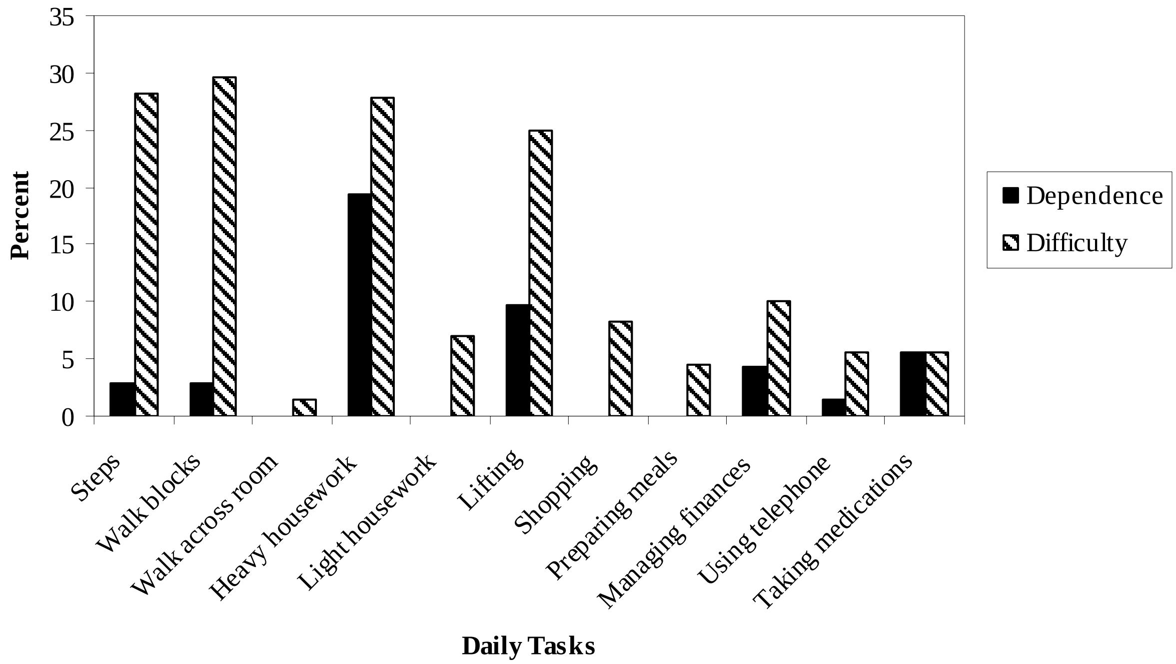


Figure 4.2. Percent of participants reporting disability in one or more items by task.



# CHAPTER V

# SYNTHESIS

## Summary of Findings

Three studies were conducted to examine the following central thesis: *Cognitive processes are associated with both concurrent and future levels of physical function and disability in older adults.*

The results of these studies produce the following answers to the proposed research questions:

Study 1

1. Does cognitive processing demonstrate a direct effect on physical function?

   **Answer:** Consistent with the initial hypothesis, cognitive processing demonstrated a significant direct effect on physical function.

2. Does cognitive processing demonstrate an indirect effect with disability mediated by physical function?

   **Answer:** Consistent with the initial hypothesis, these results provide evidence that physical function significantly mediated the effects of cognitive processing on disability.

2a. Is the magnitude of the indirect mediating effects of a comprehensive, multiple item physical function measure greater than the indirect mediating effects of a single-item physical function measure on the relationship between cognitive processing and disability?

**Answer:** Refuting the initial hypothesis, there was no difference in the magnitude of the indirect mediating effects between a multiple item measure of physical function and a single-item measure of physical function on the relationship between cognitive processing and disability.

3. Does cognitive processing demonstrate a direct effect on disability?

   **Answer:** Refuting the initial hypothesis, cognitive processes did not demonstrate a direct effect on disability.

4. Does cognitive processing demonstrate an indirect effect on disability by modifying the relationship between physical function and disability?

   **Answer:** Refuting the initial hypothesis, cognitive processing did not modify the relationship between physical function and disability.

The results from Study 1 confirmed that cognitive processing is associated with concurrent levels of physical function and disability and provided valuable insight into how cognitive processing relates to physical function and disability in older adults.

Our results demonstrated that Z-COG, our primary measure of cognitive processing, was moderately associated with physical function (standardized regression coefficients of .603 and .416 for direct effect on PPT and walking speed, respectively). Individuals with poorer cognitive processing had lower levels of physical function.

The strength of the direct effects of cognitive processing on physical function in our study appear higher than those previously reported in similar research. Rosano et al[1] reported a standardized coefficient of .32 in describing the association between the Digit Symbol Substitution Test[2] (a written test similar to the SDMT used in this study) and walking speed. Our sample included some individuals with disability, whereas, the sample examined by Rosano et al[1] was free of disability. The stronger association in this study may reflect a greater role for cognitive processing in physical function as independence diminishes. As physical function tasks become more challenging there may be an associated increase in the cognitive resources needed to perform the task. This notion is supported by prior dual-task research demonstrating increased attentional demands as task difficulty increases.[3]

Almost all of the total effects of cognitive processing on disability were indirect and mediated through physical function, with mediation through PPT and walking speed explaining 85% and 66% of the total effects, respectively. Through the indirect path, decreased cognitive processing was associated with decreased physical function and increased disability in older adults. This mediating role of physical function further illustrates the importance of cognitive processing in physical function and its indirect role in daily activities.

Contrary to our initial hypothesis, the effects of a single-item measure of physical function, walking speed, demonstrated a similar level of mediation of the relationship between cognitive processing and disability as the PPT, a more comprehensive, multiple item measure of physical function. The PPT and walking speed were well correlated ($r = .69$), which likely contributes to this finding. We hypothesized that the PPT would have a stronger mediating effect because it includes items that require upper extremity motor skills and items thought to have greater reliance on cognitive processing, such as writing a sentence. The cognitive and motor requirements necessary to perform some of the items in the PPT also appeared to be similar to those required to complete the cognitive processing tasks, particularly the TMTB. This part of our hypothesis appeared to have some merit, as the association between cognitive processing and PPT (standardized coefficient = .603 for Z-COG) was slightly stronger than for walking speed (standardized coefficient = .416 for Z-COG). However, for the physical function to disability component of the indirect effects, walking speed showed a slightly stronger association with PF-10 (standardized coefficient .586 for Z-COG) than PPT (standardized coefficient = .525 for Z-COG). So while cognitive processing did show a stronger association with PPT, the effects on disability were equally mediated by PPT and walking speed. Our results provide further evidence that walking speed is not only an important predictor of disability,[4] but also suggest that it also plays a role in mediating the effects of cognitive processing on disability.

The fact that almost all of the total effects of cognitive processing on disability were indirect and that the direct effects were not significant may have also been influenced by our choice of the PF-10 as our measure of disability. The PF-10 includes primarily mobility-related and ADL tasks but not higher order IADL items that require greater cognitive planning and sequencing. Inclusion of a disability scale with more focus on IADL may have resulted in less indirect effects and stronger direct effects, because some of these tasks, such as managing medications and finances, are less reliant on physical function. We were unable to use the OARS,[5] a self-report IADL scale, as a continuous measure to examine this because of non-normality issues.

Cognitive processing did not modify the relationship between physical function and disability in this study. One potential reason for this may have been our relatively high functioning sample. It's possible that level of cognitive processing has a greater role in the transition from physical function to disability when greater deficits in physical function exist. When physical function limitations exist individuals may rely more heavily on cognitive processing to problem solve ways to modify movement strategies in order to accomplish daily tasks. In these situations, lower levels of cognitive processing may limit one's ability to modify strategies and thus result in greater disability.

The presence of an indirect relationship of cognitive processing on disability mediated by physical function is consistent with the disablement model proposed by Nagi.[6] Our results support that impairments in cognitive processing are directly related to physical function limitations, which are then associated with disability. Nagi's theoretical model does not propose a direct association of impairments to disability and this is consistent with our finding of no direct effect between cognitive processing and disability.

Overall, the results of this study support that the combined effects of cognitive processing and physical function on disability are important to understanding problems older adults may have with daily tasks. These results support that clinicians and researchers should assess cognitive processing in older adults to better explain an older individual's level of physical function and disability. The indirect pathway of cognitive processing to disability through physical function also suggests that interventions aimed at improving cognitive processing may also help to improve physical function and indirectly decrease disability.

<u>Study 2</u>

1. Does cognitive processing measured at baseline predict changes in physical function and disability after one year?

   **Answer:** The initial hypothesis was partially supported. Poorer cognitive processing at baseline predicted decline in the timed 360° measure of physical function (balance) and disability after one year. However, baseline cognitive processing did not predict changes in physical function measured by walking speed or a general overall measure of physical function, the PPT.

2. Is change in cognitive processing associated with changes in physical function, and disability after one year?

   **Answer:** The initial hypothesis was partially supported. Change in cognitive processing was associated with change in the timed 360° turn measure of physical function (balance) but not changes in physical function measured by walking speed or a general overall measure of physical function, the PPT. Change in cognitive processing was also not associated with change in disability after one year.

Study 2 demonstrated that cognitive processing predicted decline in the physical function measure of balance (timed 360° turn), disability, and decreased independent function over one year in older adults. A decline of .336 seconds was predicted in the timed 360° turn for participants with poor cognitive processing at baseline (defined as Z-COG scores one standard deviation below the group mean). Baseline cognitive processing was not predictive of linear changes in walking speed or a general overall measure of physical function, the PPT. This sample of older adults demonstrated relatively stable levels of performance for the PPT and walking speed over one year, therefore, our analysis was likely influenced by the limited amount of change in these variables. In fact, five or fewer participants demonstrated a meaningful decline for any single measures of physical function. The limited number of participants with decline suggests that the one year study period was not long enough for detecting decline in physical function in this sample of older adults.

More participants demonstrated clinically meaningful increases in disability over one year, as measured by the PF-10 and OARS, than clinically meaningful declines in physical function. This appears to disagree with the disability pathway proposed by Nagi.[6] Nagi[6] theorized that disability developed from physical function limitations, which presumably occur before the onset of disability. One possible explanation for this is the perception of disability that is a component of self-report of disability on the PF-10 and OARS. Perhaps these participants perceived greater declines than were measured with the physical function tests.

Poor scores on cognitive processing measures were not predictive of a linear change in disability over one year, but were predictive of whether a meaningful decline in PF-10 or

OARS scores had occurred. Participants with poorer cognitive processing at baseline (Z-COG scores one standard deviation or more below the mean) were at 2.593 times the risk of IADL disability (OARS) and 2.846 times the risk of mobility disability (PF-10) at one year compared to those who didn't exhibit poor cognitive processing. These findings support a key role of cognitive processing in predicting future disability.

Inconsistencies in the prediction of disability from baseline cognitive processing were observed among the three cognitive processing measures. Only Z-COG and TMTB were predictive of increased disability over one year. Because the Z-COG score was based on the scores of the TMTB and SDMT, the prediction of disability based on baseline TMTB scores is an interesting finding. The SDMT and TMTB measures assess primarily attention and processing speed and are well correlated ($r = -.69$, $p \leq .001$); however, the TMTB also assesses mental flexibility and motor speed.[7] In light of these results, it may be possible that these additional skills required for the TMTB are particularly important to predicting future disability. It is difficult, however, to directly compare the predictive value of these two measures because the logistic regression models predicting disability based on SDMT scores also did not demonstrate adequate fit.

It is also clear from this study that poor baseline cognitive processing is predictive of decreased independent functioning. Participants with poor cognitive processing (Z-COG scores one standard deviation or more below the mean) were at 3.052 times the risk of experiencing a decline associated with decreased independent functioning than those with normal cognitive processing. Results for the three measures of cognitive processes were similar in these predictions. In these analyses, models including the SDMT demonstrated adequate fit; whereas, SDMT models predicting disability only did not demonstrate adequate fit. These differing results raise the possibility that the inadequate models for the prediction of disability only based on SDMT may have been a reflection of a smaller sample size. Peduzzi et al[8] suggest a minimum of ten events (in these analyses an event is decline in disability or decreased independent function) per independent variable. This criteria was met for analysis on both outcomes; however, there were more events for the decreased independent function outcome which may have improved model fit compared to the analyses predicting disability.

Examination of change in cognitive processing predicting change in physical function and disability was limited by the relatively stable functional levels of the sample. Decline in TMTB performance was associated, though weakly, with decreased balance performance ($R^2 = .072$, $p \leq .05$), but there were no other associations between change in cognitive processing and change in the other measures of physical function or disability.

Study 3

1. Is the association of cognitive processing to self-reported disability stronger when disability is measured as difficulty than when it is measured as dependence?

   **Answer:** In contrast to the initial hypothesis, cognitive processing was associated only with disability when it was measured as dependence.

