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The Association between High Neuroticism-Low Extraversion and Dual-Task Performance during Walking While Talking in Non-demented Older Adults

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Abstract

The Walking While Talking (WWT) dual-task paradigm is a mobility stress test that predicts major outcomes, including falls, frailty, disability, and mortality in aging. Certain personality traits, such as neuroticism, extraversion, and their combination, have been linked to both cognitive and motor outcomes. We examined whether individual differences in personality dimensions of neuroticism and extraversion predicted dual-task performance decrements (both motor and cognitive) on a WWT task in non-demented older adults. We hypothesized that the combined effect of high neuroticism-low extraversion would be related to greater dual-task costs in gait velocity and cognitive performance in non-demented older adults. Participants (N = 295; age range, = 65–95 years; female = 164) completed the Big Five Inventory and WWT task involving concurrent gait and a serial 7's subtraction task. Gait velocity was obtained using an instrumented walkway. The high neuroticism-low extraversion group incurred greater dual-task costs (i.e., worse performance) in both gait velocity {95% confidence interval (CI) [−17.68 to −3.07]} and cognitive performance (95% CI [−19.34 to −2.44]) compared to the low neuroticism-high extraversion group, suggesting that high neuroticism-low extraversion interferes with the allocation of attentional resources to competing task demands during the WWT task. Older individuals with high neuroticism-low extraversion may be at higher risk for falls, mobility decline and other adverse outcomes in aging. (*JINS*, 2015, *21*, 519–530)

Keywords: Aging, Dual-tasking, Mobility, Gait, Cognition, Personality

INTRODUCTION

Mobility decline, falls, and physical disability are common among older individuals. In addition, the prevalence of abnormal gait in community-dwelling older adults is 35 percent and increases with age (Verghese et al., 2006). As such, gait speed declines have been associated with limitations in activities of daily living (e.g., walking inside the home, climbing up and down stairs, and bathing; Verghese, Wang, & Holtzer, 2011) and greater risk of falls (Ayers, Tow, Holtzer, & Verghese, 2014; Verghese, Holtzer, Lipton, & Wang, 2009). Falls are quite common in the elderly, with up to one-third of older adults experiencing a fall at least once per year, and may result in distressing effects, including loss of mobility, placement in assisted living facility, and increased mortality (Sattin, 1992; Tinetti, Speechly, & Ginter, 1988; van Bemmel, Vandenbroucke, Westendorp, & Gussekloo, 2005; Verghese et al., 2006).

Walking becomes more problematic and more volitional with age (Woollacott & Shumway-Cook, 2002). Dual-task paradigms that involve walking while performing a cognitive task have been used to establish a causal relationship between attention resources and gait performance (Hausdorff, Schweiger, Herman, Yogev-Seligmann, & Giladi, 2008; Holtzer, Mahoney, Verghese, 2014; Holtzer, Verghese, Xue, & Lipton, 2006; Holtzer, Wang, & Verghese, 2014; 2012; Kemper, Herman, & Lian, 2003; Springer et al., 2006; Verghese et al., 2002). Dual-task performance costs represent the effect of increased attention demands on the walking and the cognitive tasks in comparison to their respective single task conditions. These costs are especially evident when older adults are compared to younger-counterparts

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(e.g., Li, Lindenberger, Freund, & Baltes, 2001; Lindenberger, Marsiske, & Baltes, 2000). Indeed, robust evidence exists in support of age-related decline in the ability to allocate attention to competing task demands during dual-tasking (for reviews, see: Glass et al., 2000; Hartley, 1992; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003). Compromised executive control (Holtzer, Stern, & Rakitin, 2004, 2005), and structural capacity limitations (Pashler, 1994) have been both implicated in dual-task performance costs. In the context of walking dual-task paradigms poor attention and executive functions predicted slower gait velocity and reduced stride length during both single- and dual-task walking conditions (Holtzer et al., 2012), and also moderated dual-task performance costs in gait and cognition in healthy older adults (Holtzer, Wang, Verghese, 2014).

As stated earlier, walking dual-task paradigms are used to determine the *causal* relationship between cognitive load and resources and mobility outcomes (Beauchet et al., 2009; Bootsma-van der Wiel et al., 2003; Sheridan, Solomont, Kowall, & Hausdorff, 2003). In such paradigms the cognitive load may be experimentally manipulated. For example, the cognitive interference tasks vary, and may include memorizing words (e.g., Lindenberger et al., 2000), reciting alternate letters of the alphabet (Verghese et al., 2002), or performing serial 7's subtractions (Li, Verghese, & Holtzer, 2014). Another study found that greater difficulty with increased cognitive load, measured by one's ability to maintain a conversation while walking, was associated with a greater incidence of falls in healthy older adults (Lundin-Olsson, Nyberg, & Gustafson, 1997). Walking While Talking (WWT), one type of dual-task paradigm, which requires reciting alternate letters of the alphabet, has been conceptualized as a mobility stress test shown to predict falls (Ayers et al., 2014; Verghese et al., 2002) and incident frailty, disability, and mortality (Verghese, Holtzer, Lipton, & Wang, 2012).

