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ORIGINAL RESEARCH

The Detrimental Effects of Mental Fatigue on Cognitive and Physical Performance in Older Adults Are Accentuated by Age and Attenuated by Habitual Physical Activity

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Objective: Our research objectives were to evaluate the extent to which cognitive and physical performance in older adults, when fresh, and when fatigued vary with age and habitual physical activity. ***Methods:*** We employed experimental study designs, with between- (Study 1: age: 51–64 and 65–80 years and Study 2: habitual physical activity: active and sedentary) and within-participants factors (Study 1: test: before cognitive task and after cognitive task and Study 2: session: fatigue and control and test: before and after cognitive task). In testing sessions, participants performed exercise (6-min walk, 30-s sit stand, and 30-s arm curl) and cognitive (response inhibition and vigilance) tasks before and after a 20-min demanding cognitive task (time load dual back [TLDB] task). In Study 2, participants completed a paced breathing task (control session) as well as the TLDB (fatigue session). Ratings of mental fatigue and exercise-related perceived exertion were obtained. ***Results:*** The 20-min TLDB task elicited a state of mental fatigue. Cognitive and physical performance was worse after than before the TLDB task. These impairments in performance were moderated by age (Study 1) and habitual physical activity (Study 2). ***Conclusion:*** The deleterious effects of mental fatigue on cognitive and physical performance were accentuated by aging and attenuated by habitual physical activity. ***Implications:*** Cognitive and/or physical training could mitigate the negative effects of mental fatigue on performance in older adults.

Keywords: aging, cognition, exercise, fatigability

Key Points

- A 20-min time load dual back (TLDB) task elicited a state of mental fatigue in older adults.
- Cognitive and physical performance was impaired by TLDB task.
- This impairment was moderated by age, which was worse for the oldest adults.
- This impairment was moderated by habitual physical activity, which was better for fitter older adults.

The global population is getting older (Osareme et al., 2024). Aging has been associated with impairments in cognitive and physical performance (Barnes, 2015; Hunter et al., 2016; Yoon et al., 2018). Specifically, research studies have noted age-related impairments in physical performance, such as balance, locomotor coordination, muscle force, walking speed, and aerobic endurance (Distefano & Goodpaster, 2018; Ghiotto et al., 2022; Salihu et al., 2024). Moreover, the aging process is associated with changes in cognitive operations (cf. Spreng & Turner, 2019), including age-related impairments in basic processing speed (Salthouse, 1996) as well as higher order executive functioning, such as inhibitory control (Hasher et al., 1999) and reasoning (Erickson et al., 2022). As a consequence, older adults do particularly poorly when required to perform higher order operations, such as inhibition (Lustig et al., 2007), and multitasking (Naveh-Benjamin et al., 2005). These age-related impairments negatively can be expected to impact older adults' quality of life and need for care (Tieland et al., 2018).

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Mental fatigue, a psychobiological state elicited by prolonged and demanding cognitive activities, can impair cognitive and physical performance (Marcora et al., 2009; Van Cutsem et al., 2017, 2022). It has been noted that the same cognitive tasks can cause greater processing demands in older than younger adults (Chen et al., 2023). These increased demands can make older adults perceive greater effort when performing physical activity, such as gait and posture control (Li et al., 2018). Accordingly, mental fatigue is likely to be higher for older adults than younger adults (Glynn & Qiao, 2023; Su et al., 2022). Such aging-related changes in mental fatigue may exacerbate aging-related impairments in performance due to a number of possible processes, including increased neuromuscular fatigue, decreased cognitive capacity, or decreased efficiency.

A study of gait in young ($M = 25$ years) and old ($M = 72$ years) adults showed that the effect of mental fatigue on gait was moderated by age (Behrens et al., 2018). Specifically, inducing a state of mental fatigue by completing a 90-min cognitive task subsequently increased speed, stride length, stance time, support time, and swing time variability in the old adults but not the young adults. Reviews of balance studies in younger and older adults have confirmed that mentally fatiguing cognitive tasks can impair subsequent balance performance, with evidence of age-related differences in susceptibility to mental fatigue in one (Salihu et al., 2024) but not the other (Brahms et al., 2022) review. To the best of our knowledge, no previous empirical studies have investigated the effects of mental fatigue on the performance of cognitive and exercise tasks as a function of aging in older adults.

The present project sought to deepen our understanding of performance and the fatigue-performance relationship in older adults and their moderation by age and habitual physical activity (Habay et al., 2023). Accordingly, our first study purpose, addressed by Study 1, was to determine whether the effects of a mentally fatiguing cognitive task on subsequent cognitive and physical performance were moderated by aging. We expected that performance and mental fatigue-related impairments in performance would be worse with age.

Study 1

Methods

Participants

Thirty older adult sedentary men ($n = 12$, $M = 56$, $SD = 3$, range = 52–64 years; $n = 18$, $M = 73$, $SD = 5$, range = 65–79 years) were recruited from the local community and gave informed consent. The two age cohorts were separated by retirement age in Spain, which is mandated when men turn 65. For this reason we only recruited male participants. Power calculations using G*Power (Faul et al., 2007) indicated that with a sample size of 30, our study was powered at 80% to detect significant ($p < .05$) between-participant ($f = 0.46$, $\eta_p^2 = .17$), within-participant ($f = 0.26$, $\eta_p^2 = .06$), and between–within ($f = 0.26$, $\eta_p^2 = .06$) effects by analysis of variance (ANOVA) corresponding to medium, small, and small effect sizes, respectively (Cohen, 1992). Currently, there are no meta-analytic reviews of studies examining the moderating effects of age on the fatigue–performance relationship for exercise or cognitive tasks. A recent review (Brown et al., 2020) identified a small-to-medium effect of prior cognitive tasks on subsequent physical performance. Accordingly, the current study was powered to detect such effects. The study protocol was approved by the Ethics Committee at the University of Extremadura in accordance with the Declaration of Helsinki. Participants were naive to our study purpose.