Study 3 demonstrated that cognitive processing was associated with a dependence measure of disability. Further analyses to examine the association of cognitive processing with mobility and IADL disability demonstrated that cognitive processing was associated with IADL disability. Participants with poor cognitive processing (defined as Z-COG scores one standard deviation below the group mean) demonstrated 2.477 times the risk for dependence disability (mobility and IADL), and more specifically 3.856 times the risk for IADL dependence compared to participants with normal cognitive processing. The relationship of poor cognitive processing with IADL disability is consistent with the notion that these skills require adequate cognitive function for successful completion, perhaps more so than daily mobility tasks.  Poor cognitive processing may be related to IADL dependence due to greater difficulty or an inability for persons with cognitive processing impairments to adequately modify their strategy to perform the task.

We were unable to directly compare the results for the difficulty and dependence scales and for the mobility and IADL task comparisons due to poor fit of the logistic regression models examining these relationships.

## Significance

Prior research demonstrated an association among cognition, physical function, and disability.  However, many of these studies utilized general cognitive screening measures thus limiting examination of relationships among specific aspects of cognition, such as attention and processing speed, to physical function and disability.  The results of these studies demonstrate important, but complex relationships among cognitive processing, physical function, and disability.  Decomposing the direct and indirect effects of cognitive processing on disability provide evidence that the effects of cognitive processing on disability is primarily mediated by physical function.  This illustrates the importance of the direct effect of cognitive processing on physical function and its indirect role in disability, posing the possibility that interventions that improve cognitive processing may also improve physical function and decrease or prevent disability in older adults.

In Study 2 we provide new information that poor cognitive processing at baseline predicted decline in balance and disability at the one-year follow-up. The prediction of balance decline from poor cognitive processing at baseline but not the other measures of physical function (PPT and walking speed), suggests that balance may be more sensitive to cognitive processing impairments and thus may also be more likely to improve with improvements in cognitive processing through directed intervention programs. In general, this identification of the risk for future decline in independence associated with poor cognitive processing is a key rationale for including measures of cognitive processing in screening programs aimed at identifying older adults at risk for future disability.

## Strengths and Weaknesses

Strengths

1. Theory-based research questions
2. Direct and indirect effect analysis examining complex relationships among cognitive processing, physical function, and disability
3. Inclusion of a longitudinal study design
4. Focus on the cognitive processes of attention and processing speed help direct intervention research to target these aspects of cognition in older adults

Weaknesses (Limitations)

1. The limited functional and sociodemographic diversity of the sample had distinct limitations. This sample of older adults was predominantly independent in ADL and

IADL, and had a relatively high educational level. In general, these factors may limit the generalizability of these results to a more diverse and frail group of older adults. Similarly, participants demonstrated relatively stable levels of physical function over one year with few experiencing meaningful decline, limiting our ability to fully examine the relationship between cognitive processing and decreases in physical function.

2. The cognitive processing measures selected also posed certain limitations. The SDMT and TMTB emphasize the cognitive processes of attention and processing speed; however, they are not pure measures of such and require other cognitive skills, such as working memory and learning. Therefore it is difficult to ascertain the precise contribution of attention and processing speed to physical function and disability. Additionally, practice effects are commonly reported on neuropsychological measures.[9-10] Experience with the SDMT and TMTB at baseline may have influenced performance at one year, possibly masking decreases in performance and limiting examination of the effects of decline in cognitive processing on the physical function and disability outcomes.

3. Limitations in the longitudinal follow-up may have biased the results of Study 2. Only 40% of the original sample returned for testing at one year, possibly biasing our results to reflect participants with the inclination to return. This also resulted in a limited sample size for longitudinal analysis. This smaller sample size combined with the relatively small number of participants who demonstrated meaningful decline in physical function over one year limited analysis of whether poor cognitive processing at baseline was predictive

of decline in physical function. The one year follow-up interval may also not have been long enough to detect meaningful decline in these mostly independent participants.

4. Modifications in testing protocols for the one year follow-up had distinct limitations. We included the Trail Making Test Part A (TMTA) as another instrument assessing attention and processing speed at the one year follow-up. Standard protocol for administration for both parts of the Trail Making Test requires that TMTA be completed before TMTB. This protocol was followed for follow-up testing; however, only the TMTB was administered at baseline. Completion of TMTA prior to TMTB may have provided participants with additional familiarity with the TMTB that they did not have at the baseline testing.

5. The design and administration of the Difficulty and Dependence Questionnaire likely caused certain limitations. During administration of the questionnaire, some participants appeared to have a limited ability to conceptualize what was meant by difficulty. The questionnaire, by design, did not clearly define what was meant by difficulty. While task modifications do sometimes occur in the absence of difficulty performing a task, they are very often the result of experiencing difficulty with a task.[11] Inclusion of specific examples of what difficulty might include may have improved the participants' understanding of task difficulty. For instance, examples or questions about modifying the method or rate of doing a task, or asking if the task is hard for them at times may have improved their conceptualization of task difficulty.

## Future Research

The role of cognitive processing in disability is important for understanding and preventing disability. This dissertation project provides additional information about the complex relationship of cognitive processing with disability in older adults. The pathway to disability is also a complex process with a wide variety of factors influencing its progression. Future research should include a larger and more diverse cohort of older adults that can be followed for longer periods. Longitudinal studies will be especially important to examine the effects of magnitude of change in cognitive processing and how they influence physical function and disability. An adequate longitudinal sample size may be able to address the effects of improvement or decline in cognitive processing. Intervention studies aimed at improving daily function may provide additional information about the relationship between cognitive processing and daily function by including measures of cognitive processing. Additionally, studies for improving cognitive processing should include measures of physical function and disability.

Overall, additional research is needed to determine (1) specific scores on measures of attention and processing speed that are predictive of physical function decline and disability, (2) the association of amount of decline in attention and processing speed with decreased physical function and disability, and (3) if interventions aimed at improving attention and processing speed can lead to improvements in physical function and reduced disability.

**REFERENCES**


1. Rosano C, Simonsick EM, Harris TB, et al. Association between physical and cognitive function in health elderly: The Health, Aging and Body Composition Study. *Neuroepidemiology*. 2005;24:8-14.

2. Wechsler D. *The Wechsler Adult Intelligence Scale-Revised*. New York: The Psychological Corporation; 1981.

3. Lajoie Y, Teasdale N, Bard C, Fleury M. Upright standing and gait: are there changes in attentional requirements related to normal aging. *Experimental Aging Research.* 1996;22:185-198.

4. Guralnik JM, Ferucci L, Pieper C, et al. Lower extremity function and subsequent disability: Consistency across studies, predictive models, and value of gait speed alone compared with the Short Physical Performance Battery. *J Gerontol: Med Sci.* 2000;55A(4):M221-M231.

5. Fillenbaum GG. Screening the elderly. A brief instrumental activities of daily living measure. *J Am Geriatr Soc.* 1985;33(10):698-706.

6. Nagi SZ. An epidemiology of disability among adults in the United States. *Milbank Mem Fund Q.* 1976;54:439-467.

7. Spreen O, Strauss E. *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press; 1998.

8. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol.* 1996;49(12):1373-1379.

9. Wilson RS, Beckett LA, Barnes LL, et al. Individual differences in rates of change in cognitive abilities of older persons. *Psychol and Aging.* 2002;17(2):179-193.

10. Mitrushina M, Satz P. Effect of repeated administration of a neuropsychological battery in the elderly. *J Clin Psychol.* 1991;47(6):790-801.

11. Gregory PC, Fried LP. Why do older adults decide they are having difficulty with a task? *Am J Phys Med Rehabil.* 2003;81(1):9-16.

# APPENDIX A:

# LITERATURE REVIEW

## Theoretical Framework

The Model of Disablement presented by Nagi and later revised by Verbrugge and Jette[1] conceptualizes a pathway to disability as a multistage process in which impairments and functional limitations mediate the pathway from pathology to disability (Figure 1, below).[1, 2] In the model disability is defined as an inability to independently participate in socially defined activities within a specific environment and is often measured as dependence performing mobility and daily living tasks. According to this model, impairment is an abnormality in structure or function at a systems level.[1] Examples of impairments include visual, hearing or memory loss, and muscle weakness. Functional limitations are defined as difficulty or an inability to perform a task, such as standing from a chair or reaching.[1] In this model functional limitations are caused by impairments, and risk factors related to the individual (e.g. age, gender) or to the environment (e.g. social environment, access to health services), may modify the pathway to disability. Theoretically, the disablement process may be modified by early detection and interventions aimed at impairments and risk factors associated with disability.

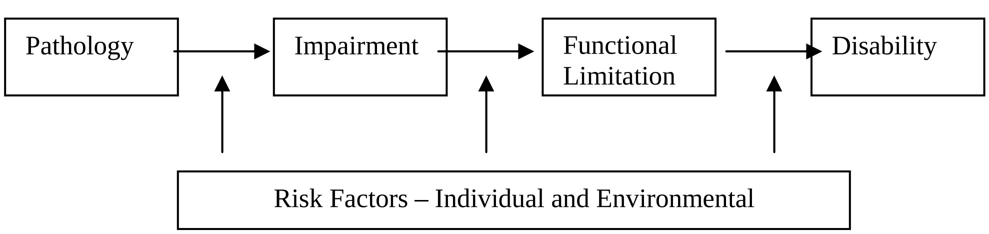



Figure 1. The modified Nagi Model of disablement[1]

*Importance of identifying predictors of future disability*

Research aimed at better understanding the disablement process and identifying predictors of future disability is key to controlling health care costs and improving quality of life for persons with disability. Dependence in Activities of Daily Living (ADL) is one predictor of further disability, hospitalization, institutionalization, and mortality[3, 4] In light of this, it is easy to see that disability is associated with reduced quality of life and increased health care costs.[5] Limitations in daily activities may be the result of system impairments and functional limitations. Improved understanding of the pathway to disability will permit identification of impairments, or combination of impairments and risk factors, that may contribute to, or predict functional limitations and disability. Identification of these predictors of disability will permit early identification of those persons at risk for future disability, aid in the development of screening tools and interventions that may prevent or delay disability, and enhance functional independence among older adults.

Role of physical function in disability

Physical function is an inherent component of daily activities. Many daily activities, such as bathing, preparing a meal, or shopping that older adults must perform to remain independent emphasize motor function, balance and mobility skills; all aspects of physical function. Much evidence exists describing the predictive validity of physical function in the onset of disability in older adults.[4, 6-10]

Because mobility tasks are inherently dynamic in nature, sufficient balance is required for independent performance. Balance involves a multidimensional coordination of sensory and motor systems, cognition, and perception.[11] Limitations in one or more of these areas may result in balance deficits. We know that the normal aging process causes some decline in all of these balance components.[11] In addition to normal aging changes, certain diseases common in older adults may also cause declines in balance (e.g. arthritis, stroke) as a result of impairments in flexibility, strength, sensorimotor coordination, and cognition.

Physical performance measures of balance and functional mobility tasks demonstrate good predictive validity for disability in older adults.[6, 7, 9, 10] Guralnik et al[7] provided evidence that older adults with poorer lower extremity function, as measured by physical performance measures of rising from a chair, balance and gait, had a 4.2-4.9 times greater risk of disability 4 years later than those with high performance scores. Decreased balance is also a risk factor for falls in older adults.[12, 13] Falls often result in injury and loss of independence in performing everyday activities, and are a leading cause of disability among older adults.[12, 14, 15] These considerations make balance an important area in the study of physical function and disability in older adults.

Role of cognition in disability

In addition to physical impairments and functional limitations, evidence demonstrates that impairment in cognition is associated with dependence in functional activities[16, 17] and increased risk of falls.[12] Particular aspects of cognition are adversely affected by the normal aging process independent of the cognitive decline associated with dementia. Cognitive processes that demonstrate the most significant age-related changes include processing speed, attention, and some aspects of memory.

ADL and IADL typically involve complex tasks that involve several steps and often incorporate the use of an instrument, such as using a key to open a door. These tasks require cognitive abilities such as memory, attention, and perception to organize and sequence the task.

Different aspects of cognition likely have different influences on various functional tasks. For example, performance of a well rehearsed everyday task may be more influenced by distractions from stimuli in the environment than by difficulty remembering how to perform the task. Previous literature provides evidence of an association between poor performance on a global cognitive screening measure (such as the Mini Mental Status Exam or Short Portable Mental Status Questionnaire) with decreased physical function, disability and falls.[12, 18, 19] However, research in aging has only begun to examine the relationship specific aspects of cognition may have with physical function and disability.

The following literature review will discuss the attention and processing speed components of cognition, physical function, disability, and the research findings of the relationship between attention and processing speed, physical function, and disability in older adults. Each aspect of function will be defined and some of the current measures used to assess each aspect will be discussed. Future directions for research with regards to the relationship between cognition, mobility and disability will also be discussed.

**Attention and Cognitive Processing Speed**

Two components of cognition that influence how we process information and show consistent age related declines are attention and cognitive processing speed.[20-23] The term attention describes various aspects of cognitive function that influence how information is processed. These aspects of attention include the ability to select relevant information for processing, sustain attentional focus on a task, and divide attention between concurrent tasks.[24] Cognitive processing speed is a measure of the time needed to process information and initiate a response. This measure of information processing time includes perception and encoding of information, integrating the information with other inputs, and selecting and programming a response.

