Cortical Function, Postural Control, and Gait

Dual-Task Decrements in Gait: Contributing Factors Among Healthy Older Adults

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Background. The factors that contribute to the dual tasking (DT) changes in performance that occur when older adults walk while simultaneously performing other tasks are not well known. We hypothesized that cognitive and motor reserve (e.g., executive function [EF], postural control, and walking abilities) and affect (e.g., anxiety, depressive symptoms) influence the DT decrements (DTDs) in gait.

Methods. Two hundred twenty-eight community-living, healthy older adults (mean: 76.2 ± 4.2 years; 59% women) walked with and without DT, for example, subtracting 7s and phoneme monitoring. Mobility (e.g., the Dynamic Gait Index), cognitive function (e.g., memory, EF), and affect (e.g., Geriatric Depression Scale) were quantified. Bivariate and multivariate analyses identified factors associated with the DTD in gait speed (a general measure of locomotor function), swing time, (reflecting balance during gait), and swing time variability (a measure of stride-to-stride consistency).

Results. Gait speed and swing time decreased (p < .001) and swing time variability increased (became worse) (p < .001) during all DTs. The DTD in gait speed was correlated with comfortable walking gait speed, but not with tests of mobility or cognitive function. The DTD in swing time variability was correlated with EF, mobility, and affect (e.g., depressive symptoms). Much of the variance in the DTDs was unexplained.

Conclusions. Usual walking abilities and cognitive function contribute to the DT effects on gait, but these relationships depend on specifics of the DT, the gait feature being studied, and the particulars of the cognitive domain. Meeting the everyday challenges of walking while dual tasking apparently relies on multiple factors including a consistent gait pattern and EF.

Key Words: Dual task—Cognitive function—Executive function—Gait—Variability.

Despite an age-old neurological dogma that motor systems are anatomically and functionally quite separate from cognitive systems, it has become clear during the past two decades that such systems are inter-related at the level of the cerebrum. Thus, even seemingly automatic motor sequences, such as gait, which normally appear to operate completely independently from cognition, can be affected by cognitive tasks. Such interactions can be seen, for example, in the normal aging process, when the overall efficiency of the brain is reduced. Indeed, a growing number of studies have demonstrated that gait in older adults is not simply an automatic process (1,2). If it was automatic, the performance of attention-demanding, “dual tasks” during walking would not alter the gait pattern. Instead, many investigations have shown that dual tasking (DT) affects gait. For example, when older adults are asked to walk and simultaneously perform another task, gait speed is reduced (3–5). In certain impaired elderly populations, DT may also increase the stride-to-stride variability of gait (4,6), a measure of the consistency of the gait pattern that has been associated with fall risk (4,7,8). The degree to which gait changes during the performance of another task has been related to the difficulty of the concurrent task and to the nature of the walk (4,6,9–11) as well as to fall risk and other disabling outcomes (12–14).

A range in the influence of DT on gait has been observed in older adults (3,4,15,16); however, the factors that contribute to the gait changes in response to DT among healthy older adults have not yet been fully elucidated. A priori, one could suggest that among a homogeneous group of healthy older adults with intact mobility and cognitive function, gait will be automatic and the DT decrement (DTD) will be minimal. Therefore, any observed effects will merely be random or stochastic within group variations not attributable to participant-specific characteristics. Alternatively, age-associated changes may produce variability in DT performance that is related to the spectrum of motor and cognitive abilities seen in healthy aging. Accordingly, participant-specific characteristics will explain the variations in the DTD in gait.
This second possibility is supported by several lines of reasoning. The DTD is generally larger in patient populations whose gait and mobility are more impaired compared to healthy controls (4,6,15,17,18). The DTD has also been related to cognitive function, in particular attention (capacity) and executive function (EF) (4,6,9,16). For example, patients with Alzheimer’s disease and patients with Parkinson’s disease who have more impaired EF show a greater DTD (6,15,19). This finding suggests that “cognitive reserve”, in other words, the background cognitive capacity that a person brings to a given task, may play an important role. Among healthy older adults, there is great heterogeneity in gait and mobility (20) as well as a wide range in cognitive abilities (21,22). This is in part the result of variability in age-associated changes in the structure and ability to recruit brain regions important to the EF and attentional systems such as the prefrontal and frontal cortex (21,22). Therefore, it is not surprising that DT abilities in general vary among older adults (4,6,9,16,23–25). As described by Colcombe and colleagues (26), some older individuals show performance on cognitive tasks that is “in the range of normal younger individuals, and others of the same cohort fall entirely out of the range of normal younger adults, even in the absence of obvious pathology.” Thus, it seems reasonable to suggest that the DTD among healthy older adults will be related to both mobility and cognitive function. For elderly persons whose walking is more automated, the DT influence will be minimal; if needed, EF will compensate to reduce the effects of DT.