Given that some non-demented older adults show modest gait costs during dual-tasking, whereas others show more substantial decrements (e.g., Pajala et al., 2005; Springer et al., 2006) researchers have been interested in examining interindividual differences that account for these costs. In addition to limitations in executive functions and attention resources, discussed earlier, other factors have also been examined including the presence of clinical gait abnormalities (Holtzer, Wang, & Verghese, 2014), measures of mobility history of falls (Hausdorff, et al., 2008), history of falls (Springer et al., 2006), and mood (Hausdorff et al., 2008). The presence of neurological disorders, including mild cognitive impairment (Montero-Odasso et al., 2009), Alzheimer's disease (Camicioli, Howieson, Lehman, & Kaye, 1997; Sheridan et al., 2003), and Parkinson's disease (Hackney & Earhart, 2010; Morris, Iansek, Smithson, & Huxham, 2000; Yogev et al., 2005) has also been associated with increased WWT dual-task costs. Overall, findings suggest that performance on dual-task paradigms that involve walking is influenced by cognitive, physical, psychological, and neurological variables.

Personality characteristics may also contribute to variation in WWT dual-task performance. This builds upon extant research in areas examining how personality influences (1) cognitive and (2) mobility function in older adults. For example, high neuroticism, or chronic trait-anxiety, has been associated with poorer cognitive performance (Jorm et al., 1993; Wetherell, Reynolds, Gatz, & Pedersen, 2002), greater report of memory problems (Mroczek & Spiro, 2003; Neupert, Mroczek, & Spiro, 2008; Ponds & Jolles, 1996), and increased risk for both cognitive decline (e.g., Wilson, Begeny, Boyle, Schneider, & Bennett, 2011) and dementia (Duchek, Balota, Storandt, & Larsen, 2007; Wilson, Arnold, Schneider, Li, & Bennett, 2007) in older adults. Furthermore, individuals with high neuroticism experience stressful situations as more aversive and with higher levels of negative affect compared others with low neuroticism (Bolger & Schilling, 1991; David & Suls, 1999). With regards to mobility, high neuroticism has also been associated with greater fear of falling (Mann, Birks, Hall, Torgerson, & Watt, 2006) and worse subjective and objective physical functioning (Jang, Haley, Mortimer, & Small, 2003) later in life.

To date, only one study has used a dual-task paradigm to examine the effect of neuroticism on procedural learning under experimental manipulations of attentional demands (Corr, 2003). Attentional control and processing efficiency theories of anxiety-attention associations propose that anxiety decreases processing efficiency of the goal-directed system and increases stimulus-driven processing and focus on threat-related stimuli (Derakshan & Eysenck, 2009; Eysenck, 1997; Eysenck, Derakshan, Santos, & Calvo, 2007). Based on this theoretical framework, the author hypothesized that neurotic individuals would be more negatively impacted by task-irrelevant and perseverative cognitive processes (e.g., anxiety and worry), leading to reduced ability to appropriately moderate behavior between the single (i.e., reaction to a moving target) and dual-task conditions (i.e., reaction to a moving target while counting of syllables). As expected, results confirmed that individuals with high neuroticism demonstrated impaired procedural learning of target locations only during the more cognitively-demanding dual-task condition, suggesting that greater stress may be underlying this association (Corr, 2003).

In contrast to the negative effects of high neuroticism, individuals with high extraversion show less cognitive decline (Barnes, Mendes de Leon, Wilson, Bienias, & Evans, 2004; Bassuk, Glass, & Berkman, 1999; Ertel, Glymour, & Berkman, 2008; Fratiglioni, Paillard-Borg, & Winblad, 2004; Lövdén, Ghisletta, & Lindenberger, 2005; Zunzunegui, Alvarado, Del Ser, & Otero, 2003), better cognitive performance (Hultsch, Hertzog, Small, & Dixon, 1999), and reduced risk for dementia (Fabrigoule et al., 1995; Karp et al., 2006; Saczynski et al., 2006). High extraversion has also been associated with more stable gait speed in old age (Tolea et al., 2010), higher levels of physical activity (Rhodes & Smith, 2006), and lower rates of disability (Krueger, Wilson, Shah, Tang, & Bennett, 2006).