## Theories of the Roles of Attention and Processing Speed in Information Processing

### *Inhibition Theory*

Performing most tasks relies on utilizing a small subset of all available information. Selective attention is the process of selecting only the information that is relevant to the current task for further processing, and disregarding the information that is irrelevant.[24] The ability to enhance activation of relevant inputs and filter out irrelevant information is important to information processing because it limits the amount of information that undergoes further processing. This process of disregarding irrelevant information is inhibition.[25] Inhibitory processes enhance the selection of relevant information by decreasing the amount of irrelevant, or distracting, information being processed or stored. Selection of pertinent inputs and minimizing distracting information for processing promotes faster, more efficient information processing and successful task performance.

Hasher and Zacks[25] hypothesize that decreased inhibition of irrelevant information results in a "crowding" of working memory and information processing with irrelevant information. This overload of processing with non-pertinent information may lead to slowing or errors in information processing. According to Hasher and Zacks,[25] inhibition capabilities decline with advancing age, resulting in selection and processing of unnecessary information. This decline in inhibitory processes with aging contributes to older adults being more distracted by irrelevant information and deficits in information processing. Functionally, declines in inhibition may allow distractions by environmental stimuli to interrupt and impair performance of daily tasks.

*Processing Speed Theory*

Because information processing is the foundation for cognitive functions, processing speed is an important factor that may affect higher cognitive functions, such as memory, attention, and reasoning. Measures of reaction time and other speeded tasks reveal a gradual slowing of processing speed with advancing age.[26, 27] This age related slowing is even greater for more complex cognitive or physical tasks as compared to simple tasks. [27, 28] Though the cause of slowing is unclear, Salthouse[29] suggests age related changes in the nervous system might contribute to the general slowing of processing speed. Some of the proposed physiologic changes in the nervous system include, diffuse cell loss, fewer dendritic branches, and reduced effectiveness of neurotransmitters.

The Processing-Speed Theory presented by Salthouse[30] hypothesizes that slowing in processing speed is a major factor in the age-related differences observed in several aspects of cognition. Salthouse[25] theorizes that slower processing results in restricted cognitive function based on two mechanisms, the limited time mechanism and the simultaneity mechanism. The limited time mechanism describes that when slowing occurs during early cognitive processes the performance of later processes will be impaired. That is, cognitive performance of higher cognitive functions is degraded when processing is slow because relevant operations cannot be successfully executed (limited time). This is especially true for cognitive tasks that must be completed in a limited length of time and for more complex tasks that depend on successful and efficient completion of earlier, simpler operations.

The central hypothesis of the simultaneity mechanism is that slower processing speed may result in decay of the products of earlier processing by the time later cognitive functions require the information. In this case, later processes would suffer if relevant information from earlier operations decayed in quality or quantity before it could be utilized. In applying the limited time and the simultaneity mechanisms, both the accuracy and time to complete cognitive processes may be affected by generalized slowing of processing speed. Support for the processing speed theory is based on evidence that performance on tests of processing speed was negatively correlated with increasing age and that processing speed accounted for a significant proportion of the age-related variance in more complex cognitive tasks.[30, 31]

Age-related changes in attention and processing speed

One aspect of attention that appears to decline with age is selective attention. Limitations in selective attention demonstrated by older adults appear to be related to an increased difficulty ignoring irrelevant information[32] and adequate activation of relevant inputs for selection.[22] Research using visual search paradigms demonstrates that older adults are more easily distracted by irrelevant information than young adults.[33, 34] When irrelevant and relevant information share similar characteristics, such as size or color, some level of selective attention and processing is required of the irrelevant information so a decision can be made on whether the information is needed or not. In these situations, age differences become even more apparent as even minimal processing of irrelevant information appears to create more substantial distractions.[33, 35] For example, searching for a target letter placed on a card with other letters of the same size and case requires more careful scanning and processing of each letter to decide if it is the target letter, as opposed to searching for a letter among numbers. Other selective attention tasks that force attention to distracting information, such as the Stroop task,[36] also demonstrate significant age differences and provide further evidence that older adults have more difficulty appropriately selecting and inhibiting various inputs for further processing than young adults.[37]

As noted above, older adults demonstrate consistent slowing of processing speed. This slowing occurs with both simple (e.g. simple reaction time tasks) and complex (e.g. multi-step movement sequences) tasks, though complex tasks appear to show a disproportionate slowing compared to young adults.[26-28] During more complex tasks information processing demands are more challenging, and the generalized slowing that occurs with age, appears to contribute to increased errors in task performance.[23]

Functional implications of decline in attention and processing speed

Deficits in selective attention may result in everyday performance decrements. For instance, driving a car requires selective attention to environmental inputs that are pertinent to the driver. Balance control involves selection, coordination, and utilization of sensory inputs. Sensory inputs from the visual, somatosensory, and vestibular systems all contribute to balance. In certain situations reliance on one type of sensory input will need to be increased while the other senses become less attended to. The selection of appropriate inputs for processing to generate motor output is very important to balance control. For example, during situations in which somatosensory input is compromised, proper selection of visual and vestibular inputs are necessary for adequate balance. Likewise, selection of somatosensory information may be more important in dark environments when visual inputs are less accurate. In some environmental situations visual or somatosensory inputs are available, but may be inaccurate in terms of the information provided for upright posture (e.g. moving room, inaccurate visual inputs). In these types of situations inaccurate sensory information must be disregarded, and other sensory inputs selected for processing balance responses.

Performing everyday balance tasks inherently includes dual-task situations. Performing a motor task while attending to sensory and environmental cues is a basic example. Complex tasks, such as crossing the street, carrying a bag of groceries or holding a conversation while walking have more attentional requirements. To perform these tasks successfully an individual must perform the dynamic balance task while selectively attending to relevant inputs in environment (e.g. color of the streetlight, upcoming curb, what a friend has said).

Research evidence provides some support for the importance and further study of selective and divided attention during balance mobility tasks. Persad et al[38] reported associations for performance on neuropsychological tests of selective attention and inhibition response with the ability of older adults to successfully clear a virtual obstacle under dual-task conditions. Higher performance in these cognitive domains was associated with better balance and obstacle avoidance performance compared to those who scored lower in these cognitive areas.

Measures of attention and processing speed

Two common standardized neuropsychological measures used to assess attention and processing speed are the Symbol Digit Modalities Test[39] and the Trail Making Tests[40] Both tests are timed and assess aspects of visual scanning and search and processing speed. Measures more specific to assessing processing speed commonly include reaction time tasks and paper-and-pencil simple comparison tasks.

*Symbol Digit Modalities Test*

The Symbol Digit Modalities Test (SDMT) presents nine symbols paired with numbers at the top of the page. On the rest of the page, just the symbols are presented and the respondent must correctly say or write the number that corresponds to the symbol in the key at the top of the page. The test can be completed orally or written, and scored by recording the number of correct items in 90 seconds. The written version also provides information about motor speed. The SDMT has been used with several types of patient populations and discriminates between normal cerebral function and cognitive deficits.[39, 41] Adequate test-retest reliability has also been shown in normal and patient populations ($r = 0.76$).[39]

*Trail Making Test*

The Trail Making Test consists of two parts, Part A (TMTA) and Part B (TMTB). Part A measures the time needed to draw lines connecting circles numbered 1-25 scattered on an 8.5 x 11 page. Part B, presents 25 circles with the numbers 1-13 and the letters A-L within the circles. The respondent is asked to draw lines connecting the numbers and letters in order, alternating between numbers and letters (e.g. 1-A-2-B, etc.). Both parts are to be performed "as quickly as possible". Performance on TMTA and TMTB provide information about visual search, processing speed, and motor function. TMTB also examines the ability to alternate between two sets of stimuli.[42] Though typically the written version is administered, the Trail Making Tests can also be administered verbally. Good interrater reliability has been reported for TMTA (r = 0.94) and TMTB (r = 0.90).[42] One year test-retest reliability is reported to be greater than r = 0.60 for TMTA and TMTB.[43]

*Processing Speed Tasks*

*Reaction time:* Processing speed is commonly measured with reaction time tasks and/or paper-and-pencil tests of simple comparisons. Reaction time is a measure of the time between the presentation of a stimulus and the initiation of a response. Reaction time is often measured using computer equipment connected to a millisecond timer to start timing at the precise moment the stimulus is presented and a sensor to indicate when the movement is initiated. Simple and choice reaction time measures are commonly assessed in this manner.

*Letter and pattern comparison tasks.* The letter and pattern comparison tasks are commonly used to assess processing speed. These paper-and-pencil tests of processing speed involve relatively simple comparison of strings of letters and patterns. The tasks require the participant to compare the strings of letters or patterns. In both tasks, the participant is asked to write a "S" on a line placed between the letters or patterns if the letters or patterns are the same or a "D" if they are different. The set of processing speed tasks consists of two pages each of the letter and pattern comparison tasks. The participant is given 30 seconds to complete as many as possible on each page. The number correct is then summed across the letters and patterns.[30] Good test-retest reliability has been demonstrated for these comparison tasks (r = 0.71 for letter comparison and r = 0.64 for pattern comparison).[21] The letter and pattern comparison tasks are significantly and positively correlated with other simple comparison reaction time tasks (r = 0.36 to 0.60), and negatively correlated with age (r = -0.45 and -0.57, respectively), self-report of general health (r = -0.25 and –0.21, respectively).[21]

**Physical Function**

Physical function is an important component of independence and quality of life in persons of all ages. Physical function refers to performance of fundamental functional tasks, whereas disability is described as an individual's ability to perform daily living tasks in the context of their social roles and environment. Physical function largely includes mobility tasks, such as walking and getting in/out of a chair or bed, but also includes upper extremity tasks, such as reaching and lifting. These types of functional skills are needed for many ADL and IADL tasks, such as bathing, dressing, grocery shopping, and household chores. Physiologic changes associated with aging, such as declines in strength and flexibility, can result in deficits in physical function, especially mobility and balance tasks.[11] Performance-based measures are frequently used to assess physical function in older adults.[6, 8-10, 19, 44-46] Reduced performance on measures of physical function are associated with future disability and falls in older adults.[6, 7, 9, 10, 12]

Because of the dynamic nature of most daily tasks, adequate balance abilities are particularly important for safe and independent function and should be included in physical function assessment.  Balance, defined in biomechanical terms, is the ability to maintain the body's center of gravity within its base of support.[11] Static and dynamic balance are two commonly discussed aspects of balance.  Static balance refers to maintaining the body in equilibrium when at rest over a fixed base of support.[11] This typically involves holding a position either sitting or standing.  Dynamic balance abilities are required when the body's center of gravity must be maintained within a changing or moving base of support, such as during walking when the feet constantly change positions.[11] Physical function and daily living tasks often require movements in different directions, speeds, and in response to environmental changes.  Therefore, maintenance of dynamic balance involves continuously adjusting motor responses to maintain balance while moving during functional tasks.

## Standardized Measures of Physical Function

The following is a description of some of the performance-based measures of physical function more commonly used with community dwelling older adults.  Each measure is quick and easy to administer and useful in both research and clinical settings.

### *Physical Performance Test*

The Physical Performance Test (PPT) is a performance-based measure of overall physical function.[47] The PPT was designed for assessing function in older adults in several domains; upper extremity fine motor function, balance, coordination, mobility, and endurance.  The 7-item version of the PPT includes the following timed tasks; writing a sentence, simulated eating, donning and doffing a jacket, lifting a book, picking a penny up from the floor, and walking 50-feet; plus a 360 degree turn task which is scored based on steadiness and smoothness of steps while turning.  The 9-item version of the PPT includes the same items as the 7-item version, plus two stair climbing tasks. Individual items on the PPT vary greatly in difficulty, making it useful in assessing older adults with a wide range of functional abilities. For all items except the 360-degree turn, the time to complete each task is measured using a stopwatch and then translated into scaled scores. The scores for each item range from 0 (poor performance) to 4 (best performance). The 360-degree turn item is scored based on whether it is performed with continuous or discontinuous steps (score 2 or 0) and steady or unsteady (scored 2 or 0). Higher summary scores represent higher levels of physical function. The maximum score for the 7 and 9-item versions of the PPT are 28 and 36, respectively. The PPT takes approximately 10 minutes to administer and requires only a few props, making it a feasible measure for research and clinical assessments.