Design

The study employed a mixed factorial design, with one between-participant factor (age: 51–64 and 65–80 years) and one within-participant factor (test: before and after time load dual back [TLDB] task). The study adopted the sequential task design that is commonly used in the literature to study the effects of fatigue on later performance (Brown et al., 2020).

Exercise Tasks

Chair-Stand Test. The 30-s chair-stand test (Jones et al., 1999) measured lower body (leg) strength. Participants sat on a chair with arms crossed at the chest and hands over shoulders, stood up, and sat down again. This sequence was repeated as many times as possible in 30 s. A successful repetition was counted for each complete knee extension. The number of repetitions was recorded.

Arm-Curl Test. The 30-s arm-curl test (Rikli & Jones, 2013) measured upper body (arm) strength. Participants sat on a chair, held a 5-kg dumbbell in their dominant hand, curled the elbow until fully flexed to touch the shoulder, and slowly lowered the dumbbell to the starting position. This action was repeated as many times as possible in 30 s. A successful repetition was counted for each complete movement. The number of repetitions was recorded.

Walking Test. The 6-min walk test (ATS, 2002) measured aerobic exercise capacity. Participants walked up and down a flat 30-m corridor. They walked as far as possible in 6 min. The distance (in meters) covered was recorded.

Cognitive Tasks

Stroop Task. An incongruent color-word Stroop task (Stroop, 1935) was used to assess response inhibition, an executive function, and core cognitive operation. The color words were displayed on a smartphone. Participants were asked to call out the color of the written word and ignore its meaning. The task lasted 45 s. Performance was measured as the number of correct responses.

Brief Psychomotor Vigilance Task. A brief psychomotor vigilance task (PVT-B) was used to measure simple reaction time (Dinges & Powell, 1985). The interstimulus duration was random and ranged from 1 to 4 s. The task was implemented using the SOMA-NPT app (Soma Technologies; https://soma-npt.ch/) running on a smartphone. Participants were required to touch the screen of a mobile phone as fast as possible after a visual stimulus appeared in the center of the screen. The task lasted 3 min. Performance was measured as reaction time (in milliseconds).

Time Load Dual Back. A TLDB cognitive task (Kirchner, 1958) was used to induce mental fatigue (Jacquet et al., 2021a; Mortimer et al., 2024). The task imposes a high cognitive load and elicits a state of elevated mental fatigue (e.g., O'Keeffe et al., 2019). The task alternates between primary and secondary tasks. The primary one-back task presents a series of letters on the screen, and participants respond with arrows to indicate if the letter was the same (press "left") or different (press "right") as the previous trial. The secondary decision-making task requires participants to decide whether flashing numbers were odd (press "1") or even (press "2"). The task lasted 20 min. The task was implemented using the SOMA-NPT app.

Subjective Ratings

Visual Analog Scale—Mental Fatigue. Participants were asked *How mentally fatiguing do you feel?* and responded by marking a 10-cm line, with anchors *not at all* and *maximum level of mental fatigue possible* (Smith et al., 2019).

Rating of Perceived Exertion. Participants provided a rating of perceived exertion (RPE), on a scale anchored by 0 = *minimal* and 10 = *maximal* (Borg, 1982), upon completion of the set of exercise tasks.

Procedure

Participants attended one testing session. Before and after the 20-min TLDB task, they completed a series of tests and measures: rating of mental fatigue, 6-min walking test, RPE, PVT-B task, arm-curl test, chair-stand test, and Stroop task.

Data Analysis

A series of mixed factorial ANOVAs, with age (51–64 and 65–80 years) as the between-participant factor and test (before and after

TLDB task) as the within-participants factor, were performed on the measures. Significance was set at $p < .05$. We report the multivariate solution to minimize the risk of violating sphericity and compound symmetry assumptions in ANOVA designs. Partial eta squared (η_p^2) was reported and interpreted as small (.02), medium (.13), and large (.26). Statistical analysis was completed using SPSS software, version 29.

Results

Physical Performance

ANOVAs on physical performance yielded large effects for age (performance worse with increased age), test (performance worse after 20-min TLDB task), and age by test (see Figure 1 and Table 1). These interactions were explored using ANOVAs on the before-to-after changes in physical performance. For walking, the TLDB impaired the older cohort ($\Delta M = -71$ m) more than the younger cohort ($\Delta M = -46$ m), $F(1, 28) = 21.43$, $p < .001$, $\eta_p^2 = .43$ (Figure 1A). For chair stands, the TLDB impaired the older cohort ($\Delta M = -3.39$) more than the younger cohort ($\Delta M = -2.75$), $F(1, 28) = 4.98$, $p = .03$, $\eta_p^2 = .15$ (Figure 1B). For arm curls, the TLDB impaired the older cohort ($\Delta M = -3.78$) more than the younger cohort ($\Delta M = -2.83$), $F(1, 28) = 5.84$, $p = .02$, $\eta_p^2 = .17$ (Figure 1C).