As described above, traditionally neuroticism and extraversion have been studied separately. More recently, the importance in examining the interaction between extraversion and neuroticism in relation to cognitive outcomes has been identified (Robinson, 2001). One theory of personality suggests that anxiety and impulsivity are based upon four different permutations of neuroticism and extraversion combinations (Gray, 1981). In this four-quadrant model, anxiety spans from a high neuroticism-low extraversion quadrant (hypothesized to be high anxiety) to a low neuroticism-high extraversion quadrant (hypothesized to be low anxiety). Impulsivity spans from a high neuroticism-high extraversion quadrant (high impulsivity) to a low neuroticism-low extraversion quadrant (low impulsivity). One-large scale study found that in a community-based sample of individuals, those with high neuroticism-low extraversion demonstrated greater odds of cognitive impairment 25 years later relative to others (Crowe, Andel, Pedersen, Fratiglioni, & Gatz, 2006). Similarly, effects of the combination of *low* neuroticism-*high* extraversion has been found to be protective and associated with better episodic memory performance (Meier, Perrig-Chiello, & Perrig, 2002) and reduced risk of mortality (Wilson et al., 2005).

It is important for clinicians to appropriately recognize older adults at risk for cognitive and mobility decline to identify individuals who may benefit from early interventions and increased supportive services before injury or disease progression. Part of early detection is identifying measureable and reliable factors (e.g., cognitive, psychological, physical) that may serve as markers of vulnerability. As detailed above, neuroticism and extraversion have been separately linked to cognitive (e.g., Barnes et al., 2004; Wetherell et al., 2002) and mobility (e.g., Jang et al., 2003; Tolea et al., 2010) outcomes in older adults, whereas the combination of neuroticism-extraversion has only been associated with greater risk of cognitive deficits in community-dwelling individuals (Crowe et al., 2006). That is, the effect of the neuroticism-extraversion combination on mobility and/or on WWT dual-task performance has not yet been examined. As a result, personality and/or anxiety dimensions have not been given prominence in current fall prevention guidelines or strategies (Gray-Miceli & Quigley, 2012; Kenny et al., 2011), though they may be of importance.

The present study was novel in that it was designed to investigate the association between neuroticism-extraversion personality groups and performance on a walking dual-task paradigm in a sample of community-dwelling non-demented older adults. In light of the previously reviewed literature, we aimed to examine whether the combination of high neuroticism-low extraversion was associated with greater dual-task costs in both gait velocity and cognitive performance relative to the other three personality combination groups (i.e., high neuroticism-low extraversion, low neuroticism-high extraversion, low neuroticism-low extraversion, and high neuroticism-high extraversion) after controlling for the individual contributions of neuroticism and extraversion, medical and demographic confounders. These aims were based on (1) Gray's (1981) theoretical model hypothesizing that individuals with high neuroticism and low extraversion will demonstrate the greatest levels of anxiety, (2) empirical evidence supporting associations among high anxiety and cognitive (Derakshan & Eysenck, 2009; Eysenck, 1997), motor (Calvo, Alamo, & Ramos, 1990), and gait outcomes (Jahn, Zwergal, & Schniepp, 2010), (3) empirical findings indicating that individuals in this personality group demonstrate greater cognitive declines later in life (Crowe et al., 2006), and (4) the association found between neuroticism and dual-task costs (Corr, 2003).

METHODS

Study Population

Participants were 295 men and women aged 65 and older who were enrolled in the Central Control of Mobility in Aging (CCMA) study, a cohort study investigating cognitive and brain predictors of mobility functioning in healthy, community-dwelling older adults (see Holtzer, Mahoney, & Verghese, 2014; Holtzer, Wang, & Verghese, 2014). Potential participants residing in the lower Westchester County, NY were recruited *via* an institutional review board-approved letter in the mail and a follow-up telephone call screening for study eligibility. Persons were excluded if they reported physician diagnosed dementia, acute or terminal illness, progressive neurodegenerative diseases, major psychiatric illnesses, traumatic brain injury, seizures, hearing or vision loss, were unable to ambulate independently or recently underwent surgery affecting mobility (therefore, overall, older adult participants were relatively healthy), did not speak English, or did not reside in the catchment area.

Procedures

Eligible participants were scheduled for two visits at our research center. Procedures on both days were standard for all participants. During the first visit, participants received comprehensive neuropsychological evaluation (including a brief cognitive screening measure, Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, Tierney, Mohr, & Chase, 1998) and other measures assessing a variety of cognitive domains) and mobility assessments (i.e., dual-task WWT protocol, described below), and completed several psychological, medical, and health questionnaires During the second visit, which took place approximately 2 weeks after the first, participants completed additional psychological, medical, and health questionnaires and a structured neurological and gait examination by the study clinician (for more details regarding procedures, see Holtzer, Mahoney, & Verghese, 2014; Holtzer, Wang, & Verghese, 2014). Following the evaluations, cognitive status (normal, mild cognitive impairment, dementia) was determined at consensus clinical case conferences as previous described (see Holtzer, Verghese, Wang, Hall, & Lipton, 2008). CCMA participants are followed longitudinally at annual intervals. The current study included data from individuals with normal cognitive status enrolled in the study between July 2011 and January 2012. Written informed consent was obtained from participants in person according to study protocols approved by the institutional review board.