Another potential source of variations in DTD performance is affect and emotional well-being. Both cognitive and motor performance may be influenced by anxiety, fear, and depression (27). For example, patients who are depressed walk more slowly and take longer to respond to cognitive challenges (28,29), and fear of falling has been associated with an altered gait pattern (30–32). Given the prevalence of age-related changes in mental well-being among elderly persons, it is possible that these factors may also play a role in any observed DTDs on gait.

The present study was designed to evaluate the factors that contribute to the DTD in healthy older adults. We hypothesized that, even among relatively healthy older adults, the DTD in gait would be: a) smaller in persons with better cognitive function, especially attention and EF; and b) smaller in persons with better postural control (i.e., balance and gait). Put differently, the present study tested the hypothesis that EF and usual walking abilities both contribute to the DTD in gait among community-living, healthy older adults and evaluated how the DTD depends on affect, emotional well-being, the nature of the concurrent task, and specific gait features (e.g., gait speed vs variability).

**METHODS**

**Participants**

Participants were older adult men and women who were participating in a prospective study designed to examine the relationship between gait and cognitive function. More specifically, the objectives of this longitudinal study include determination of how age-associated changes in cognitive function contribute to DT deficits in gait; how gait, cognitive function and fall risk change over time; and how cognitive function changes contribute to fall risk among older adults. The results presented are based on the available DT data from the first year of the study. Potential participants were recruited from local senior centers, via flyers, advertising, and word of mouth. After an initial screening by phone or interview, eligible persons were invited to participate if they were between the ages of 70 and 90 years, were living in the community, were able to ambulate independently (without walking aids), and if they were free from disease likely to directly impact gait (e.g., vestibular, orthopedic, neurologic disease). Persons were also excluded if they had acute illness, brain surgery, major depression, or history of stroke, or if they scored <25 on the Mini-Mental State Examination (MMSE; Hebrew version) (33). The study was approved by the local human studies committee of the Tel-Aviv Sourasky Medical Center, and informed written consent was obtained.

To characterize the study population, demographic information was obtained along with fall history and medical history using a structured interview, clinical examination, and questionnaires. Height and weight were measured. The Charlson Comorbidity Index was used to quantify disease burden (higher scores indicate greater comorbidity) (34). The Barthel Activities of Daily Living Index (35), the Frenchay Activities Index (36), the Physical Activity Scale for the Elderly (PASE) (37), and the relative components of the Short Form (SF)-36 (38) were used to characterize disability, lifestyle and functional independence, physical activity levels, and self-report of general health, respectively. Higher scores on these four tests reflect better health and abilities.

**Cognitive Assessment**

The Mindstreams® (NeuroTrax Corp., Newark, NJ) computerized neuropsychological test battery was used to quantify four domains of cognitive function: EF, attention, memory, and visual spatial orientation (39,40). The battery included the Go-NoGo and the Stroop tests of EF, tests of nonverbal memory, tests of visuospatial function, and tests of finger tapping and hand–eye coordination. Age- and education-adjusted composite indices of each different cognitive domain were computed as previously established (6,39,40). The tests used were designed for and have been used in cognitively intact older adults as well as in older adults with Parkinson’s disease, dementia, mild cognitive impairment, Gaucher’s disease, and Attention-Deficit Hyperactivity Disorder (ADHD), and have been significantly associated with traditional pen-and-paper-based tests in a variety of populations (4,6,39,41,42).

**Performance-Based Measures of Balance and Mobility**

The Berg Balance Test and the Dynamic Gait Index, widely used performance-based measures of balance and mobility, were used to evaluate these properties (43–45) (higher scores indicate better function). We also performed the Timed Up and Go Test (46), a simple, but commonly
used measure of lower extremity function, functional mobility, and fall risk (47).

Assessment of Affect

The Activities-specific Balance Confidence Scale was administered to assess fear of falling (higher scores indicate less fear and greater confidence) (48). The Geriatric Depression Scale (30 questions) measured depressive symptoms and emotional well-being (49). The State-Trait Anxiety Inventory (STAI) quantified anxiety (50).