Good validity and reliability properties have been reported for the PPT. Interrater reliability was high for both versions of the PPT (r = 0.99 and 0.93, for the 7- and 9-item tests).[47] Concurrent validity of the PPT was demonstrated through correlations with self-report ADL and IADL measures (Katz ADL Scale,[48] Rosow-Breslau Scale[49]) and the gait score of the Performance Oriented Mobility Assessment.[50] Pearson correlation coefficient values for concurrent validity ranged from 0.50-0.69 for the 7-item version and 0.65-0.80 for the 9-item version.[47] Evidence also supports that the PPT has good predictive validity for fall risk, institutionalization and death in older adults.[47, 51] Scores of 15 or less on the 7-item version are associated with increased fall risk, institutionalization, and death.[4, 51]

*Gait Speed*

Gait speed is a frequently used measure of physical function in older adults.[9, 10, 45, 52] It is easily and quickly measured by the time it takes an individual to walk a known distance at their self-selected or fast pace. Distances between 2.4 m and 10 m are most commonly used to calculate gait speed.[7, 8, 44, 53] Several researchers report self-selected gait speed in community dwelling older adults to range from 0.99-1.3 m/s.[54-56]

Gait speed measurements of varying distances have demonstrated excellent intrarater and test-retest reliability for healthy older adults and older adults with Parkinson Disease and osteoarthritis (ICC range from 0.87 to 0.97).[55, 57, 58] Self-selected gait speed was an independent predictor of self-perceived physical function as measured by the Sickness Impact Profile[59] in a group of community dwelling older adults and nursing home residents.[55] Significant correlation between gait speed and weight-shifting abilities during tasks on the Balance Master (r = -.49 to -.72; NeuroCom International, Clackamas, OR) and the Berg Balance Scale (r = .81)[60] provides support for the relationship between dynamic balance and gait mobility. Evidence also supports the predictive value of self-selected gait speed of less than 0.56 m/s for increased fall risk in community dwelling older adults.[51]

*Short Physical Performance Battery for Lower Extremity Function*

Guralnik and colleagues[6] constructed the Short Physical Performance Battery for Lower Extremity Function from three individual performance-based measures to assess function in older adults for the Established Populations for Epidemiological Studies of the Elderly (EPESE).[6] This short battery takes about 10 minutes to administer and consists of gait speed (8-ft walk), timed repeated chair rise (five repetitions) and standing balance (side-by-side, semi-tandem, and tandem stance). Participant scores for the gait and repeated chair rise tasks are based on the time to complete the task. Scoring for the sequence of balance positions is based on how long participants could hold each position, up to a maximum of 10 seconds. Ordinal scores of 0 (unable to do task) to 4 (best score) for each task are based on the time to complete each task and summed across tasks (possible range 0-12). Each ordinal score is based on quartiles of the time to complete each task in the study sample population.[6] Higher summary scores are indicative of better physical function.

Good test-retest reliability correlations were previously reported for the individual measures; 8-ft walk (r = 0.89),[61] repeated chair rise (r = 0.73),[46] and the balance tasks (r = .97).[62] Reliability for the complete battery has not been established, though the battery has been used extensively in aging research. Evidence supports the predictive validity of the battery for future disability in community dwelling older adults.[7] Individuals with the lowest summary scores, measured as those scores in the lowest quartile, were 4.2 to 4.9 times as likely to have disability four years later than those with the highest levels of physical function.[7]

*Timed 360-degree turn*

The 360-degree turn task is a fast, functionally based physical performance measure of dynamic standing balance that has been included as a single item on more comprehensive measures of balance and physical performance (e.g. the Berg Balance Scale,[60, 63] and Physical Performance Test[47]). As an item in balance and physical performance scales, the 360-degree turn is usually scored based on steadiness and not timed. Adequate validity of the un-timed task of turning 360-degrees was demonstrated by correlations with other function and balance tasks; such as, rising from a chair (r = 0.78), transfers (r = .68), standing with eyes closed (r = 0.58), tandem standing (r = 0.80), and total score of the Berg Balance Scale (r = 0.88).[60]

The timed 360-degree turn has also been used as a single physical performance measure in epidemiological research of aging.[9] The timed 360-degree turn task requires participants to turn in a complete circle at either their self-selected or fastest speed. Typically two trials are performed and the average time recorded. Good test-retest reliability for the timed 360-degree turn has been established (ICC = 0.80).[64] A time of greater than 3.8 seconds on the timed 360-

degree turn is associated with functional dependence in ADL after one year.[9] On average, a decline in timed 360-degree turn performance of 2.3 seconds or more over one year is also associated with ADL dependence after one year.[10]

*Position Balance Measure (parallel, semi-tandem, tandem, and single-leg stance)*

The ability to maintain balance in a progression of narrowed base of support positions is a commonly used measure of balance. This measure of static balance was used in the Frailty and Injuries Cooperative Studies of Intervention Techniques (FICSIT) trials[65] and the EPESE, as included in the Short Physical Performance Battery described above. The test assesses one's ability to maintain progressively more challenging standing positions. Individuals attempt to maintain balance with their feet in the following positions; side-by-side, semi-tandem (heel of one foot beside the big toe of the other foot), and tandem (heel of one foot directly in front of the other foot). Some sites of the FICSIT trials added a fourth position of single-leg stance.[66] Scoring of these tasks is an ordinal score based in the time in position, up to a maximum of 10 seconds for each position. The FICSIT sites used scores from 0 (unable to hold side-by-side stance) to 5 (able to hold all four stances for 10 seconds).[66] In the EPESE, these tasks were scored as described in the above discussion of the Short Physical Performance Battery for Lower-Extremity Function.

Test-retest reliability of these balance measures varies according to the time between tests. Lower correlation values of r = 0.25 and r = 0.38 were found for the FICSIT sites with the longest time between tests. FICSIT sites with shorter time intervals between tests reported correlation values of r = 0.50 to r = 0.74.[66] Rossiter-Fornoff et al[66] report criterion-related validity for the balance self report of gait and measurement of sway (correlation values range from r = 0.35 to r = 0.52). A problem with this balance sequence measure is that even the tandem stance position commonly demonstrates ceiling effects in community dwelling older adults.[65] Single-leg stance, the most challenging of the stance positions, does reduce some of this ceiling effect.[66]

**Disability**

Disability is often operationally defined as the dynamic interaction between individuals and their environment that effects their ability to perform personal and societal roles.[1] Within the context of the disablement process, disability refers to the consequences an individual's functional limitations have on their ability to participate and act in typical ways in society.[67] Examples of disability include, but are not limited to, difficulty or an inability to grocery shop, drive, walk, dress or bath oneself.

Disability is typically measured by self-report surveys completed by interview or self-administration. Disability outcome measures commonly define disability as dependence or difficulty with a particular task. Measuring disability as dependence measures the degree of assistance one needs to perform a particular activity. This includes human and/or mechanical (special equipment) assistance, though often only human assistance is considered. Measuring disability as difficulty assesses the degree of difficulty in performing a particular activity. The difference between asking "how much assistance do you need to __?" vs. "how much difficulty do you have performing __?" can result in substantial differences in the incidence or prevalence of disability reported.[67, 68]

Standardized Measures of ADL and IADL

Several standardized measures have been utilized to assess disability in ADL and/or IADL tasks in older adults. Activities of daily living include basic tasks of everyday life such as eating, bathing, dressing, toileting, continence, and transferring. IADL tasks include more complex activities necessary for daily living such as; driving a car, meal preparation, shopping, doing housework, traveling, handling one's finances, and taking medications. Measures of ADL and IADL typically ask individuals how much assistance they need for performing these tasks. Depending on the measure or research question, assistance may be limited to active physical assistance of another person. Although measures of dependence are more widely used to assess disability several researchers suggest that measuring difficulty may provide a more realistic picture of disability. In general, dependence measures of disability generally show good to excellent test-retest reliability. Crawford et al[69] reported Cohen's kappa statistic ranged from 0.60 - 0.86 for all ADL and IADL items except eating and using the toilet (0.49 and 0.50 respectively). Test-retest reliability for difficulty measures of disability is somewhat lower, though still acceptable. Crawford et al[69] reported Cohen's kappa statistic range from 0.51-.64 for all ADL items except getting in and out of bed/chairs (0.38) and range from 0.62-0.72 for all IADL items except managing money (0.25). This lower reliability for may be related to greater subjectivity in the interpretation of "difficulty".

The presence of limitations in ADL and IADL measures is associated with increased risk of further disability, institutionalization, and mortality in older adults.[3, 68, 70] Several standardized measures of disability assess self reported performance during ADL, IADL, or both. Estimates of the number of elderly with ADL disabilities differ substantially across studies. These differences may be due to which ADL items are measured, what constitutes a disability, survey methodology, and age of the population surveyed.

*ADL and IADL*

*Katz ADL Index*

The Katz Index of Independence with Activities of Daily Living is the most commonly used measure of ADL disability in older adults. This measure assesses the amount of personal assistance needed in eating, bathing, dressing, transferring, using the toilet, and continence.[48] Occasionally, researchers make minor modifications of the tasks depending on the research question; for instance, a question on the ability to walk a short distance is sometimes added or no differentiation is made between toileting and continence. The Katz ADL Index has been extensively used in aging research; however, because of the basic nature of the tasks, ceiling effects are problematic with community dwelling older adults. The Katz ADL Index was originally developed to measure the functional status of chronically ill people who had significant disability. In a community dwelling population, the prevalence of disability is low and the result is the majority of those tested score very high on this scale. For this reason using measures of ADL may be inappropriate to identify disability in community dwelling older adults or to detect early signs of disability.

*Older Americans Research and Service Center Instrument*

A commonly used instrument to measure IADL function is the Older Americans Research and Service Center Instrument (OARS).[71] This survey asks individuals to report their ability to use the telephone, get to places out of walking distance, shop for groceries or clothes, prepare meals, perform housework, take medications, and handle money. The scale is scored according to how much help individuals report needing to complete the task. Another popular IADL measure similar to the OARS is the Lawton & Brody scale.[72] The Lawton & Brody scale adds an eighth item regarding doing laundry and like the OARS uses a three point scale based on amount of help needed. Like the Katz ADL scale,[48] the OARS IADL may demonstrate a ceiling effect with independent community dwelling older adult because of the relatively low percentage of community dwelling older adults needing assistance with IADL. However, because of the higher complexity of IADL, difficulty with IADL may be hypothesized to occur before loss of ADL. For this reason assessing IADL may be helpful for identifying people at risk for acquiring disability that would limit their ability to remain in the community.

*Combination ADL/IADL*

The Functional Status Index (FSI) is a standardized measure of both ADL and IADL performance.[73] The original FSI consisted of 45 items, but has since been reduced to 18 items in 5 categories (gross mobility, hand activities, personal care, home chores, and social/role activities). The FSI aims to provide information across 3 dimensions of task performance; dependence, difficulty, and pain. For each of the items individuals are asked; 1) How much assistance did you need to do the activity? 2) How difficulty was it for you to do the activity? 3) How much pain did you have doing the activity? Each dimension is scored separately using a 4 point scale, whereby 0 represents independent or no difficulty/pain and 4 represents dependent or severe difficulty/pain. An advantage of the FSI dependence scale is that it scores assistance from another person and devices. Inclusion of both types of assistance provides information regarding individuals who are independent in a task, but require a device to complete the task.

The FSI was validated for use with arthritis patients.[73] The FSI shows good internal consistency and test-retest reliability. Cronbach's alpha values for the three sub-scales range from 0.67 to 0.90 for all categories except hand activities that had a value of 0.23 for the dependence scale. The intraclass correlation coefficients (ICC) for test-retest reliability the three sub-scales range from 0.69 to 0.88 for all categories except social role that had a ICC of 0.40 for the dependence scale.[74]

*Health Status/Health-Related Quality of Life*

*Medical Outcomes Study Questionnaire Short Form*

The short form of the Medical Outcomes Study Questionnaire (SF-36) was designed as a generic measure of general health status and health-related quality of life for the general population without complicated medical problems.[75] The SF-36 is a self-report measure comprised of 36 items that include impairments, limitations in function, and/or activity restriction. These items assess 8 dimensions of health and quality of life; limitations in physical function, physical role, social function, emotional role, bodily pain, mental health, vitality, and general health perceptions. The SF-36 can be administered self report or by interview in about 10 minutes, although those with health problems may need assistance to complete the survey. Scoring algorithms are used to score each dimension with scores ranging from 0-100, with 0 representing worst health and 100, best health. Good psychometric properties have been widely reported for the SF-36. Internal consistency assessed with Cronbach's alpha reveals values of 0.80 to 0.92 and test-retest ICC values range from 0.65 to 0.87for the eight sub-scales.[76-78] Convergent and divergent validity for health differences are satisfactory (correlation coefficients range from 0.41 to 0.68).[79] Adequate sensitivity to change over a 12 month period has also been demonstrated in a sample of disadvantaged older adults.[80]

The SF-36 has demonstrated inconsistent response rates and distributions when use with particular sub-groups of older adults. Parker et al[81] reported low response rates and missing data for a group of hospitalized older adults. Although response rates in this study improved with interview administration, many ill older adults were still unable to answer all of the questions, resulting in missing data. Frail older adults are also more likely to demonstrate floor effects on the SF-36.[82] When the questionnaire was administered by mail to community-dwelling older adults, Hayes et al[83] reported that missing data was also problematic. In healthy older adults, ceiling effects have been observed on the physical function and role-physical subscales.[84] Despite these limitations, the SF-36 is still considered applicable for use with older adults, though careful consideration should be given to the method of administration and the sub-group of older adults being examined.