Single- and dual-task protocol

Participants were asked to walk on the instrumented gait walkway and perform a cognitive task (i.e., serial 7's subtractions) in a quiet, well-lit room, dressed in comfortable clothes and shoes without any attached monitors. Participants completed one trial for each of the three task conditions: (1) normal pace walking (NW; single *walking* condition), (2) standing in-place while performing the cognitive task (Normal Talking, NT; single *talking* condition), and (3) normal pace walking while performing the cognitive task (WWT; dual-task condition for both *walking* and *talking*). These study methods enabled the examination of the two main outcome variables, which include dual-task costs in: (1) *gait speed* (NW *vs*. WWT) and (2) *cognitive performance* (NT *vs*. WWT). The NT and WWT conditions used serial 7's subtractions as the cognitive task, which has been validated in a sample of relatively healthy older adults and was found to be more complex than reciting alternate letters of the alphabet (Li et al., 2014). During the NW condition participants were told to walk using his/her normal, everyday walk. During the WWT condition, participants were told to pay equal attention to both tasks to minimize task prioritization effects, as previously described (Holtzer et al., 2006). The order of the NW, NT, and WWT tasks was counterbalanced to reduce practice effects.

Measures

Gait speed

Participant's gait speed served as the first outcome and was measured using an instrumented walkway with embedded pressure-sensitive sensors, which quantify temporal and spatial parameters of gait (GAITRite, CIR systems, PA). The walkway measurements are: $8.5\,m \times 0.9\,m \times 0.01\,m$ ($L \times W \times H$) with an active recording area of $6.1\,m \times 0.61\,m$ ($L \times W$). The GAITRite system calculates key gait parameters, including velocity, based on recorded footfalls. The system has been used extensively in clinical and research settings, and has demonstrated excellent test–retest reliability for gait speed during normal pace and WWT conditions (Holtzer, Wang, & Verghese, 2012; McDonough, Batavia, Chen, Kwon, & Ziai, 2001; Oh-Park, Holtzer, Xue, & Verghese, 2010). Gait speed was measured in centimeters per second.

Cognitive interfere task- serial 7's subtractions

Participant's cognitive performance on the serial 7's subtraction task served as the second outcome and was measured by calculating percent correct responses (i.e., [number of correct responses] ÷ [number of total responses] ×100; for similar procedure see Li et al., 2014). This calculation was used to account for differences in assessment time between single (i.e., fixed 10 s) and dual-tasks (i.e., variable time it took to walk across the instrumented walkway).

Big Five Inventory

The Big Five Inventory (BFI; John, Donahue, & Kentle, 1991) is a self-report measure designed to assess the Big Five dimensions of personality using a 5-point Likert scale (John et al., 1991; John & Srivastava, 1999) and was used to quantify neuroticism and extraversion in the present study. The BFI has good internal consistency, retest reliability, convergent and discriminant validity, and appropriate and expected factor structure (John & Srivastava, 1999). Two studies have published normative data for the BFI in older populations (John & Srivastava, 1999; Srivastava, John, Gosling, & Potter, 2003). In the present study, neuroticism-extraversion combination groups (high neuroticism-low extraversion-reference group, low neuroticism-high extraversion, high neuroticism-high extraversion, and low neuroticism-low extraversion) were generated based on a median split using the sample distribution (neuroticism = 17; extraversion = 26). This empirical approach is consistent with that used by other researchers studying combined personality dimensions (see Crowe et al., 2006).

Covariates

While the premise of the study was to examine the association of the *combined* effect of neuroticism-extraversion, we included neuroticism and extraversion *separately*, as continuous covariates in both models to examine their individual contributions. Consistent with our previous studies, participants' report of physician diagnosed medical conditions (i.e., diabetes, chronic heart failure, arthritis, hypertension, depression, stroke, Parkinson's disease, chronic obstructive lung disease, angina, and myocardial infarction) was used to calculate an illness comorbidity score (range 0–10; Holtzer et al., 2006; Verghese, Wang, Lipton, Holtzer, & Xue, 2007). Depressive symptoms were assessed using the 30-item Geriatric Depression Scale (GDS), which has been reported to have good reliability, validity, and external consistency with other measures (Yesavage et al., 1983). As noted above, participants completed the RBANS to screen cognitive functioning (Randolph et al., 1998). The RBANS has demonstrated good test–retest relability, and validity (Wilk et al., 2002) and has been effective in both detecting and characterizing dementia of different etiologies (Randolph et al., 1998). Additional covariates included gender, age, and education.

Statistical Analysis

Two separate linear mixed-effects models (LMEMs) were conducted. In each LMEM, the single task condition (i.e., normal walking, NW or normal talking, NT) and dual-task condition (i.e., WWT) served as a within-subjects factor. Personality group (i.e., high neuroticism-low extraversion-reference group, low neuroticism-high extraversion, low neuroticism-low extraversion, and high neuroticism-high extraversion) served as a four-level between-subject variable. The moderating effects of personality groups on dual-task costs were assessed *via* two-way interactions. Gait velocity and cognitive performance (percent accuracy) served as the dependent measures in each model. Individual contributions of neuroticism and extraversion were assessed by entering both as separate continuous covariates in the models. Statistical analyses were performed using SPSS version 20 for Apple. Level of statistical significance was set to $p = .05$.