Cognitive Performance

ANOVAs on cognitive performance yielded large effects for age (worse performance with increased age), test (worse performance after 20-min TLDB task), and age by test (see Figure 2 and Table 1). These interactions were explored using ANOVAs on the before-to-after changes in task performance. For Stroop task performance (Figure 2A), the TLDB reduced the number of correct words spoken by the oldest age cohort ($\Delta M = -7.94$ words) more than the middle age cohort ($\Delta M = -5.83$ words), $F(1, 28) = 13.91$, $p < .001$, $\eta_p^2 = .33$. For PVT-B performance (Figure 2B), the TLDB slowed the responses of the older cohort ($\Delta M = 58$ ms) more than those of the younger cohort ($\Delta M = 29$ ms), $F(1, 28) = 71.05$, $p < .001$, $\eta_p^2 = .71$.

Subjective Ratings

ANOVAs on ratings yielded large effects for age (higher ratings with increased age) and test (higher ratings after 20-min TLDB task) for visual analog scale—mental fatigue (VAS-MF) and RPE and a large age by test effect for VAS-MF (see Figure 2 and Table 1). This interaction was explored using ANOVA on the before-to-after changes in ratings. The TLDB increased perceived mental fatigue more in the older ($\Delta M = 5.06$) than younger ($\Delta M = 3.25$) cohort, $F(1, 28) = 18.67$, $p < .001$, $\eta_p^2 = .40$ (Figure 2C). The TLDB increased subsequent exercised-induced perceived exertion similarly in older ($\Delta M = 1.39$) and younger ($\Delta M = 1.17$) participants, $F(1, 28) = 0.71$, $p = .41$, $\eta_p^2 = .03$ (Figure 2D).

Discussion

Cognitive and physical performance declined with age. These findings agree with a large body of evidence showing age-related declines in physical (e.g., Hunter et al., 2016; Melsæter et al., 2022) and cognitive (e.g., Harada et al., 2013) performance. Age-related neuromuscular changes, such as fewer and larger motor units, less stable neuromuscular functions, lower and more variable motor unit action potential, and/or smaller and slower skeletal muscle

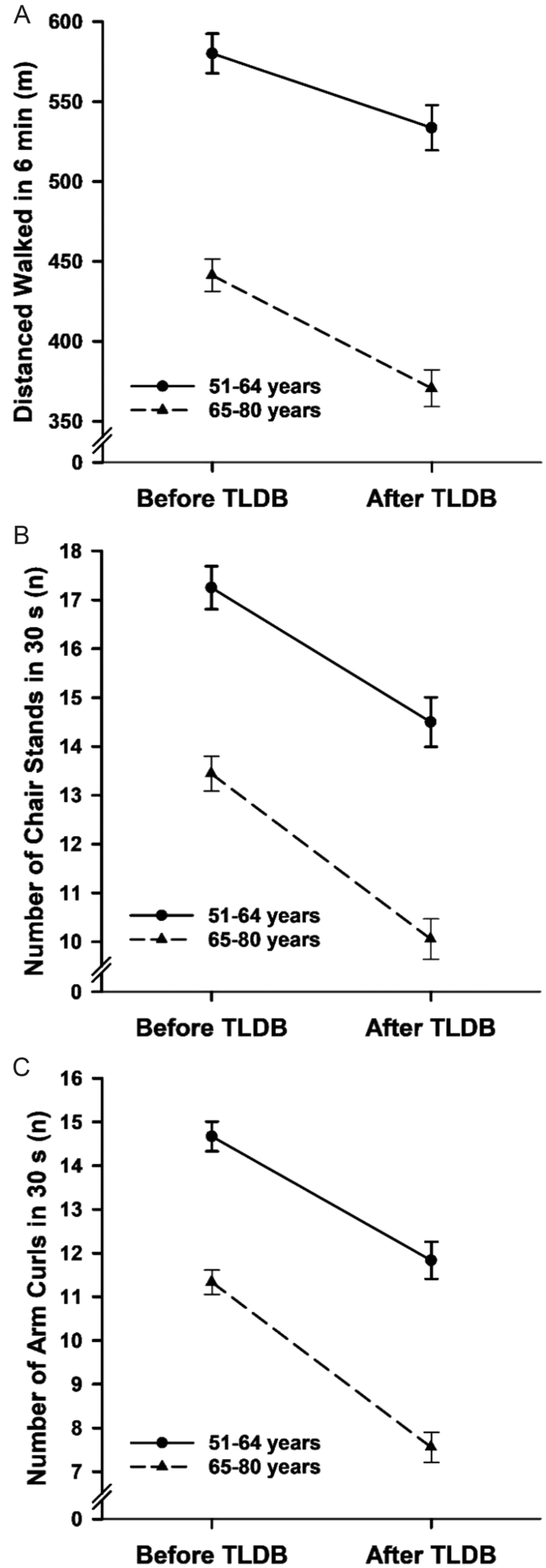

Figure 1 — Mean (*SE*) exercise performance before and after completing a 20-min TLDB cognitive task as a function of age in Study 1. TLDB = time load dual back.