Assessment of Gait and DT

Gait was evaluated four times, during usual walking and under three DT conditions: a) phoneme monitoring, b) serial 3 subtractions, and c) serial 7 subtractions. During phoneme monitoring, participants listened to a story (via headphones) while walking (knowing that they would be questioned about its contents) and counted the number of times two pre-specified words appeared in the text at random intervals. During the serial subtraction tasks, participants walked while reciting out loud serial subtractions of seven or three, starting from a random three-digit number. Before performing the task while walking, each of these tasks was conducted while sitting. A different text was used for phoneme monitoring, and different starting three-digit numbers were used for the serial subtractions, but otherwise the tasks during sitting and walking were identical (e.g., same duration). Phoneme monitoring and serial subtractions were both applied to more broadly assess the DTD. These different constructs may tax distinct cognitive resources (51,52), and hence may have differential effects on gait. The nature of the DT also differs (e.g., the attention demands of phoneme monitoring are essentially uniform over time). Previous work in other populations supports the idea that, although both phoneme monitoring and serial subtractions elicit a DT effect on gait, the consequences are not the same (4,6); furthermore, even healthy young adults slow down when they perform these tasks (4,6). Another reason for using these two tasks is that, aside from increasing reliability of findings, a priori, the two subtraction tasks provide distinct levels of difficulties.

Participants were instructed to walk at their self-selected, normal (comfortable) pace under each of the four conditions (i.e., four walking trials). The instructions for the DT conditions were to walk at a comfortable pace and to perform the additional task simultaneously. No instruction for prioritization of one of the tasks (walking vs cognitive task) was given. After a practice walk, the order of the tasks, including the “usual walking” condition, was randomized. Performance on the phoneme-monitoring task was evaluated using the total number of words counted correctly and the number of multiple choice questions about the story correctly answered. Evaluation of performance on the serial subtractions included the total number of subtractions and the number of mistakes.

Under each of the four conditions, participants walked up and down a 25-meter long, 2-meter wide hallway at their self-selected, usual walking speed for 2 minutes while wearing force-sensitive insoles. Average values and the coefficient of variation (CV) of the swing time of the leg with lowest variability during usual walking were determined using previously described methods that quantify balance during walking and the intrinsic dynamics of steady-state walking (7,20,53). The CV assesses the variability, stride-to-stride consistency, and rhythmicity of gait (i.e., lower values reflect a more consistent gait pattern), a measure previously associated with fall risk (7,54,55). Swing time variability is an aspect of dynamic balance that differs (e.g., the attention demands of phoneme monitoring are essentially uniform over time).

Statistical Analysis

The DTD was defined as the difference between the single task and DT performance for each of the gait parameters, i.e., single task minus DT value. The results were generally similar if we analyzed percent change or if the value under
the DT condition was considered to be the dependent measure (i.e., unadjusted). After applying analysis of variance (ANOVA) to determine the presence of any significant DT effects, post hoc paired least significant differences (LSDs) were applied to determine whether the usual walking gait measure differed from the measures obtained during each of the three DT conditions, for each of the three dependent gait measures (i.e., gait speed, swing time, swing time variability). Pearson’s correlation coefficients were used to quantify the bivariate associations between the DTD in gait speed, average swing time, and swing time variability and independent measures. To build a multivariate, parsimonious model of the factors associated with the DTDs, we used regression models (forward stepwise) to identify potential independent predictors within each domain (e.g., subject characteristics, cognitive function, affect; see Table 1). More specifically, any independent measure that was marginally associated (i.e., \( p < .10 \)) with a DTD was included in a multivariate model. Subsequently, the results of these tests were included in another model to establish a single multivariate model for each DTD in gait (i.e., gait speed, average swing time, and swing time variability). The resulting multivariate models are parsimonious descriptors of the independent predictors of the DTDs. Values of \( p \) reported are based on two-tailed comparisons. Statistical analyses were performed using SPSS 14.0 for Windows (SPSS, Chicago, IL).