RESULTS

Sample Characteristics and Descriptive Data

Descriptive information for key demographic characteristics, gait and cognitive performance during single- and dual-task conditions for the total sample and each of the four neuroticism-extraversion combination groupings are provided in Table 1.

As shown, there were slightly more females (56%) than males. Participants' average age was 76 ± 7.05 years, and their average education exceeded a high school diploma (14.41 ± 3.03 years). The majority (89%) of participants were Caucasian, and 8% African American, which is relatively representative of the racial composition of the catchment area. The RBANS total score revealed that their cognitive functioning was in the average range and similar across the four personality groups (Standard Score range for total sample, 62–137). Table 1 also summarizes data on velocity and performance on the cognitive interference task during single- and dual-task conditions. These data reveal that as expected, gait velocity during the single condition was faster than during the dual condition across all four groups. Similarly, percent accuracy was higher in the single *versus* dual-task condition. BFI means and standard deviations for the total sample and each of the four neuroticism-extraversion groupings are presented in Table 2, and reveal substantial variations in all personality dimensions.

The summary of the LMEM examining the effects of neuroticism-extraversion groupings on costs to gait velocity is presented in Table 3. As expected, gait velocity for all individuals declined from the NW (single) condition to the WWT (dual) condition (estimate = 37.40; positive estimate reflects faster velocities at baseline relative to the referent dual-task condition; 95% CI: 32.57 to 42.57; $p < .001$).

There was no effect of personality group status on gait velocity during the dual-task condition. However, personality group status moderated the effect of task on gait performance. Specifically, participants in the high neuroticism-low extraversion group showed a greater decline in gait velocity during the WWT condition compared to the NW condition relative to individuals in the low neuroticism-high extraversion group (estimate = −10.37; 95% CI: −17.68 to −3.07; $p = .006$), with a moderate effect size (d = .45).

Summary of the LMEM examining the effect of combined neuroticism-extraversion groupings on costs to percent accuracy of serial 7's subtraction interference task is presented in Table 4. Individuals' percent accuracy was higher on the NT condition compared to the WWT condition (estimate = 13.46; again, positive estimate reflects higher scores at baseline relative to dual-task; 95% CI [7.65 to 19.27]; $p < .001$).

There was no effect of personality group status on cognitive performance during the dual-task condition. However, group status moderated the effect of task on cognitive performance. Specifically, participants in the high neuroticism-low extraversion group showed a significant cost in their accuracy on the serial 7's subtraction task in the WWT condition compared to the NT condition relative to individuals in the low neuroticism-high extraversion group (estimate = −10.89; 95% CI [−19.34 to −2.44]; $p = .01$). Additionally, there was a trend for individuals in the high neuroticism-low extraversion group to show a greater decline in cognitive performance compared to the high neuroticism-high extraversion group (estimate = 7.90; 95% CI [−16.11 to 0.31]; $p = .06$), with a moderate effect size (d = .41).

DISCUSSION

Our findings reveal that non-demented older adults with high neuroticism-low extraversion incur greater dual-task costs in gait and cognitive performance relative to other neuroticism-extraversion combination groups. Results from the current study are consistent with previous studies indicating that individuals with high neuroticism-low extraversion show greater cognitive impairment later in life (Crowe et al., 2006) and that individuals with high neuroticism demonstrate worse dual-task performance (Corr, 2003). These results are also in line with studies examining neuroticism and extraversion alone reporting that high neuroticism is associated with cognitive decline (Wilson et al., 2011), while high extraversion is related to better cognitive performance (Hultsch et al., 1999).

Revisiting Gray's (1981) theory of personality, individuals with high neuroticism-low extraversion are most prone to high anxiety, given negative affect (high neuroticism) and reduced sociability (low extraversion). Therefore, based on attentional control and processing efficiency theories (Derakshan & Eysenck, 2009; Eysenck, 1997; Eysenck et al., 2007) of anxiety and attention, individuals with high neuroticism-low extraversion should evidence greatest interference in performance during dual-tasking. Our results are the first to corroborate this theory in the context of WWT, as findings suggest that the combined effect of high neuroticism-low extraversion had an incremental contribution to both gait and cognitive outcomes even after controlling for neuroticism and extraversion *separately*.