Table 1 **Summary of the 2 Age (51–64 and 65–80 Years) × 2 Test (Before and After TLDB) ANOVAs on Physical Performance, Cognitive Performance, and Subjective Ratings in Study 1**

Measure	Age		Test		Age × Test	
	$F(1, 28)$	η_p^2	$F(1, 28)$	η_p^2	$F(1, 28)$	η_p^2
Distance walked (m)	78.90***	.74	501.79***	.95	21.43***	.43
Chair stands (*n*)	48.18***	.63	459.68***	.94	4.98*	.15
Arm curls (*n*)	70.04***	.99	286.29***	.91	5.84*	.17
Brief Stroop words (*n*)	52.48***	.65	592.30***	.96	13.91***	.33
PVT-B reaction time (ms)	88.73***	.76	615.62***	.96	71.05***	.72
VAS—mental fatigue (0–10)	8.72**	.24	395.14***	.93	18.64***	.40
RPE (0–10)	36.27***	.56	94.42***	.77	0.40	.03

Note. TLDB = time load dual back; ANOVA = analysis of variance; PVT-B = brief psychomotor vigilance task; VAS = visual analog scale; RPE = rating of perceived exertion.
*$p < .05$. **$p < .01$. ***$p < .001$.

fibers, can explain age-related declines in physical performance (Hunter et al., 2016). Age-related brain changes, such as gray matter volume decline, neuronal size decrease, loss of connectivity between neurons, and/or white matter decrease can explain age-related declines in cognition (Harada et al., 2013).

Both cognitive and physical performance were worse after compared with before the mentally fatiguing cognitive task. These findings add to the extant literature showing that mental fatigue can impair performance of physical and cognitive tasks in young adults (Van Cutsem et al., 2017, 2022). The current findings also extend the literature by showing that the detrimental effects extend to older adults in their 50s, 60s, and 70s. Importantly, we showed, for the first time, that the deleterious effects of mental fatigue on cognitive and physical performance were moderated by age, with the greatest negative impact observed in the oldest adults. This novel evidence supports arguments that demanding cognitive tasks cause more mental fatigue as we age, potentially leading to greater impairments in performance (Hess & Ennis, 2012) and that older adults are less able to adapt their behavior when in a state of increased mental fatigue (De Jong et al., 2018).

Age-related exacerbations in the fatigue-performance relationship, such as those documented in Study 1, may be moderated by a number of individual difference factors. Two potential moderating factors are physical fitness and habitual physical activity (Habay et al., 2023). It is well established that physical fitness and activity can improve both cognitive and physical performance (Falck et al., 2019; Ludyga et al., 2016). However, the evidence regarding their role as moderators of the fatigue–performance relationship is mixed, and their contribution unclear. Experience-related individual differences (e.g., professional vs. recreational athletes, athletes vs. non-athletes, and years of training or competitive experience) in the effects of mental fatigue on physical performance were reported in a study by Martin et al. (2016) but not in subsequent studies (Clark et al., 2019; Rubio-Morales et al., 2022; Van Cutsem et al., 2019). However, evidence from studies of young adults shows that physiological responses, such as heart rate, and blood pressure reactivity to cognitive tasks (similar to the ones used in mental fatigue studies), are smaller among active, fitter individuals, suggesting that the impact of cognitive tasks on the nervous system can be moderated by fitness (for review, see Forcier et al., 2006). Given the heterogeneous nature of the extant literature, the influence of physical fitness and regular physical activity on the fatigue–performance relationship warrants further investigation. Accordingly, our second study purpose, addressed by Study 2, was to determine whether the effect of a mentally fatiguing cognitive task on subsequent cognitive and physical performance was moderated by habitual physical activity. We expected that performance and mental fatigue-related impairments in performance would be less in regular exercisers.

Study 2

Methods

Participants

Forty-eight older ($M = 71$, $SD = 2$, range = 66–76 years) adult men and women were recruited from the local community. All were retired. The 24 active participants regularly engaged in demanding physical activities, such as resistance exercises (eight men and three women) or walking (four men and nine women), at least 2 days/week. The 24 (12 men and 12 women) sedentary participants were inactive. Power calculations using G*Power (Faul et al., 2007) indicated that with a sample size of 30, our study was powered at 80% to detect significant ($p < .05$) between-participant ($f = 0.36$, $\eta_p^2 = .11$), within-participant ($f = 0.21$, $\eta_p^2 = .04$), and between–within ($f = 0.21$, $\eta_p^2 = .04$) effects by ANOVA corresponding to medium, small, and small effect sizes, respectively (Cohen, 1992). Currently, there are no meta-analytic reviews of studies examining the moderating effects of fitness on the fatigue–performance relationship for exercise or cognitive tasks. A recent review (Brown et al., 2020) identified a small-to-medium effect of prior cognitive tasks on subsequent physical performance. Accordingly, the current study was powered to detect such effects. The study protocol was approved by the Ethics Committee at the University of Extremadura in accordance with the Declaration of Helsinki.

Design

The study employed a mixed factorial design, with one between-participant factor (habitual physical activity: active and sedentary) and two within-participant factors (session: fatigued and relaxed and test: before and after task). The task was either TLDB or control (paced breathing).

Exercise Tasks

The chair-stand, arm-curl, and walk tests were as per Study 1.

Cognitive Tasks

The Stroop, PTV-B, and TLDB tasks were as per Study 1.