Problems with defining disability as dependence vs. difficulty

The main limitation of defining disability solely as dependence is that there are large numbers of people who report having difficulty performing daily tasks but do not need human assistance.[67] Dependence scales of disability, such as the Katz ADL and OARS, also do not account for assistance from the use of equipment, which could be a limitation of these measures, depending on the purpose for assessing disability. Verbrugge and Jette[1] define disability as "difficulty doing activities in any domain of life due to a health or physical problem." Because dependency assumes "severe disability" some consider it a more reliable indicator of disability than measures of difficulty.[1] However, questions of difficulty have been shown to have good reliability over short time intervals.[85, 86] Consistency tends to decrease with increased time intervals for self-report of difficulty.[85] Fried et al[86] reported weighted Kappa statistics ranging from 0.64 to 1.00 for test-retest reliability of self-report of difficulty performing five mobility, ADL, and IADL tasks.

Including a measure of difficulty in disability assessments captures a greater number of persons with limitations. Estimates of disability defined as difficulty demonstrate a 1.2 to 5 times greater prevalence rate for disability than when it is defined as assistance or dependence.[67]

Difficulty with mobility tasks is particularly frequent in older woman. Data from the WHAS reports that of the 3841 women screened for the WHAS I and II, 49.6% reported difficulty walking ¼ mile and 23.0% reported difficulty climbing 10 steps.[87] These data highlight that daily task difficulty is a cause for concern for a substantial portion of older adults.
Evidence supports the theoretical perspective that, except in cases of acute events, individuals experience difficulty with a task before they require assistance.[68] Gill et al[68] reported that older adults who were independent but reported difficulty with ADL tasks, demonstrated physical performance scores and rates of health care utilization and death intermediate to groups of older adults who were either independent with ADL and reported no difficulty or were dependent in ADL tasks. This theoretical perspective and empirical evidence support the assumption that disablement is a dynamic process and research should include disability measures along the continuum.

**Relationship of Cognition to Physical Function and Disability**

Age-related declines in cognition and physical function are well documented.[9, 22, 27, 31, 33, 45, 47, 88, 89] However, the relationship between these important areas of function remains unclear. Physical function and performance of daily living tasks require adequate cognitive function to plan, initiate, and sequence movements, and adapt to various environments and situations. To better understand the process of disablement and identify predictors of future dependence it is important to better understand the relationship of cognition to physical function and disability.

<u>Relationship of global measures of cognition to disability, falls risk, and physical function</u>

Research exploring the relationship of cognition to disability and domains of physical function has often used global cognitive screening measures, such as the Mini Mental Status

Exam (MMSE)[90] and the Short Portable Mental Status Questionnaire (SPMSQ).[91] One of these two cognitive screening measures was used in several large epidemiological studies of older adults.[12, 18, 19, 92]

*Cognition and Disability*

Several authors have described a relationship between low scores on cognitive screening measures and increased risk of ADL and/or IADL disability.[18, 19, 92] Gill and colleagues[19] determined that nondisabled community dwelling older adults who performed poorly on the MMSE were more likely to report ADL dependence within 3 years. Those who scored less than 23 and between 23 and 25 were 2 and 1.5 times, respectively, more likely to develop ADL dependence than those who scored between 28 and 30. Greiner et al[18] also determined that subjects with low-normal scores on the MMSE (scores of 24-27) at baseline had an increased risk of developing ADL disability in 2 years compared to subjects who scored within the high-normal range on the MMSE (scores of 28-30).

Njegovan et al[92] compared scores across individuals on the Modified Mini-Mental State Examination[93] (3MS) based on their level of independence in 14 IADL and ADL tasks. Significant decline in 3MS scores was reported for subjects who developed disability over 5 years compared with those who remained independent. The IADL tasks of doing housework, shopping, ability to use transportation, and meal preparation demonstrated the most dependence with smaller declines in 3MS scores. The ADL tasks of bathing, walking, toileting, and transferring demonstrated more dependence with smaller declines in cognition. Despite some overlap between specific tasks, dependency in IADL tasks generally occurred at higher 3MS scores (higher cognition) than for ADL tasks and also occurred with less decline in scores from baseline, supporting a hierarchy among daily living tasks based on cognitive function.

*Cognition and Falls Risk*

In a one year prospective study of risk factors for falling in community dwelling older adults age 75 years and older, Tinetti and colleagues[12] report that individuals with cognitive impairment as assessed by the SPMSQ had 5 times more risk for falling than those without cognitive impairment. The risk for falling in subjects with cognitive impairment was higher than for those with lower extremity disability (odds ratio 3.8) and balance and gait abnormalities (odds ratio 1.9).

*Cognition and Physical Function*

Evidence also supports a predictive relationship between MMSE scores and physical function. Raji et al[94] assessed lower body physical function in a group of Mexican Americans aged 65 years and older using the timed 8-ft walk, rising from a chair 5 times, and a sequence of progressive standing balance tasks. A summary score for the three physical performance measures was created and used as the outcome variable. Baseline MMSE score was used as a continuous measure in a multivariate regression analysis and found to be an independent predictor of lower body physical function at a 2 year follow-up.

*Use of Cognitive Screening Measures*

The research discussed above provides support for as association between cognitive screening measures and disability, falls, and physical function. Among daily living tasks, cognition appears to have a stronger relationship with more complex IADL tasks than with basic ADL tasks. However, these global measures do not discriminate well between variations in "normal" cognitive function or age-related cognitive changes. Much of the research examining cognitive function compares individuals with cognitive impairment to those without. It may be assumed that some of the individuals with cognitive impairment may be experiencing deficits associated with pathological processes as opposed to age-related cognitive changes. Use of these global measures (MMSE, SPMSQ) does not permit exploration of the relationship between age-related changes in specific aspects of cognition and physical function and disability.

Relationship of attention and processing speed to physical function, disability, and falls risk

Research to explore the relationship between specific aspects of cognition and physical function and disability typically use batteries of standardized psychometric measures. Researchers can examine the relationships of different aspects of cognition to physical function by using a battery of measures testing various aspects of cognition and examining the relationships between aspects of cognition and physical function, disability, and falls. Several researchers reported that the aspects of cognition most strongly related to physical function are processing speed and attention.[95]

*Attention and processing speed and physical function*

Binder and colleagues[95] investigated the relationship between psychometric test performance in various aspects of cognition and performance on a modified Physical Performance Test (m-PPT) in community dwelling older adults aged 75 and older. The Physical Performance Test[47] was modified to include 9 items that emphasized gross motor and mobility function. The psychometric test battery included measures of memory, language, attention, and processing speed. Principal components analysis of the psychometric measures revealed two factors; tests of processing speed and attention (Trailmaking Test Parts A & B, Letter and Figure Cancellation) and tests of global cognition, and memory (Short Blessed Test, Associate learning and 20-minute delayed recall of word pairs). Pearson correlation analyses of individual psychometric tests and m-PPT scores revealed that measures of attention and processing speed were significantly correlated with m-PPT score. Regression analysis revealed that only the factor representing attention and processing speed was a significant independent predictor of m-PPT score.

Persad et al[38] examined the relationships of performance on psychometric tests of different aspects of cognition and performance on a complex obstacle avoidance task during walking. The complex obstacle avoidance task required dual-task processing of visual stimuli and the walking obstacle avoidance task.[96] The authors chose tests measuring aspects of attention, problem solving, spatial discrimination, memory, and anxiety for the psychometric test battery based on the nature of the task and known age-related declines in attention and visual-spatial ability. Poorer performance on measures of problem solving, attention, and anxiety were found to be predictive of decreased success on the obstacle avoidance task.

*Attention and processing speed and disability*

Carlson et al[97] examined the relationship between psychometric test performance of different aspects of cognition and a small set of IADL and mobility ADL as part of the Women's Health and Aging II Study of high functioning older women 70-80 years old. Inclusion criteria for this study included scores of greater than 23 on the MMSE and reports of no difficulty with daily living tasks. Carlson and colleagues[97] administered a battery of psychometric tests of attention, verbal memory, and spatial memory. Cognitive factors were derived through factor analysis and entered into hierarchical regression analyses to examine whether attentional abilities were associated with IADL and mobility ADL task performance. IADL and mobility ADL measures included timed performance-based assessment of locking a door, dialing a phone, plugging a cord into an outlet, walking 4 meters, climbing up and down 13 stairs, and putting on a pair of pants. Hierarchical regression on IADL task performance revealed that the attention factor was the strongest significant predictor of performance, accounting for almost 7% of the variance. The Trail Making Test Part B was the only individual measure that was a significant predictor of IADL performance. The cognitive factors of attention and spatial memory were predictors of ADL task performance. However, inclusion of all cognitive factors in a regression model for ADL performance accounted for only 10.5% of the variance compared with 22% for IADL performance, after controlling for age, education, race and number of chronic diseases.

*Attention and processing speed and falls risk*

Nevitt et al[98] conducted a prospective study of risk factors for injurious falls in older adults. Demographic characteristics, fall history, the MMSE, visual acuity, simple motor reaction time and the Trail Making Test Part B (TMTB, measure of attention and processing speed) were examined for their ability to predict injurious falls over a 12 month period. Being Caucasian, having had a prior fall with a fracture, and needing longer than 180 seconds to complete the TMTB were independent predictors of injurious falls. Simple motor reaction time was not predictive of injurious falls. When MMSE score was substituted for TMTB time in another model, the MMSE was not an independent predictor of fall related injury.

<u>What we know about the relationship of cognition to physical function, disability, and falls risk</u>

The research discussed above provides support for an association and predictive relationship between cognition, specifically attention and processing speed, and physical function, disability, and falls risk. In contrast, measures of memory were not associated with aspects of physical function and disability. The significant relationship between attention and processing speed and physical function and disability appears to hold true for high functioning older persons as well as for those with a history of falls. A possible explanation for this may be that many IADL and mobility tasks involve a sequence of steps. Poor performance on these tasks may be more related to being distracted during the task or improper sequencing of steps than to forgetting how to do these typically well rehearsed tasks.

What we don't know about the relationship of cognition to various aspects of physical function, and disability

What is not clear from the current literature is the nature of the relationship of attention and processing speed to balance, physical function, and a broader range of IADL and ADL tasks. Daily living tasks require adequate balance abilities for safe and independent function. We may hypothesize that the relationship between processing speed and disability may be due to the relationship of processing speed to coordination of balance responses. Slowed processing speed may result in balance deficits, which may contribute to difficulty with mobility and daily tasks. Carlson et al[97] only examined the role of attention in measured performance of a small subset of IADL and mobility ADL tasks. A more extensive investigation of IADL, ADL, and mobility tasks and the direct and indirect relationships between attention and processing speed, physical function, and disability is needed to better understand the intricacies of this relationship and its impact on daily function in older adults.

## REFERENCES


1. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med.* 1994;38:1-14.

2. Nagi SZ. An epidemiology of disability among adults in the United States. *Milbank Mem Fund Q.* 1976;54:439-467.

3. Mor V, Wilcox V, Rakowski W, Hiris J. Functional transitions among the elderly: patterns, predictors, and related hospital use. *Am J Pub Health.* 1994;84:1274-1280.

4. Reuben DB, Rubenstein LV, Hirsch SH, Hays RD. Value of functional status as a predictor of mortality: results of a prospective study. *Am J Med.* 1992;93:663-669.

5. Pope AM, Tarlov AR. *Disability in America: Toward a National Agenda for Prevention. Executive Summary*. Washington, DC: Institute of Medicine, National Academy Press; 1991.

6. Guralnik JM, Simonsick EM, Ferucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol: Med Sci.* 1994;49:M85-94.

7. Guralnik JM, Ferucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *New Engl J Med.* 1995;332:556-561.

8. Guralnik JM, Ferucci L, Pieper C, et al. Lower extremity function and subsequent disability: Consistency across studies, predictive models, and value of gait speed alone compared with the Short Physical Performance Battery. *J Gerontol: Med Sci.* 2000;55A(4):M221-M231.

9. Gill TM, Williams CS, Tinetti ME. Assessing risk for the onset of functional dependence among older adults: the role of physical performance. *J Am Geriatr Soc.* 1995;43:603-609.

10. Gill TM, Williams CS, Mendes de Leon CF, Tinetti ME. The role of change in physical performance in determining risk for dependence in Activities of Daily Living among nondisabled community-living elderly persons. *J Clin Epidemiol.* 1997;50(7):765-772.

11. Shumway-Cook A, Woollacott MH. Motor Control: Theory and Practical Applications. Vol Second Edition. Baltimore, MD: Williams and Wilkens; 2001:400.

12. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med.* 1988;319:1701-1707.

13. Lipsitz LA, Jonsson PV, Kelley MM, Koestner JS. Causes and correlates of recurrent falls in ambulatory frail elderly. *J Gerontol: Med Sci.* 1991;46(4):M114-M122.

14. Tinetti ME, Williams CS. The effect of falls and fall injuries on functioning in community-dwelling older persons. *J Gerontol: Med Sci.* 1998;51A:M112-119.

15. Langlois JA, Norton R, Campbell AJ, Leveille S. Characteristics and behaviours associated with difficulty in performing activities of daily living among older New Zealand women. *Disability Rehabil.* 1999;21(8):365-371.