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Table 1. Key demographic characteristics and dual-task performance scores for the total sample and four neuroticism-extraversion combination groups

	Total sample $N = 295$ M (SD)	High N-Low E $n = 114$ (SD)	Low N-High E $n = 58$ M (SD)	High N-High E $n = 67$ M (SD)	Low N-Low E $n = 56$ M (SD)
Female	56%	59%	47%	66%	47%
Age (years)	76.47 (7.05)	76.49 (7.24)	76.16 (6.78)	76.99 (7.65)	76.16 (6.31)
Education (years)	14.41 (3.03)	13.93 (3.17)	14.53 (2.92)	14.72 (2.72)	14.88 (3.13)
Illness comorbidity					
Diabetes	17.0%	23.7%	10.3%	22.4%	3.6%
Hypertension	61.4%	62.3%	36.2%	62.7%	44.6%
Myocardial infarction	6.6%	7.9%	5.2%	4.5%	1.8%
Congestive heart failure	1.5%	1.8%	1.7%	3.0%	0%
Arthritis	3.3%	3.5%	3.4%	3.0%	5.4%
Depression	16.2%	13.2%	8.6%	16.4%	14.3%
Stroke	6.9%	11.4%	5.2%	7.5%	1.8%
Parkinson's disease	0%	0%	0%	0%	0%
COPD	8.1%	10.5%	8.6%	4.5%	7.1%
Angina	3.6%	2.6%	1.7%	4.5%	1.8%
Ethnicity (%)					
Caucasian	89%	87%	90%	89%	93%
African American	8%	9%	9%	9%	5%
Other	3%	4%	1%	2%	2%
RBANS Total Score (SS)	91.10 (12.33)	90.48 (11.98)	93.77 (11.68)	92.05 (12.84)	90.62 (11.94)
NW Velocity	99.56 (23.28)	97.28 (22.55)	96.16 (23.60)	103.23 (25.75)	103.08 (22.60)
WWT Velocity	64.40 (25.42)	58.77 (22.90)	68.33 (26.71)	68.10 (28.57)	66.47 (23.53)
DTD in Velocity	35.16	38.51	27.83	35.13	36.61
NT % Accuracy	86.30 (20.99)	88.36 (20.34)	84.47 (22.44)	82.67 (24.04)	91.38 (14.62)
WWT % Accuracy	78.25 (25.24)	75.18 (25.83)	81.90 (23.00)	77.11 (27.18)	80.04 (24.20)
DTD in % Accuracy	8.05	13.18	2.57	5.56	11.34

Note. N = neuroticism; E = extraversion; M = mean; SD = standard deviation; COPD = chronic obstructive pulmonary disease; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status; SS = Standard Score; NW = Normal Walking; NT = Normal Talking; WWT = Walking While Talking; DTD = Dual-Task Decline; % Accuracy = measure of cognitive performance on serial 7's subtraction task.

Of interest, when examined *separately*, neuroticism and extraversion were not associated with dual-task costs. These findings further our understanding of how the *combination* of personality dimensions relates to dual-task costs. However, findings also raise questions regarding underlying etiology of the negative association between WWT performance and the high neuroticism-low extraversion personality group. Previous neuroimaging studies have found white matter changes in the prefrontal cortex in individuals with chronic anxiety disorders (Charney, 2003; Phan et al., 2009; Rauch et al., 1997). The pre-frontal cortex has been identified as a key brain region that is involved in executive control (Koechlin, Ody, & Kouneiher, 2003; MacDonald, Cohen, Stenger, & Carter, 2000). Moreover, recent studies using functional near infrared spectroscopy (fNIRS) have shown that this brain region is functionally involved in allocating and monitoring cognitive resources to support task performance during walking while talking in

Table 2. Big Five Inventory means and standard deviations for the total sample and four N-E combination groups

	Total sample $N = 295$ $M \pm SD$	High N-Low E $n = 114$ M (SD)	Low N-High E $n = 58$ M (SD)	High N-High E $n = 67$ M (SD)	Low N-Low E $n = 56$ M (SD)
Openness	36.90 (6.82)	36.01 (7.04)	40.78 (5.35)	39.24 (5.96)	35.27 (7.04)
Consciousness	37.18 (5.43)	35.05 (5.53)	40.41 (4.31)	37.91 (4.59)	37.73 (5.02)
Extraversion	27.62 (6.43)	23.24 (4.31)	34.40 (2.90)	33.01 (3.08)	23.32 (4.02)
Agreeableness	38.43 (4.61)	37.34 (4.60)	40.10 (4.18)	38.12 (4.39)	39.68 (4.58)
Neuroticism	18.30 (6.31)	22.63 (4.53)	11.60 (2.54)	22.06 (4.31)	12.84 (2.03)

Note. N = neuroticism; E = extraversion; M = mean; SD = standard deviation.