**RESULTS**

**Participant Characteristics**

As summarized in Table 1, the 228 individuals who participated in this study were generally healthy, with intact mobility and postural control, and a low comorbidity index. The effects of DT on gait are summarized in Figure 1. ANOVA demonstrated significant DT effects for each of the three dependent measures. Post hoc pairwise analysis using the LSD method identified small, but significant effects on

![Figure 1. Gait speed and swing time variability during usual walking (without any dual task [DT]) and during the three dual tasks. For each DT and each gait parameter, differences to the usual walking condition were highly significant (\( p < .0001 \)). PM = phoneme monitoring.](image)

<table>
<thead>
<tr>
<th>Table 2. Bivariate Correlations Between the Dual-Task Decrements (DTD), Cognitive Function, and Affect</th>
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</thead>
<tbody>
<tr>
<td><strong>Outcome Measure</strong></td>
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<tr>
<td>Cognitive Function</td>
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<tr>
<td>Executive function index</td>
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<td></td>
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<tr>
<td>Attention index</td>
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<tr>
<td>Memory index</td>
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<td></td>
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<tr>
<td>Visual-spatial function index</td>
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<td></td>
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<tr>
<td>Affect</td>
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<tr>
<td>ABC Scale</td>
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<td>Geriatric Depression Scale</td>
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<td></td>
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<td>Trait Anxiety Inventory</td>
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<td>State Anxiety Inventory</td>
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</table>

*Notes: Data are presented as Pearson’s correlation coefficients (\( p \) value). Results were similar using Spearman’s correlation coefficients and if the DTDs were first log transformed. The DTD in gait speed was not significantly correlated with any measure of cognitive function or affect.

\*\( p < .05 \).

ABC = Activities-specific Balance Confidence.
gait speed, average swing time, and swing time variability for all three dual tasks, compared to the baseline, usual walking values \( (p < .0001) \). Gait speed and average swing time were reduced in response to phoneme monitoring and reduced further in response to serial subtractions, whereas swing time variability increased. Eighty-eight percent of all participants reduced their gait speed during phoneme monitoring, and 97% and 93% slowed down during serial 3 and serial 7 subtractions, respectively. A DT-related increase in swing time variability was observed in 72%, 82%, and 85% of the participants during phoneme monitoring, serial 3 subtractions, and serial 7 subtractions, respectively. Compared to the usual walking value, gait speed decreased on average by 0.10 ± 0.12 m/s, 0.15 ± 0.12 m/s, and 0.17 ± 0.16 m/s during phoneme monitoring, serial 3 subtractions, and serial 7 subtractions, respectively. Compared to the usual walking value, swing time variability increased by 0.30 ± 0.69%, 0.58 ± 1.01%, and 0.78 ± 1.14% during phoneme monitoring, serial 3 subtractions, and serial 7 subtractions, respectively. For all results (e.g., Tables 2 and 3), the findings with respect to serial 3 and 7 subtractions were generally similar, therefore, henceforth, we only report the latter to conserve space.

Which of the Participant Characteristics Were Related to the DTDs?

The DT decrements in gait speed were mildly correlated with usual walking gait speed for phoneme monitoring \( (r = 0.11) \), and 97% and 93% slowed down during serial 3 and serial 7 subtractions, respectively. A DT-related increase in swing time variability was observed in 72%, 82%, and 85% of the participants during phoneme monitoring, serial 3 subtractions, and serial 7 subtractions, respectively. When dividing the participants using a median split of EF scores, the mean EF index for participants who did relatively worse was 90.6 ± 6.8, compared to 108.1 ± 5.4 in those who did relatively better \( (p < .001) \).

![Figure 2](http://biomedgerontology.oxfordjournals.org/)

**Table 3. Bivariate Correlations Between the Dual-Task Decrements (DTD), Mobility, and Gait**

<table>
<thead>
<tr>
<th>Performance-Based Measures of Mobility and Balance</th>
<th>Phoneme Monitoring</th>
<th>Serial 7 Subtractions</th>
<th>Phoneme Monitoring</th>
<th>Serial 7 Subtractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Gait Index</td>
<td>–0.11</td>
<td>–0.07</td>
<td>–0.26</td>
<td>–0.19</td>
</tr>
<tr>
<td>(0.106)</td>
<td>(.309)</td>
<td>(.0001)*</td>
<td>(.005)*</td>
<td></td>
</tr>
<tr>
<td>Berg Balance Score</td>
<td>–0.05</td>
<td>–0.11</td>
<td>–0.19</td>
<td>–0.19</td>
</tr>
<tr>
<td>(0.481)</td>
<td>(.124)</td>
<td>(.005)*</td>
<td>(.006)*</td>
<td></td>
</tr>
<tr>
<td>Timed Up &amp; Go</td>
<td>–0.10</td>
<td>0.02</td>
<td>0.19</td>
<td>0.20</td>
</tr>
<tr>
<td>(0.896)</td>
<td>(.726)</td>
<td>(.005)*</td>
<td>(.003)*</td>
<td></td>
</tr>
</tbody>
</table>