16. Moritz DJ, Kasl SV, Berkman LF. Cognitive functioning and the incidence of limitations in activities of daily living in an elderly community sample. *Am J Epidemiol.* 1995;141:41-49.

17. Scherr PA, Albert MS, Funkenstein HH, et al. Correlates of cognitive function in an elderly community population. *Am J Epidemiol.* 1988;128:1084-1101.

18. Greiner PA, Snowden DA, Schmitt FA. The loss of independence in activities of daily living: the role of low normal cognitive function in elderly nuns. *Am J Public Health.* 1996;86(1):62-66.

19. Gill TM, Williams CS, Richardson ED, Tinetti ME. Impairments in physical performance and cognitive status as predisposing factors for functional dependence among nondisabled older persons. *J Gerontol: Med Sci.* 1996;51A(6):M283-M288.

20. Salthouse TA. Aging and measures of processing speed. *Biol Psychol.* 2000;54:35-54.

21. Earles JL, Salthouse TA. Interrelations of age, health, and speed. *J Gerontol: Psychol Sci.* 1995;50B(1):P33-P41.

22. Allen PA, Weber TA, Madden DJ. Adult age differences in attention: filtering or selection? *J Gerontol: Psychol Sci.* 1994;49:213-222.

23. Jordan TC, Rabbitt PMA. Response times to stimuli of increasing complexity as a function of aging. *Br J Psychol.* 1977;68:189-201.

24. Posner MI, Petersen SE. The attention system of the human brain. *Ann Rev Neurosci.* 1990;13:25-42.

25. Hasher L, Zacks RT, May CP. Inhibitory control, circadian arousal, and age. In: Gopher D, Koriat A, eds. Cambridge, MA: The MIT Press; 1999:653-675.

26. Cerella J. Information-processing rates in the elderly. *Psychol Bull.* 1985;98:67-83.

27. Salthouse TA. The role of processing resources in cognitive aging. In: Howe ML, Brainerd CJ, eds. *Cognitive Development in Adulthood*. New York: Springer-Verlag; 1988:185-239.

28. Light KE, Spirduso WW. Effects of adult aging on the movement complexity factor of response programming. *J Gerontol.* 1990;45:107-109.

29. Salthouse TA. *Mechanisms of age-cognition relations in adulthood*. Hillsdale, NJ: Erlbaum; 1992.

30. Salthouse TA. The processing-speed theory of adult age differences in cognition. *Psychol Rev.* 1996;103(3):403-428.

31. Salthouse TA, Babcock RL. Decomposing adult age differences in working memory. *Dev Psychol.* 1991;27:763-776.

32. Connelly SL, Hasher L, Zacks RT. Age and reading: the impact of distraction. *Psychol Aging.* 1991;6:533-541.

33. Plude DJ, Doussard-Roosevelt JA. Aging, selective attention and feature integration. *Psychol Aging.* 1989;4:98-105.

34. Plude DJ, Hoyer WJ. Adult age differences in visual search as a function of stimulus mapping and information load. *J Gerontol.* 1981;36:598-604.

35. Madden DJ, Pierce TW, Allen PA. Adult age differences in the use of distractor homogeneity during visual search. *Psychol Aging.* 1996;11(3):454-474.

36. Golden C. *Stroop Color and Word Test Manual*. Chicago, IL: Shoelting Company; 1978.

37. West R, Alain C. Age-related decline in inhibitory control contributes to the increased Stroop effect observed in older adults. *Psychophysiol.* 2000;37(2):179-189.

38. Persad CC, Giordani B, Chen HC, et al. Neuropsychological predictors of complex obstacle avoidance in healthy older adults. *J Gerontol Psych Sci.* 1995;50B(5):P272-277.

39. Smith A. *Symbol Digit Modalities Test Manual*. Los Angeles, CA: Western Psychological Services; 1982.

40. Reitan RM. Validity of the Trailmaking test as an indicator of organic brain damage. *Percept Mot Skills.* 1958;8:271-276.

41. Emmerson RY, Dustman RE, Shearer DE, Turner CW. P3 latency and symbol digit performance correlations in aging. *Exp Aging Res.* 1990;15:151-150.

42. Spreen O, Strauss E. *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press; 1998.

43. Snow WG, Tierney MC, Zorzitto ML, Fisher RH, Reid DW. One-year test-retest reliability of selected neuropsychological tests in older adults. *J Clin Exp Neuropsychol.* 1988;10:60 (abstract).

44. Jylha M, Guralnik JM, Balfour J, Fried LP. Walking difficulty, walking speed, and age as predictors of self-rated health: The Women's Health and Aging Study. *J Gerontol: Med Sci.* 2001;56A(10):M609-M617.

45. Onder G, Penninx B, Lapuerta P, et al. Change in physical performance over time in older women: The Women's Health and Aging Study. *J Gerontol: Med Sci.* 2002;57A(5):M289-M293.

46. Seeman TE, Charpentier PA, Berkman LF, et al. Predicting changes in physical performance in a high-functioning elderly cohort: MacArthur Studies of Successful Aging. *J Gerontol: Med Sci.* 1994;49(3):M97-108.

47. Reuben DB, Siu AL. An objective measure of physical function of elderly outpatients: the Physical Performance Test. *J Am Geriatr Soc.* 1990;38:1105-1112.

48. Katz S, Ford A, Moskowitz R, Jackson B, Jaffe M. Studies of illness in the aged. The Index of ADL: a standardized measure of biological and psychological funtion. *JAMA.* 1963;185(12):914-919.

49. Rosow I, Breslau N. A Guttman health scale for the aged. *J Gerontol.* 1966;21:556-559.

50. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc.* 1986;34:119-126.

51. VanSwearingen JM, Paschal KA, Bonino P, Chen TW. Assessing recurrent fall risk of community-dwelling, frail older veterans using specific tests of mobility and the Physical Performance Test of Function. *J Gerontol: Med Sci.* 1998;53A(6):M457-M464.

52. Guralnik JM, Fried LP, Simonsick EM, Kasper JD, Lafferty ME. *The Women's Health and Aging Study: Health and social characteristics of older women with disability (NIH Publication No. 95-4009)*. Bethesda, MD: National Institute on Aging; 1995.

53. Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and Gait Speeds. *Phys Ther.* 2002;82:128-137.

54. Ostrosky KM, VanSwearingen JM, Burdett RG, Gee Z. A comparison of gait characteristics in young and old subjects. *Phys Ther.* 1994;74(7):637-646.

55. Cress ME, Schechtman KB, Mulrow CD, Fiatarone MA, Gerety MB, Buchner DM. Relationship between physical performance and self-perceived physical function. *J Am Geriatr Soc.* 1995;43:93-101.

56. Fried LP, Bandeen-Roche K, Chaves PHM, Johnson BA. Preclinical mobility disability predicts incident mobility disability in older women. *J Gerontol: Med Sci.* 2000;55A(1):M43-M52.

57. Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. *Age Ageing.* 1997;26:15-19.

58. Fransen M, Crosbie J, Edmonds J. Reliability of gait measurements in people with osteoarthritis of the knee. *Phys Ther.* 1997;77(9):944-953.

59. Bergner M, Babbitt RA, Carter WB, et al. The sickness impact profile development and final revision of a health status measure. *Med Care.* 1981;19:787-805.

60. Berg K, Dauphinee S, Williams JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. *Physiother Can.* 1989;41(6):304-311.

61. Nevitt MC, Cummings SR, Kidd S, Black D. Risk factors for recurrent non-syncopal falls: a prospective study. *JAMA.* 1989;261:2663-2668.

62. Winograd CH, Lemsky CM, Nevitt MC, et al. Development of a physical performance and mobility examination. *J Am Geriatr Soc.* 1994;42:743-749.

63. Berg KO, Maki BE, Williams JI, Holliday PJ, Wood-Dauphinee SL. Clinical and laboratory measures of postural balance in an elderly population. *Arch Phys Med Rehabil.* 1992;73:1073-1080.

64. Schenkman M, Cutson TM, Kuchibhatla M, Chandler J, Pieper C. Reliability of impairment and physical performance measures for persons with Parkinson's Disease. *Phys Ther.* 1997;77(1):19-27.

65. Buchner DM, Hornbrook MC, Kutner NG, et al. Development of the common data base for the FICSIT trials. *J Am Geriatr Soc.* 1993;41:297-308.

66. Rossiter-Fornoff JE, Wolf SL, Wolfson LI, Buchner DM. A cross-sectional validation study of the FICSIT common data base static balance measures. *J Gerontol: Med Sci.* 1995;50:M291-M297.

67. Jette AM. How measurement techniques influence estimates of disability in older populations. *Soc Sci Med.* 1994;38(7):937-942.

68. Gill TM, Robison JT, Tinetti ME. Difficulty and dependence: two components of the disability continuum among community-living older persons. *Ann Intern Med.* 1998;128(2):96-101.

69. Crawford SL, Jette AM, Tennstedt SL. Test-retest reliability of self-reported disability measures in older adults. *J Am Geriatr Soc.* 1997;45:338-341.

70. Keller BK, Potter JF. Predictors of mortality in outpatient geriatric evaluation and management clinic patients. *J Gerontol: Med Sci.* 1994;49(6):M246-M251.

71. Fillenbaum GG. Screening the elderly. A brief instrumental activities of daily living measure. *J Am Geriatr Soc.* 1985;33(10):698-706.

72. Lawton MP, Brody EM. Assessement of older people: self-maintaining and instrumental activities of daily living. *Gerontologist.* 1969;9:179-186.

73. Jette AM. The Functional Status Index: reliability and validity of a self-report functional disability measure. *J Rheumatol.* 1987;(suppl 15)(14):15-19.

74. Jette AM, Harris BA, Cleary PD, Campion EW. Functional recovery after hip fracture. *Arch Phys Med Rehabil.* 1987;68:735-740.

75. Ware JE, Sherbourne CD. The MOS 36-item short form health survey (SF-36). I. Conceptual framework and item selection. *Med Care.* 1992;30:473-483.

76. Andresen EM, Bowley N, Rothenberg BM, Panzer R, Katz P. Test-retest performance of a mailed version of the Medical Outcomes Study 36-Item Short-Form Health Survey among older adults. *Med Care.* 1996;34(12):1165-1170.

77. Brazier JE, Walters SJ, Nicholl JP, Kohler B. Using the SF-36 and Euroqol on an elderly population. *Qual Life Res.* 1996;5:195-204.

78. Lyons RA, Perry HM, Littlepage BN. Evidence for the validity of the Short-Form 36 Questionnaire (SF-36) in an elderly population. *Age Ageing.* 1994;23:182-184.

79. Brazier JE, Harper R, Jones NM, et al. Validating the SF-36 health survey questionnaire: new outcome measure for primary care. *BMJ.* 1992;305:160-164.

80. Wolinsky FD, Wan GJ, Tierney WM. Changes in the SF-36 in 12 months in a clinical sample of disadvantaged older adults. *Med Care.* 1998;36(11):1589-1598.

81. Parker SG, Peet SM, Jagger C, Farhan M, Castleden CM. Measuring health status in older patients. The SF-36 in practice. *Age Ageing.* 1998;27:13-18.

82. McHorney CA. Measuring and monitoring general health status in elderly persons: practical and methodological issues in using the SF-36 Health Survey. *Gerontologist.* 1996;36(5):571-583.

83. Hayes V, Morris J, Wolfe C, Morgan M. The SF-36 Health Survey Questionnaire: is it suitable for use with older adults? *Age Ageing.* 1995;24:120-125.

84. Andresen EM, Patrick DL, Carter WB, Malmgren JA. Comparing the performance of health status measures for healthy older adults. *J Am Geriatr Soc.* 1995;43:1030-1034.

85. Rathouz PJ, Kasper JD, Zeger SL, et al. Short-term consistency in self-reported physical functioning among elderly women. *Am J Epidemiol.* 1998;147(8):764-773.

86. Fried LP, Bandeen-Roche K, Williamson JD, et al. Functional decline in older adults: expanding methods of ascertainment. *J Gerontol: Med Sci.* 1996;51A(5):M206-M214.

87. Fried LP, Young Y, Rubin G, Bandeen-Roche K. Self-reported preclinical disability identifies older women with early declines in performance and early disease. *J Clin Epidemiol.* 2001;54:889-901.

88. Fried LP, Tangen CM, Walston J, et al. Frailty on older adults: evidence for a phenotype. *J Gerontol: Med Sci.* 2001;56A(3):M146-M156.

89. Schretlen D, Pearlson GD, Anthony JC, et al. Elucidating the contributions of processing speed, executive ability, and frontal lobe volume to normal age-related differences in fluid intelligence. *J Int Neuropsychol Soc.* 2000;6:52-61.

90. Folstein MF, Folstein SE, McHugh PR. Mini-Mental State: A practical method for grading the cognitive state of the patient for the clinician. *Journal of Psychiatric Research.* 1975;12:189-198.

91. Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficits in elderly patients. *J Am Geriatr Soc.* 1975;23:433-441.