Table 3. Linear mixed effects model analysis: Contribution of demographic variables and neuroticism-extraversion Personality Combination to the decline in gait velocity

	Estimates of fixed effects			
Variable	Estimate	*t*	95% CI	*p*
Condition	37.40	14.26	32.24 to 42.57	< .001***
Age	−1.14	−6.93	−1.47 to −0.82	< .001***
Gender	4.44	1.86	−0.26 to 9.13	.06⁺
Education (years)	0.40	1.03	−0.37 to 1.17	.31
Comorbid illness	1.95	2.48	0.40 to 3.50	.014*
Depressive symptoms	−4.27	−2.08	−8.30 to −0.23	.038*
Neuroticism	0.05	0.15	−0.58 to.68	.88
Extraversion	0.06	0.18	−0.57 to.68	.86
High N-Low E *vs*. Low N-High E	−3.62	−0.95	−11.14 to 3.89	.34
High N-Low E *vs*. High N-High E	3.61	0.86	−4.67 to 11.89	.39
High N-Low E *vs*. Low N-Low E	6.85	1.57	−1.72 to 15.43	.12
Condition × High N-Low E *vs*. Low N-High E	−10.37	−2.80	−17.68 to −3.07	.006**
Condition × High N-Low E *vs*. High N-High E	−0.29	−0.09	−6.89 to 6.31	.93
Condition × High N-Low E *vs*. Low N-Low E	−4.26	−1.12	−11.77 to 3.26	.27

Note. Condition: dual-task (WWT; reference) *vs*. single-task (NW). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.
N = neuroticism; E = extraversion.

aging (Holtzer et al., 2011; Holtzer et al., 2015). Hence, while admittedly speculative, the association between high neuroticism-low extraversion and worse walking dual-task performance maybe attributed, in part, to compromised pre-frontal cortex structure and function.

LIMITATIONS

Several limitations of the present study should be noted. First, the baseline (single task) cognitive condition and the dual-task condition were not consistent in terms of assessment times. In the single cognitive task, individuals were asked to count backward by 7 starting from 100 and were timed for 10 s. The dual-task condition consisted of individuals walking on a 20-foot long instrumented walkway while counting backward from 100 by 7. Because individuals varied in their walking speed (NT *M* = 99.56 cm/s, range = 26.70–170.20 cm/s; WWT *M* = 64.40, range = 10.00–156.30) time during the task varied as well; in turn the number of responses was partly a function of time. To control for time (and by proxy number of responses), a percent accuracy score

Table 4. Linear mixed effects model analysis: Contribution of demographic variables and neuroticism-extraversion personality combination to the decline in cognitive performance on Serial 7’s Subtraction Task

	Estimates of fixed effects			
Variable	Estimate	*t*	95% CI	*p*
Condition	13.46	4.56	7.65 to 19.27	.001***
Age	0.14	0.90	−0.16 to.44	0.37
Gender	2.15	0.97	−2.21 to 6.50	0.33
Education (years)	1.25	3.42	0.53 to 1.97	0.001**
Comorbid illness	.22	−0.70	−1.48 to 3.10	0.50
Depressive symptoms	−4.82	−2.46	−8.68 to −0.97	0.01*
Neuroticism	.07	.25	−0.51 to 0.66	.80
Extraversion	.01	.04	−0.57 to 0.59	.97
High N-Low E *vs*. Low N-High E	−0.31	−0.08	−7.90 to 7.28	0.94
High N-Low E *vs*. High N-High E	0.80	0.19	−7.57 to 9.16	0.85
High N-Low E *vs*. Low N-Low E	4.92	1.12	−3.74 to 13.58	0.27
Condition × High N-Low E *vs*. Low N-High E	−10.88	−2.54	−19.34 to −2.44	0.01*
Condition × High N-Low E *vs*. High N-High E	−7.90	−1.90	−16.11 to −0.31	0.06⁺
Condition × High N-Low E *vs*. Low N-Low E	−0.27	−0.07	−7.69 to 7.15	0.49

Note. Condition: dual-task (WWT; referent group) *vs*. single-task (NT). $^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.
N = neuroticism. E = extraversion.

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was calculated, a method previously validated (Li et al., 2014). Given that different time windows may have influenced the validity of calculated percent scores we empirically evaluated the relationship between total score and percent correct stratified by condition. Pearson's correlations revealed significant associations (single condition, $r = .68$; dual-task condition, $r = .74$). Thus, the method above appears to have adequately controlled for the time variability between tasks.

Second, the present study examined the relation between neuroticism-extraversion combination and dual-task performance on a cognitively demanding serial 7's subtraction task. Whether effects of personality dimensions on dual-task performance would generalize to other paradigms will have to be determined in future research. Third, the sample included only adults aged 65 and older and conclusions regarding the influences of personality on dual-task performance may not apply to younger adults or to disease populations.

FUTURE DIRECTIONS

In the present study, we found that the combination of high neuroticism-low extraversion was associated with greater dual-task costs even after controlling for the individual components (i.e., neuroticism and extraversion separately) and other key demographics. The association between the high neuroticism-low extraversion and dual-task performance may be mediated by other cognitive factors. For example, performance on measures of executive functioning has been associated with gait velocity during dual-tasking in healthy older adults (Holtzer et al., 2006; Holtzer, Wang, Lipton, & Verghese, 2012). Future studies may wish to examine links between neuroticism-extraversion combinations and cognitive performance on measures of executive functioning. It may be that the high neuroticism-low extraversion personality type interferes with higher order executive processes, which influences dual-tasking.