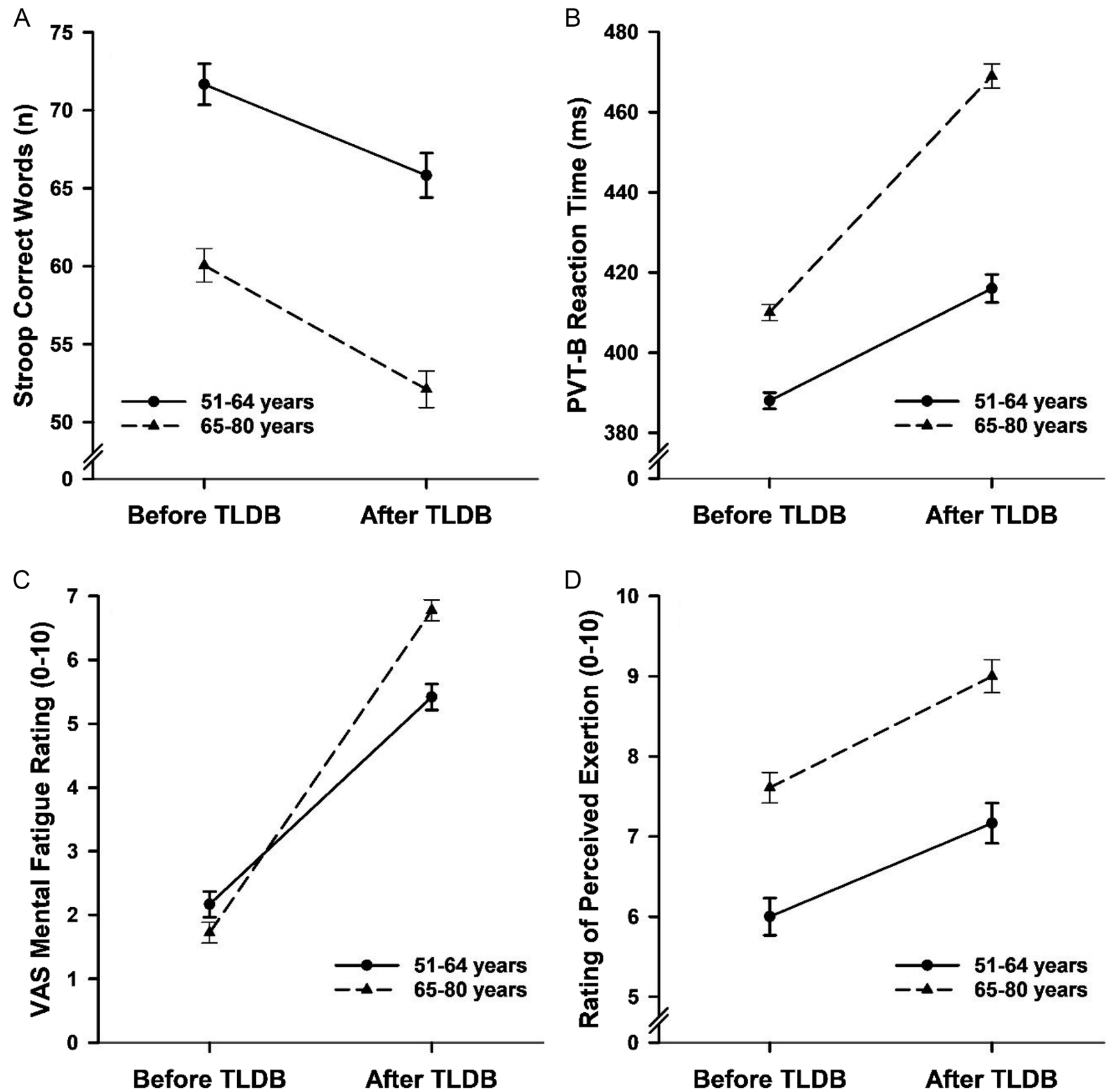

Figure 2 — Mean (*SE*) cognitive performance and subjective ratings and before and after completing a 20-min TLDB cognitive task as a function of age in Study 1. PVT-B = brief psychomotor vigilance task; VAS = visual analog scale; TLDB = time load dual back.

Paced Breathing (Control) Task

A 20-min paced breathing task was used to relax participants and create a state of low mental fatigue. Participants paced their breathing in the following repeated sequence: inhale nasally for 4 s as a circle on the screen expanded, pause, exhale orally for 4 s as the circle contracted, and pause. The task was implemented using the SOMA-NPT app. This task was an active control condition, with participants using their phones as per the TLDB fatigued condition.

Subjective Ratings

The VAS-MF and RPE ratings were as per Study 1.

Procedure

Participants attended two testing sessions, 48 hr apart, with session order counterbalanced across participants. The sessions differed by midsession task, which was either a 20-min TLDB task or a 20-min paced breathing task. Before and after each of these tasks, they completed a series of exercise and cognitive tasks and provided subjective ratings of fatigue and exertion as per Study 1.

Data Analysis

Mixed factorial ANOVAs, with habitual physical activity (active and sedentary) as the between-participant factor and session (fatigued and control) and test (before and after task) as within-participants factors, were performed on the measures.