92. Njegovan V, Man-Son-Hing M, Mitchell SL, Molnar. The hierarchy of functional loss associated with cognitive decline in older persons. *J Gerontol: Med Sci.* 2001;56A(10):M638-M643.

93. Teng EL, Chue HC. The modified mini-mental state (3MS) examination. *J Clin Psychiatr.* 1987;48:314-318.

94. Raji MA, Ostir GV, Markides KS, Goodwin JS. The interaction of cognitive and emotional status on subsequent physical functioning in older Mexican Americans: findings from the Hispanic Established Population for the Epidemiological Study of the Elderly. *J Gerontol: Med Sci.* 2002;57A(10):M678-M682.

95. Binder EF, Storandt M, Birge SJ. The relation between psychometric test performance and physical performance in older adults. *J Gerontol: Med Sci.* 1999;54A(8):M428-M432.

96. Chen HC, Schultz AB, Ashton-Miller JA, Giordani B, Alexander NB, Guire KE. Stepping over obstacles: dividing attention impairs performance of old more than young adults. *Journal of Gerontology: Medical Sciences.* 1996;51A(3):M116-M122.

97. Carlson MC, Fried LP, Xue QL, Bandeen-Roche K, Zeger SL, Brandt J. Association between executive attention and physical functional performance in community-dwelling older women. *J Gerontol: Soc Sci.* 1999;54B(5):S262-S270.

98. Nevitt MC, Cummings SR, Hudes ES. Risk factors for injurious falls: a prospective study. *J Gerontol: Med Sci.* 1991;46(5):M164-M170.

# APPENDIX B:

# PROTOCOL AND TESTING FORMS

Participant # ________ Date___________ Tester__________

**HEALTH STATUS QUESTIONS**

1) Do you have ANY pain today? If YES, where?

2) Have you had any signs of problems with your blood pressure today (such as dizziness or headache)?

3) Have you had any signs of problems with your blood sugar today?

4) Have you had ANY surgical or medical procedures in the past 6 months? If yes, what type?

5) Do you have any concerns that you may not be able to participate in the testing today?

Participant # ___________________________ Date ___/___/____ Tester __________________

**CES-D**

Here is a list of the ways you might have felt or behaved. Please indicate how often you have felt this way during the past week.

**During the past week……**

| | | **Rarely/NONE of the Time (less than 1 day)** | **Some/LITTLE of the Time (1-2 days)** | **Occasionally/ MODERATE amount of Time (3-4 days)** | **Most/ALL of the Time (5-7 days)** |
|---|---|---|---|---|---|
| 1 | I was bothered by things that usually don't bother me. | | | | |
| 2 | I did not feel like eating; my appetite was poor. | | | | |
| 3 | I felt that I could not shake off the blues even with help from my family or friends. | | | | |
| 4 | I felt that I was just as good as other people. | | | | |
| 5 | I had trouble keeping my mind on what I was doing. | | | | |
| 6 | I felt depressed. | | | | |
| 7 | I felt like everything I did was an effort. | | | | |
| 8 | I felt hopeful about the future. | | | | |

Participant # ________________________   Date ___/___/____   Tester ________________

| | | **Rarely/NONE of the Time (less than 1 day)** | **Some/LITTLE of the Time (1-2 days)** | **Occasionally/ MODERATE amount of Time (3-4 days)** | **Most/ALL of the Time (5-7 days)** |
|---|---|---|---|---|---|
| 9 | I thought my life had been a failure. | | | | |
| 10 | I felt fearful. | | | | |
| 11 | My sleep was restless. | | | | |
| 12 | I was happy. | | | | |
| 13 | I talked less than usual. | | | | |
| 14 | I felt lonely. | | | | |
| 15 | People were unfriendly. | | | | |
| 16 | I enjoyed life. | | | | |
| 17 | I had crying spells. | | | | |
| 18 | I felt sad. | | | | |
| 19 | I felt that people disliked me. | | | | |
| 20 | I could not "get going." | | | | |

Score __________________

Participant__________________________Date__________ Tester_______________________

## KATZ ADL SCALE

These questions are about how you usually take care of yourself. By usually, I mean half the time or more during the week. Please answer each item below as it applies to you.

| | **Without Help** | **With some help** | **Unable** | **No Answer** |
|---|---|---|---|---|
| | (2) | (1) | (0) | |
| 1. During the past week, did you usually get in and out of bed or a chair | | | | |
| 2. During the past week, did you usually dress and undress yourself | | | | |
| 3. During the past week, did you take a sponge bath, tub bath or shower | | | | |
| 4. During the past week, did you eat | | | | |
| 5. During the past week, did you usually use the toilet for both bowel and bladder functions. | | | | |

TOTAL SCORE: (0-10)__________________________

## PROTOCOL:  SYMBOL DIGIT MODALITIES TEST

Description: This test measures visual attention and how quickly you process information

Administration:  Place the test form in front of the examinee and read the following verbatim.

Resident Instructions: **"Please look at these boxes at the top of the page.  You can see that each box in the upper row has a little mark in it.  Now look at the boxes in the row just underneath the marks.  Each of the marks in the top row is different, and under each mark in the bottom row is a different number."**

**"Now look at the next line of boxes** ***(examiner points to the line of boxes)*** **just under the top two rows.  Notice that the boxes on the top have marks, but the boxes underneath are empty.  I want you to tell me what number to fill in each empty box according to the way they are paired in the key at the top of the page."**

**"For example, if you look at the first mark, and then at the key, you will see that the number 1 goes in the first box.  Now, what number should go in the second box?  That's right.  What number goes in the third box? (Number 2)  Two, right.  That is the idea."**

**"You are to tell me which number to write in each of the empty boxes according to the key.  Now for practice, let's do the rest of the boxes on the top line until we come to the double line."**

Check to see that nature of the test is clearly understood before proceeding.  If not, repeat directions with further examples.

**Now, when I say "Go" tell me which numbers to fill in like you have been doing until I say "Stop".  When you come to the end of the first line, go quickly to the next line without stopping, and so on.  Do not skip any boxes and work as quickly as you can. Ready?  Go.**

Time: 90 seconds and stop.

SCORING:  the number of correct substitutions in each 90 second interval.  Do not include those of the practice period.

KEY

| ( | ⨪ | ⊢ | Γ | ⊣ | > | + | ) | ∸ |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

| ( | ⊣ | ⨪ | ( | ⊢ | > | ⨪ | Γ | ( | > | ⨪ | ( | > | ( | ⨪ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |

| Γ | > | ( | ⨪ | ⊣ | > | ⊢ | Γ | ( | ⨪ | > | ∸ | Γ | ⊢ | ) |
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| | | | | | | | | | | | | | | |

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| | | | | | | | | | | | | | | |

**PROTOCOL: TRAILS PART B**

Equipment: Trails Part B paper test, pencil.

Directions: Have the resident seated at a table. Hand him/her the SAMPLE sheet for practice.

Instruct the participant: *"On this page are some numbers and letters. Begin at number 1 draw a line from 1 to A, A to 2, 2 to B, B to 3 and so on in order until you reach the end. Remember, first you have a number, then a letter, then a number and so on. Draw the lines as fast as you can. Ready? Begin!"*

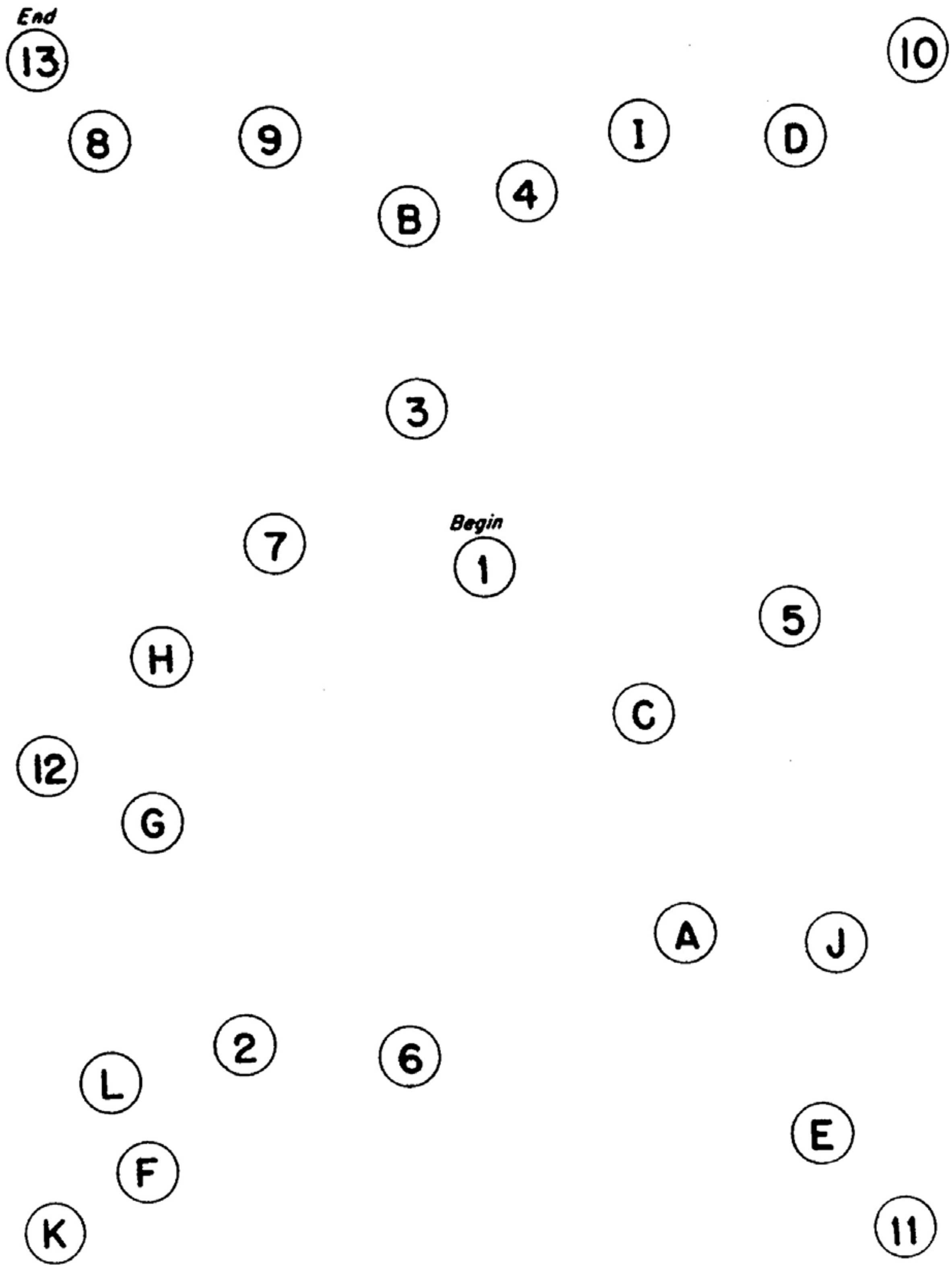
Review the sample test, and make sure the resident did it correctly. If there were errors, point them out and make sure the resident understands. Common mistakes include skipping a circle or starting at the wrong point.
**If the subject was NOT able to complete the practice test, stop the test at this point

NOW HAND THE SUBJECT THE TEST SHEET. Instruct the participant: *"On this page are some numbers and letters. Begin at number 1 draw a line from 1 to A, A to 2, 2 to B, B to 3 and so on in order until you reach the end. Remember, first you have a number, then a letter, then a number and so on. Draw the lines as fast as you can. Ready? Begin!"*

You need to watch the subject as he or she performs the test, and watch for mistakes. If a mistake is made, point it out, and have him correct it and continue the test from that point. DO NOT stop timing.

Scoring: Scores are reported as the time required to complete the test.
If after 5 minutes the resident has not completed the test, stop the test.

Record the time on the scoring sheet.


End
13
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**PROTOCOL: PHYSICAL PERFORMANCE TEST (PPT)**

Description: **"This test measures your ability to perform common daily tasks such as writing and walking. I will be timing you as you complete each item on the test"**

Tester notes: Score ALL items (except 6 and 7) to the nearest **.5** seconds. Residents are given up to 2 chances to complete each item. They may use assistive devices for items 6 and 7.

Resident Instructions:

1. Sentence. Resident seated at table. Hand the resident a paper and pencil.
   **"When I say, "go", I want you to write the sentence "whales live in the blue ocean. Are you ready? Go".** Time from the word "go" until the pen is lifted from the paper at the end of the sentence. Spelling and punctuation do not matter. All words must be legible.

2. Simulated eating. Resident seated. Place five kidney beans in a bowl 5 inches from the edge of the table. Place a coffee can on the table at the patient's non-dominant side. Place a teaspoon in the resident's dominant hand.
   "**When I say "go" I want you to place the beans one at a time into the can. Are you ready? Go".** The resident can move the can closer to the bowl after the "go" if they wish. Time from the word "go" until you hear the last bean hitting the bottom of the can.

3. Book on shelf. Resident stands in front of a shelf that is about ear level. Place a Physician's Desk Reference or other heavy book on the table in front of the resident. If no shelf is available, hold your hands in front of the resident at a height approximately at the top of their ears, and have them lift the book and place it on your hands.
   **"When I say, "go", I want you to place the book on the shelf/ my hands. Are you ready? Go"**. . Time from the command "go" until the book is placed on the shelf/your hands.