**Usual Walking Measures of Gait**

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Phoneme Monitoring</th>
<th>Serial 7 Subtractions</th>
<th>Phoneme Monitoring</th>
<th>Serial 7 Subtractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait Speed</td>
<td>0.03</td>
<td>–0.03</td>
<td>–0.26</td>
<td>–0.23</td>
</tr>
<tr>
<td>(.645)</td>
<td>(.643)</td>
<td>(.001)*</td>
<td>(.002)*</td>
<td></td>
</tr>
<tr>
<td>Average Swing Time</td>
<td>–0.06</td>
<td>–0.03</td>
<td>–0.15</td>
<td>0.07</td>
</tr>
<tr>
<td>(.364)</td>
<td>(.611)</td>
<td>(.033)*</td>
<td>(.294)</td>
<td></td>
</tr>
<tr>
<td>Swing Time Variability</td>
<td>0.28</td>
<td>–0.11</td>
<td>0.21</td>
<td>0.14</td>
</tr>
<tr>
<td>(.001)*</td>
<td>(.116)</td>
<td>(.002)*</td>
<td>(.046)*</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Data are presented as Pearson’s correlation coefficients \( (p \text{ value}) \). Results were similar using Spearman’s correlation coefficients, and if the DTDs were first log transformed.

\* \( p < .05 \).
with the DTD in swing time variability were similar, but not similar results were obtained if the EF index was replaced with the measurement and, for serial 7 subtractions, with the DTD in gait speed, swing time, and swing time variability. In multivariate analyses, the DTD in gait speed, swing time, and swing time variability shared properties of the other two gait measures. (Table 2). As detailed further in Tables 2 and 3, average swing time under serial 7 subtractions was 0.18 (0.029) in gait speed, the final model included usual walking gait speed as a single task in the seated position. Adjustment for sitting task performance in the multivariate regressions generally did not change the results. For example, inclusion of measures of phoneme-monitoring performance did not change the final model for average swing time or for swing time variability; for gait speed, the final model included usual walking gait speed (β = 0.33; p < .001) and the number of correct answers to content recall (β = −0.19; p < .012).

**DISCUSSION**

Participants in this study were relatively healthy older adults whose scores on tests of balance and mobility were near the maximum and who also had good scores on a cognitive test battery. Nonetheless, these participants altered their gait pattern in response to DT. Most participants reduced their gait speed, as seen in other studies (3–6), spent less time in swing, and increased their stride-to-stride variability. These changes were generally small. For example, the DT increase (Δ) in swing time variability during serial 7s was 0.7% in the present study (recall Figure 1), compared to a change of 1.5% and 1.1% in patients with Parkinson’s disease and elderly fellers, respectively (4,6). Still, the response to DT was highly consistent, demonstrating that even passive listening (i.e., phoneme monitoring) elicits a non-zero DTD in healthy older adults. This finding stands in contrast to previous reports in healthy older adults in whom significant effects were not observed (4,6). This difference could be explained by the large sample size and/or the heterogeneity of the cohort studied in the present sample. Thus, the current results seem more likely to reflect the spectrum seen in healthy aging.
The present findings are consistent with previous reports that observed that EF is associated with the DT effects on gait (4,6,9,10,16). We find that, even among healthy older adults with intact cognitive function, the DTD is associated with EF, at least with respect to certain aspects of gait. In addition, motor abilities (e.g., gait speed), mobility, and, to a lesser degree, memory are also associated with DT changes. Affect and mental well-being also appeared to play a role in the DTD: however, the multivariate findings suggest that these factors may not have had an independent contribution. In general, the results suggest that gait under DT is a multidimensional task.