Results

Physical Performance

ANOVAs on physical performance yielded large main effects for group (active group outperformed sedentary group), session (performance worse for TLDB than control), and test (performance worse after than before the 20-min tasks; see Figure 3 and Table 2). Importantly, there were medium/large group by session

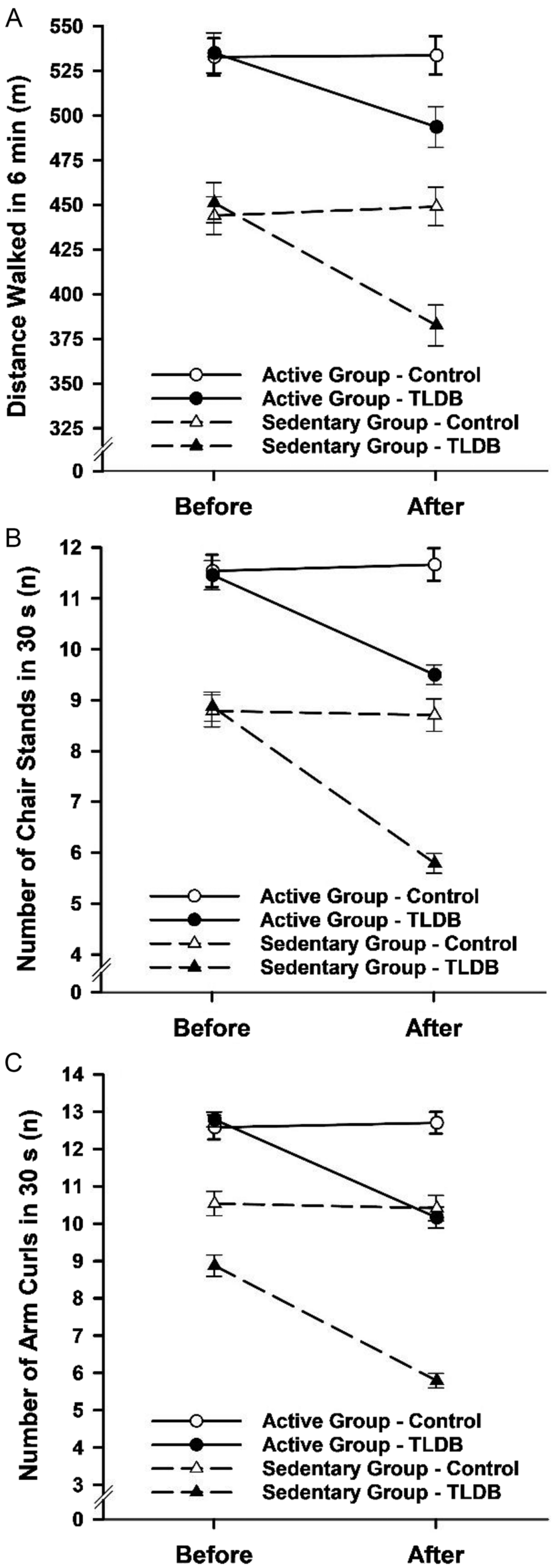

Figure 3 — Mean (*SE*) exercise performance before and after completing 20-min TLDB and paced breathing (Control) tasks as a function of group (Active and Sedentary) in Study 2. TLDB = time load dual back.

by test interaction effects: Performance of both groups was similar before and after the paced breathing task (control), whereas performance deteriorated less in the active group than the sedentary group from before to after the TLDB cognitive task. These group-related performance impairments were found for walking, $F(1, 46) = 76.52$, $p < .001$, $\eta_p^2 = .63$ ($\Delta M_{\text{active}} = -41$ m $> \Delta M_{\text{sedentary}} = -69$ m; Figure 3A), chair stand, $F(1, 46) = 20.08$, $p < .001$, $\eta_p^2 = .30$ ($\Delta M_{\text{active}} = -1.96$ stands $> \Delta M_{\text{sedentary}} = -3.08$ stands; Figure 3B), and arm curl, $F(1, 46) = 61.33$, $p < .001$, $\eta_p^2 = .57$ ($\Delta M_{\text{active}} = -2.63$ curls $> \Delta M_{\text{sedentary}} = -4.13$ curls; Figure 3C) tests.

Cognitive Performance

ANOVAs on cognitive performance yielded large main effects for group (better performance for the active group than the sedentary group), session (worse performance for TLDB than paced breathing), and test (worse performance after than before the 20-min tasks; see Figure 4 and Table 2). The key group by session by test interaction effects were also large; performance was not affected by the paced breathing task, whereas performance was affected by the TLDB task, with less impact for active than sedentary participants. Specifically, from before to after the TLDB task, stroop task word production (Figure 4A) decreased less for the active group ($\Delta M = -5.21$ words) than the sedentary group ($\Delta M = -8.92$ words), $F(1, 46) = 76.07$, $p < .001$, $\eta_p^2 = .62$. Similarly, PVT-B reaction times (Figure 4B) slowed less for the active group ($\Delta M = 30$ ms) than the sedentary group ($\Delta M = 51$ ms), $F(1, 46) = 73.81$, $p < .001$, $\eta_p^2 = .62$.

Subjective Ratings

ANOVAs on ratings yielded large main effects for group (lower ratings for the active group than sedentary group), session (higher ratings for TLDB than paced breathing), and test (higher ratings after than before the 20-min tasks; see Figure 4 and Table 2). The key group by session by test interaction effects were also large; ratings were not affected by the paced breathing task, but they were affected by the TLDB task, with less impact for active than sedentary participants. Specifically, from before to after the TLDB task, rated mental fatigue (Figure 4C) increased less for the active group ($\Delta M = 4.88$) than the sedentary group ($\Delta M = 7.38$), $F(1, 46) = 122.12$, $p < .001$, $\eta_p^2 = .73$. Similarly, rated exertion (Figure 4D) increased less for the active group ($\Delta M = 4.83$) than the sedentary group ($\Delta M = 7.13$), $F(1, 46) = 90.71$, $p < .001$, $\eta_p^2 = .66$.