4. Jacket. Resident standing. If the resident has on a jacket or cardigan, ask him to remove it. If not, hand the resident a lab coat or cardigan**.**
   **"When I say, "go", I want you to put on the coat completely, so that it is straight on your shoulders and then remove the coat completely. Watch me as I demonstrate"**. Demonstrate. "**Are you ready? Go".** Time from the command "go" until the coat has been removed completely.

5. Pick up penny. Place a penny on the floor approximately 12 inches in front of the resident's dominant foot.
   **"When I say, "go", I want you to pick up the penny from the floor and stand back up. Watch me as I demonstrate**". Demonstrate. **" Are you ready? Go".** Time from the command "go" until the resident is standing erect with the penny in hand.

6. <u>360 turn.</u> Resident standing. **"When I say, "go" I want you to turn all the way around until you are facing me again. Turn at your comfortable pace. You can choose the direction you would like to turn. Watch me as I demonstrate".** Demonstrate the turn. **"Are you ready? Go".** Do two trials and evaluate and score according to the criteria on the PPT score sheet. In addition, record the TIMES on the score sheet. Refer to the 360 Turn Protocol.

*7.* <u>50 foot walk</u>. The resident will walk a 50-foot walking course (25 feet out and back). *(At this station you will first do the PPT test and then you will do the self-selected and speeded 25-foot walk. Refer to 25 Foot Walk Protocol.)*
**"We will do several tests here. First when I say go, I want you to walk to that tape mark, turn around and come back. I want you to walk at your usual comfortable pace. This is not a race. Watch while I demonstrate".** Demonstrate the task. **"Are you ready? Go".** Time from the command "go" until the resident crosses the starting line on the way back.

**TIMED 360° TURN**

**Description:** Measures the time for a person to make a 360 degree turn to the right and to the left.

**Equipment:** Stop watch.

**Administration:**

1. The subject stands with arms at his/her side and feet comfortable apart and pointing straight ahead.

2. Instruct the subject:

   **"When I say go, I want you to turn to your right at your normal pace making sure to go I a complete circle and make sure you end up with your feet facing straight ahead."**

3. Ask the subject to turn to the right as a practice and observe to ensure that he/she takes steps (no pivots or slides) and that he/she ends up facing straight ahead.

4. Then instruct the subject:

   **"I want you to start when I say 'go'. At your normal pace, turn to the right. Ready, go."**

5. No attempt is made to keep the feet apart at the end, although they should be facing forward. If one or both of the feet end up greater than 45 degrees rotated to the left or right, redo the trial.

6. Record the time to complete the turn and the number of steps taken by the subject.

7. This test is repeated with the subject initiating the turn toward the left.

**PROTOCOL: 10-METER WALK TEST**

Description: The 10 meter walk test is a measure of self-selected and “speeded” walking speed.

Tester Notes: The participant should be wearing flat shoes or shoes with a heel less than 1/2 inch. If the subject usually walks with an assistive device, they should use it for this test.

1. Measure out 10 meters on the floor and mark the start and finish line with masking tape. These are the start and end lines.
2. Measure and mark 1 meter before and after start and finish lines for 10 meters.
3. Have the participant start by standing at the line 1 meter before the start line.
4. Instruct the participant to walk to the farthest line (the line 1 meter past the “finish” line).
5. Walk with the participant (slightly behind and to the side). Begin timing when the participant's foot crosses the start line and stop when the foot first crosses the finish line.
6. Record (in seconds) the time in hundredths of a second
7. Complete two trials for each speed
8. Calculate the average self-selected and fast walking speeds

Instructions:

1. Comfortable Pace (2 trials). **"I want you to walk from here to ______** (give destination past the finish line) **at your normal comfortable pace when I say, "go". Keep walking until I say stop. Ready, go".**

   Be sure to say **"Ready, go"** in a neutral tone of voice so that the subject does not feel like it is a race.

2. Fast Pace (2 trials). **"I want you to walk from here to ______** (give destination past the finish line) **as fast as possible safely. When I say, "go". Keep walking until I say stop. Ready, “go".**

**SF-36v2 Health Survey**

**INSTRUCTIONS:** This survey asks you for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Answer every question by marking the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can. *Thank you for completing this survey!*

1. In general, would you say your health is: (circle one)

Excellent....................................................1

Very good..................................................2

Good..........................................................3

Fair............................................................4

Poor...........................................................5

2. **Compared to one year ago**, how would you rate your health in general **now**? (circle one)

Much better now than one year ago................1

Somewhat better now than one year ago.........2

About the same as one year ago......................3

Somewhat worse now than one year ago.........4

Much worse now than one year ago................5

3. The following items are about activities you might do during a typical day. Does **your health now limit you** in these activities? If so, how much?

(Check the appropriate box)

| ACTIVITIES | Yes, Limited A Lot | Yes, Limited A Little | No, Not Limited At All |
|---|---|---|---|
| a. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports | | | |
| b. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf | | | |
| c. Lifting or carrying groceries | | | |
| d. Climbing several flights of stairs | | | |
| e. Climbing one flight of stairs | | | |
| f. Bending, kneeling, or stooping | | | |
| g. Walking more than a mile | | | |
| h. Walking several hundred yards | | | |
| i. Walking one hundred yards | | | |
| j. Bathing or dressing yourself | | | |

4. During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of your physical health**?

(Check the appropriate box)

| | **All of the time** | **Most of the time** | **Some of the time** | **A little of the time** | **None of the time** |
|---|---|---|---|---|---|
| a. Cut down the amount of time you spent on work or other activities | | | | | |
| b. Accomplished less than you would like | | | | | |
| c. Were limited in the kind of work or other activities | | | | | |
| d. Had difficulty performing the work or other activities (for example, it took extra effort) | | | | | |

**5.** During the **<u>past 4 weeks</u>**, have you had any of the following problems with your work or other regular daily activities **<u>as a result of any emotional problems</u>** (such as feeling depressed or anxious).

(Check the appropriate box)

| | **All of the time** | **Most of the time** | **Some of the time** | **A little of the time** | **None of the time** |
|---|---|---|---|---|---|
| a. Cut down on the amount of time you spent on work or other activities | | | | | |
| b. <u>Accomplished less</u> than you would like | | | | | |
| c. Didn't do work or other activities as carefully as usual | | | | | |

**6.** During the **past 4 weeks**, to what extent have your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups? Circle your response.

| Not at all | Slightly | Moderately | Quite a Bit | Extremely |
|---|---|---|---|---|

**7.** How much **bodily** pain have you had during the **past 4 weeks**? Circle your response.

| None | Very mild | Mild | Moderate | Severe | Very Severe |
|---|---|---|---|---|---|

**8.** During the **past 4 weeks**, how much did **pain** interfere with your normal work (including both work outside the home and housework)?  Circle your response.

| Not at all | Slightly | Moderately | Quite a Bit | Extremely |
|---|---|---|---|---|

**9.** These questions are about how you feel and how things have been with you **during the 4 weeks**. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the 4 weeks. . .

(Check the appropriate box)

| | **All of the Time** | **Most of the time** | **A Good Bit of the Time** | **Some of the Time** | **A Little of the Time** | **None of the Time** |
|---|---|---|---|---|---|---|
| a. Did you feel full of life? | | | | | | |
| b. Have you been a very nervous person? | | | | | | |
| c. Have you felt so down in the dumps that nothing could cheer you up? | | | | | | |
| d. Have you felt calm and peaceful? | | | | | | |
| e. Did you have a lot of energy? | | | | | | |
| f. Have you felt downhearted and depressed? | | | | | | |
| g. Did you feel worn out? | | | | | | |
| h. Have you been happy? | | | | | | |
| i. Did you feel tired? | | | | | | |

10. During the **past 4 weeks**, how much of the time has your **physical health or emotional problems** limited your social activities (like visiting with friends or close relatives)? Circle your response.

| All of the Time | Most of the time | Some of the Time | A Little of the Time | None of the Time |
|---|---|---|---|---|

11. How **TRUE** or **FALSE** is each of the following statements is for you?

(Check the appropriate box)

| | **Definitely True** | **Mostly True** | **Don't Know** | **Mostly False** | **Definitely False** |
|---|---|---|---|---|---|
| a. I seem to get sick a little easier than other people | | | | | |
| b. I am as healthy as anybody I know | | | | | |
| c. I expect my health to get worse | | | | | |
| d. My health is excellent | | | | | |

***THANK YOU FOR COMPLETING THESE QUESTIONS!***

Participant__________________________Date__________Tester_______________________

## OARS INSTRUMENTAL ADL

I would like to ask you about some of the activities of daily living, things that we all need to do as a part of our daily lives. I would like to know if you can do these activities ***without any help at all, or if you need some help to do them, or if you can't do them at all...*** **Please circle the response that applies to you for each item below.**

1. Can you use the telephone...

   ***2=without help****, including looking up numbers and dialing*
   ***1=with some help*** *(can answer phone or dial operator in an emergency but need special phone or help in getting the number or dialing)*
   ***0=are you completely unable*** *to use the telephone?*

2. Can you get to places out of walking distance...

   ***2=without help*** *(drive your own car, or travel alone on buses or taxis)*
   ***1=with some help*** *(need someone to help you or go with you when traveling)*
   ***0=are you completely unable*** *unless emergency arrangements are made for a specialized vehicle like an ambulance?*

3. Can you go shopping for groceries or clothes (ASSUMES TRANSPORTATION)...

   ***2=without help*** *(taking care of all shopping needs yourself, assuming you had transportation)*
   ***1=with some help*** *(need someone to go with you on all shopping trips)*
   ***0=are you completely unable*** *to do any shopping?*

4. Can you prepare your own meals...

   ***2=without help*** *(plan and cook full meals yourself)*
   ***1=with some help*** *(can prepare some things but unable to cook full meals yourself)*
   ***0=are you completely unable*** *to prepare any meals?*

5. Can you do your housework...

   ***2=without help*** *(can clean floors, etc.)*
   ***1=with some help*** *(can do light housework but need help with heavy work)*
   ***0=are you completely unable*** *to do any housework?*

Participant__________________________Date__________Tester_______________________

6. Can you take your own medicine...

   ***2=without help*** *(in the right dose at the right time)*
   ***1=with some help*** *(able to take medicine if someone prepares it)*
   ***0=are you completely unable*** *to take your medicines?*

7. Can you handle your own money...

   ***2=without help*** *(write checks, pay bills, etc.)*
   ***1=with some help*** *(manage day-to-day buying but need help with managing your checkbook, and paying bills)*
   ***0=are you completely unable*** *to handle money?*

## DIFFICULTY AND DEPENDENCE QUESTIONNAIRE

**In this questionnaire, you will be asked questions about everyday activities and specific tasks you may do in a normal week, such as walking, using a telephone, and shopping.**

DIFFICULTY

**By yourself, that is, without help from another person or special equipment (such as a cane, walker or other device), how much difficulty do you have ___?**

| | | | | |
|---|---|---|---|---|
| Walking up 10 steps without resting? | None | A little | Some | Alot |
| Walking for a quarter of a mile, that is about 2 or 3 blocks? | None | A little | Some | Alot |
| Doing heavy housework, such as washing windows, walls or floors? | None | A little | Some | Alot |
| Walking across a small room? | None | A little | Some | Alot |
| Lifting or carrying something as heavy as 10 pounds, for example a bag of groceries? | None | A little | Some | Alot |
| Shopping for personal items, such as toilet items or medicine? | None | A little | Some | Alot |
| Doing light housework, such as doing dishes, straightening up, or light cleaning? | None | A little | Some | Alot |
| Preparing your own meals? | None | A little | Some | Alot |
| Managing your money, for example paying bills or keeping a back account by yourself and without help from another person? | None | A little | Some | Alot |
| Using the telephone? | None | A little | Some | Alot |
| Taking medications? | None | A little | Some | Alot |

DEPENDENCE

**Do you need help from another person ___?**

**N = No**
**Y = Yes**
**U = Unable to do task**
**D = Don't perform the task for reasons unrelated to my health**

| | | | | |
|---|---|---|---|---|
| Walking up 10 steps without resting? | N | Y | U | D |
| Walking for a quarter of a mile, that is about 2 or 3 blocks? | N | Y | U | D |
| Doing heavy housework, such as washing windows, walls or floors? | N | Y | U | D |
| Walking across a small room? | N | Y | U | D |
| Lifting or carrying something as heavy as 10 pounds, for example a bag of groceries? | N | Y | U | D |
| Shopping for personal items, such as toilet items or medicine? | N | Y | U | D |
| Doing light housework, such as doing dishes, straightening up, or light cleaning? | N | Y | U | D |
| Preparing your own meals? | N | Y | U | D |
| Managing your money, for example paying bills or keeping a back account by yourself and without help from another person? | N | Y | U | D |
| Using the telephone? | N | Y | U | D |
| Taking medications? | N | Y | U | D |