DT gait performance was not always related to usual walking abilities or to the single task performance of the cognitive task, especially in multivariate analyses (e.g., recall Table 4). The results also underscore the fact that the effect on gait is related to the nature of the DT and, equally important, to the specific aspect of gait under study. Different aspects of gait have different DT dependencies. As noted in Table 4, the usual walking gait speed was included among the multivariate predictors of the DTD in gait speed, but it did not predict the DTD in swing time variability. It is also important to keep in mind that, during steady state, obstacle-free walking, the observed correlations are relatively small, and the combination of mobility and cognitive function still does not fully explain the observed changes in the walking pattern in response to DT (note the β values in Table 4). That being said, it is interesting to note the non-zero influence of EF on the DTD in a relatively homogenous group of healthy older adults, even after adjusting for potential confounds. Perhaps when gait and/or EF becomes impaired as a result of disease, the modest association between EF and gait, especially during DT, may take on a more prominent role, as seen in other studies where the DTD in gait speed was related to EF (9,16).

Several theories have been put forth to explain why gait is altered in response to DT, including the bottleneck theory and the capacity-sharing theory (2,57–59). Some have argued that when serial subtractions are performed out loud, the motor act of articulation brings about competition for limited, overlapping resources and leads to the DTD, perhaps because this requires coordination between articulatory, phonatory, and respiratory processes (51,52). In the present study of healthy older adults, even passive listening (i.e., phoneme monitoring) had a significant effect on three aspects of gait (i.e., gait speed, swing time, and swing time variability), lending support to the capacity-sharing model over the bottleneck theory. Still, if the capacity-sharing theory is correct, one has to wonder why a relatively simple task like phoneme monitoring exceeds capacity and causes a DTD in gait in healthy older adults, with respect to both gait speed and gait variability. It is somewhat surprising that healthy older adults whose gait and balance were largely intact were not able to perform another task without altering their gait pattern.

A possible explanation for the observed decline in walking performance relates to the concept of prioritization. When asked to walk and perform another task, certain participant groups may give inappropriate prioritization to the concurrent task, sacrificing attention resources needed for gait by using a “posture second” strategy (17). In the present study, participants were not given explicit instructions regarding which task to prioritize (similar to what happens during normal activities of daily living), yet gait was clearly affected by all of the dual tasks. In the future, it would be interesting to examine whether explicit instructions regarding prioritization alter these changes in healthy older adults, as it does in a more impaired cohort (60). Nonetheless, the present results suggest that, under normal conditions, healthy older adults do not give full priority to gait during DT situations.

The present study has several limitations. A ceiling effect likely contributed to the low magnitude of the correlations observed. One can speculate that, in a more heterogeneous cohort, the magnitude of the correlations would be higher. In contrast, the observation of non-zero correlations between the DTD and other factors, even though only participants with good mobility and cognitive function were included, is an important finding. Our results demonstrate that, among healthy older adults, such associations exist and thus may give us added insight into aging and age-associated changes in gait and DT. Another limitation is that we did not explicitly adjust for the multiple comparisons or control for the timing of the DT with respect to the gait cycle. The loading of attention during phoneme monitoring was relatively constant; however, we did not examine whether participants timed their serial subtractions to specific events in the gait cycle, possibly minimizing the DT effects. Perhaps this contributed to the modest nature of the observed associations. Studies that contrast the present findings to those of young adults would also be helpful to shed further light on these issues and on aging of the processes that are involved in the DTD.

Prospective studies that directly examine the clinical relevance of the observed DTDs would also be of interest. Nonetheless, the results from the present study shed some light on this important question. A previous study reported that swing time variability increased by 1.15% (Δ with respect to usual walking performance) during serial 7 subtractions in elderly fallers, whereas it essentially did not change in elderly nonfallers (4). In the present study, the increase in swing time variability among the participants who had relatively poor EF (recall Figure 2) was similar to that previously reported among elderly fallers. This finding suggests that, for these participants, the observed changes are likely associated with an increased risk of falls and supports the idea that, to meet the everyday challenges of DT, a consistent gait pattern is influenced, to some degree, by EF as well as motor abilities.

Conclusions

The present findings provide additional evidence to support the idea that concurrent performance of other tasks affects the gait of healthy older adults. Different factors apparently mediate the changes in gait speed and gait variability in response to the simultaneous performance of another task and both motor and cognitive functions apparently influence the DTD in healthy older adults, along with other factors that have yet to be identified. This dependence on motor and cognitive functions may explain...
why the effects of DT are even more pronounced among patients who have impaired mobility and reduced EF. Furthermore, these findings provide insight into the factors that contribute to the association between DT performance and fall risk.

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REFERENCES


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