Discussion

Study 2 again found that mental fatigue impaired cognitive and physical performance in older adults. These findings replicated those observed in Study 1. Novelly, we showed that regular physical activity mitigated the deleterious effects of mental fatigue on performance in older adults. Active (physically fitter) participants outperformed sedentary participants. The findings for performance when rested corroborate existing evidence that regular physical activity improves both the physical (Eckstrom et al., 2020; Sun et al., 2013) and cognitive (Angevaren et al., 2008; Cordes et al., 2019) performance of older adults. The findings for performance when tired are compatible with evidence that physical activity counteracts mental fatigue and its effects on performance (Jacquet et al., 2021b). A popular account of the fatigue–performance relationship argues that mental fatigue makes endurance exercise feel harder (Marcora, 2019). Interestingly, combined

Table 2 Summary of the 2 Group (Active and Sedentary) × 2 Session (TLDB and Control) × 2 Test (Before and After Task) ANOVAs on Physical Performance, Cognitive Performance, and Subjective Ratings in Study 2

	Group		Session		Test		Group × Session		Group × Test		Session × Test		Group × Session × Test	
Measure	$F(1, 46)$	η_p^2	$F(1, 46)$	η_p^2	$F(1, 46)$	η_p^2	$F(1, 46)$	η_p^2	$F(1, 46)$	η_p^2	$F(1, 46)$	η_p^2	$F(1, 46)$	η_p^2
Distance walked (m)	35.74***	.44	421.81***	.90	809.66***	.95	20.55***	.31	39.42***	.46	645.15***	.93	47.41***	.51
Chair stands (*n*)	69.08***	.60	95.20***	.67	235.23***	.84	1.25	.03	16.73***	.27	238.39***	.84	7.75**	.14
Arm curls (*n*)	36.12***	.44	284.38***	.86	621.00***	.93	15.42***	.25	41.74***	.48	729.00***	.94	25.00***	.35
Brief Stroop words (*n*)	209.84***	.82	163.41***	.78	749.50***	.94	22.84***	.33	44.97***	.49	480.99***	.91	37.97***	.45
PVT-B reaction time (ms)	160.01***	.78	1,259.34***	.97	995.31***	.96	70.38***	.61	61.77***	.57	1,198.34***	.93	81.82***	.64
VAS—mental fatigue (0–10)	111.07***	.71	1,957.79***	.98	1,783.20***	.98	67.88***	.60	69.46***	.60	1,656.33***	.97	73.93***	.62
RPE (0–10)	44.63***	.49	2,059.73***	.98	1,361.43***	.97	76.71***	.63	42.40***	.48	1,382.81***	.97	59.26***	.56

Note. TLDB = time load dual back; ANOVA = analysis of variance; PVT-B = brief psychomotor vigilance task; VAS = visual analog scale; RPE = rating of perceived exertion.
$^{**}p < .01$. $^{***}p < .001$.