Furthermore, high neuroticism is often used as a proxy for anxiety and high neuroticism-low extraversion has been theorized as putting individuals at risk for even higher levels of anxiety (Gray, 1981). Anxiety may be a potential moderator in the association between neuroticism or neuroticism-extraversion combination and dual-task performance on cognitive and motor tasks. Thus, future research should focus on the intersections of personality, attention and executive abilities, anxiety, and cognitive and motor functioning among older individuals.

Finally, risk of dementia is associated with high neuroticism (Wetherell et al., 2002), whereas high extraversion may protect against risk of dementia (Fabrigoule et al., 1995). Therefore, individuals with high neuroticism-low extraversion may be considered to be in "double jeopardy." That is, not only are they at greater risk for cognitive impairment given high and life-long predisposition to anxiety and negative affect, but they are less sociable and may lack key social interactions/relationships (i.e., low extraversion) and, therefore, lack the buffer against degenerative neurological processes that has been associated with individuals with high extraversion (e.g., Barnes et al., 2004; Ertel et al., 2008). These findings highlight that individuals with high neuroticism-low extraversion are at increased risk for gait and cognitive decline when engaging in concurrent tasks. Future studies may wish to investigate the relation between these two variables, as this personality combination may be an independent risk factor for dementia.

CLINICAL IMPLICATIONS

A major issue in the field of neuropsychology involves the assessment of seniors to aide in differentiating between declines associated with benign aging compared to the declines associated with progressive neurological disorders (Attix & Welsh-Bohmer, 2006). As such, it is important for neuropsychologists and other clinicians to be involved in research aimed at understanding the normal developmental process of cognitive aging and continue to be involved in assessing cognition, activities of daily living, and functional abilities of older adults with non-pathological cognitive changes. Better understanding of healthy age-related declines will improve knowledge regarding progressive dementia and other neurological conditions. Moreover, neuropsychological testing and research in healthy older adults provides data for understanding individuals at risk for mild cognitive impairment, dementia, and forms of other malignant neurological insult. Experimental walking dual-task testing provides additional information beyond typical neurocognitive assessment, as these types of paradigms allows neuropsychologists to measure gait and cognitive abilities under manipulations of task demands. These paradigms also help investigators differentiate between individuals with "healthy" gait and cognitive performance costs and those with greater, "at risk" costs. Individuals with greater dual-task costs may be at risk for developing a neurodegenerative disorder. Furthermore, given that concurrent WWT requires divided attention and behavioral modifications (such as altered gait), this type of "everyday task" may put older adults at increased risk for falls (Chu, Tang, Peng, & Chen, 2012). A recent study found that WWT performance was a more powerful predictor of falls than other gait variables, especially velocity (Ayers et al., 2014). Additionally, experimental WWT dual-task paradigms have been found to be highly predictive of frailty, disability, and mortality (Verghese et al., 2012), as well as falls (Verghese et al., 2002). Seniors that demonstrate greater dual-task interference costs compared to age-matched individuals are at increased risk of falls (e.g., Beauchet et al., 2009).

Determining the association between dual-task costs and personality traits (i.e., neuroticism-extraversion combinations) will help identify novel contributors and provide insights to develop interventions to potentially improve locomotion by modifying traits in older adults. As such, the results from the present study suggest that individuals with high neuroticism-low extraversion incur the greatest dual-task costs in gait velocity (i.e., a measure of altered gait) and suggest a reduced ability to allocate attention to competing task demands. Such individuals may be at increased risk for falls, especially when walking while simultaneously engaging in other activities. Thus, the present study highlights the importance of determining inter-individual markers, such as personality traits, when evaluating who among older individuals may be at increased risk for mobility declines (e.g., falls) and less cognitive preservation. Identification of such individuals may allow for tailored gait and cognitive interventions at earlier time-points in the aging process. For example, older adults with high neuroticism-low extraversion may tend to avoid activities requiring dual-tasking (e.g., walking with friends while talking, interactive classes requiring both cognitive and physical activity, like dance classes) and, therefore, have less practice multi-tasking and using executive control than other less neurotic-more extraverted individuals. Additionally, given the vulnerability that this group of individuals has toward chronic anxiety, they may benefit from interventions aimed at reducing symptoms of worry, stress, and related negative emotions. Alternatively, given the protective effects of extraversion (e.g., Barnes et al., 2004; Saczynski et al., 2006) novel treatments developed to increase social engagement and interaction, may improve outcomes in older adults. Taken together, interventions aimed at increasing participation in cognitively demanding tasks, decreasing anxiety, and increasing sociability may help those older adults at risk for mobility and cognitive decline. Measurement of neuroticism-extraversion may be an important aspect of early identification of these individuals at risk.

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