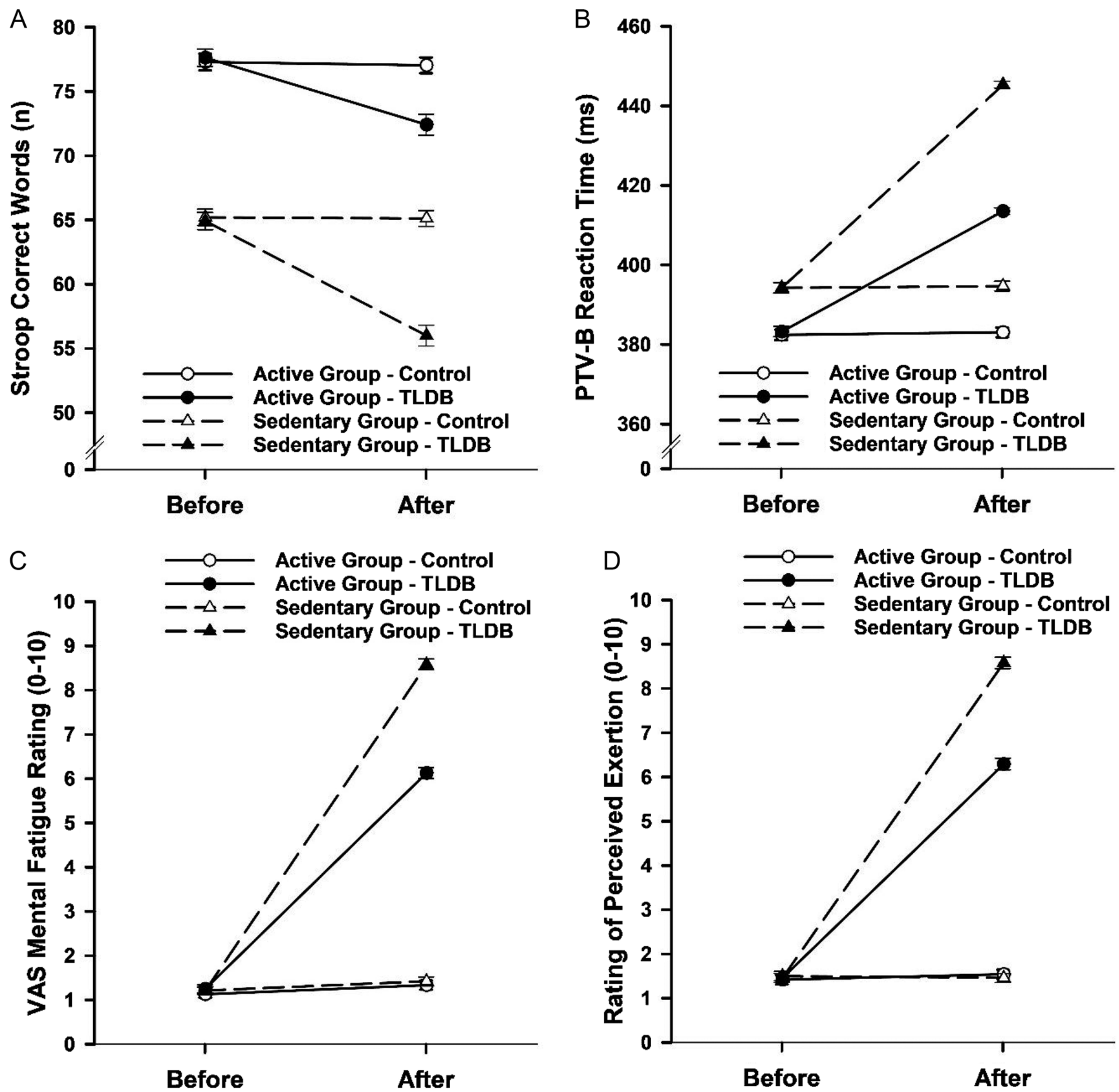

Figure 4 — Mean (*SE*) cognitive performance and subjective ratings before and after completing 20-min TLDB and paced breathing (Control) tasks as a function of group (Active and Sedentary) in Study 2. PVT-B = brief psychomotor vigilance task; VAS = visual analog scale; TLDB = time load dual back.

exercise and cognitive training in young adults recalibrates the relationship between perceived and actual effort, especially when fatigued thereby improving task performance (Staiano et al., 2023; Dallaway et al., 2023). A recent study extends the benefits of such combined exercise and cognitive training to sedentary older adults (Díaz-García et al., 2025).

General Discussion

The current studies sought to improve our understanding of the effects of aging on cognitive and physical performance under rested and fatigued conditions in older adults and to explore the moderating role of age and habitual physical activity. We confirmed that fatigue impaired performance and showed that performance when in states of fatigue and relaxation were worsened by aging and inactivity. We discuss our key findings in the sections below.

Mental Fatigue and Performance

The present studies confirm that mental fatigue impairs cognitive and physical performance in older adults. Studies 1 and 2 observed impairments in aerobic and strength endurance exercises as well as response inhibition and sustained attention assessed subsequent to a long and difficult cognitive task. Systematic reviews establish that mental fatigue can impair aerobic (Van Cutsem et al., 2017) and strength endurance (Alix-Fages et al., 2023) exercise and conclude that the most likely explanation is because mental fatigue increases perceived effort thereby reducing time to exhaustion/failure or decreasing exercise intensity (Marcora, 2019). In the case of cognition, previous studies suggest that mental fatigue decreases response speed and accuracy when performing cognitive tasks (De Jong et al., 2020; Van Cutsem et al., 2022). The mechanism underlying the detrimental effects of mental fatigue on cognitive performance remains open to lively debate. A number of accounts have been proposed, including motivational control theory, underload theory, resource depletion theory, and the neurotoxic waste disposal hypothesis (for review, see Wu et al., 2024).

To the best of our knowledge, the present studies are the first to confirm fatigue-related detrimental effects on aerobic endurance, strength (muscular) endurance, and cognitive performance in older adults. Such impairments may increase the risk of falls and accidents (Salihu et al., 2024; Shaik et al., 2016), leading to health problems and health care costs. They may also decrease older adults' quality of life, well-being, and independence (Toledano-González et al., 2019). Therefore, countermeasures to tackle the problem of mental fatigue in older adults are needed (e.g., Díaz-García et al., 2025).

Aging and Performance

Study 1 confirmed that aging is detrimental to cognitive and physical performance. Previous studies have reported age-related declines in physical (Hunter et al., 2016; Melsæter et al., 2022) and cognitive (Harada et al., 2013) performance. As previously explained, impairments in neuromuscular and brain functioning have been suggested for this finding. Study 1 is the first to add an age-related gradual exacerbation in the detrimental effects of mental fatigue on physical and cognitive performance in older adults. A possible explanation for this phenomenon is the higher mentally fatiguing and demanding nature of the same task among older adults (Hess & Ennis, 2012). Mechanistic studies should explore the reason(s) for the observed effects. Our findings highlight the importance of tackling mental fatigue in older adults. A systematic review suggests the effectiveness of various interventions to tackle the effects of mental fatigue in the short-term (Proost et al., 2022). Long-term interventions need to be developed, adapted, and evaluated in older adults.

Habitual Physical Activity and Performance

Study 2 confirmed that habitual physical activity counteracts the detrimental effects of aging on cognitive and physical performance. This is expected, given that regular physical activity can counter sarcopenia, prevent muscle loss, and maintain cognitive functioning (Escriche-Escuder et al., 2021; Stillman et al., 2020). A possible explanation for our finding would be an adaptation to the cognitively demanding nature of physical activity because brisk walking and jogging impose increased cognitive demands, such as self-pacing, and monitoring. This finding resembles that observed with combined exercise and cognitive training, such as brain endurance training (Dallaway et al., 2024; Díaz-García et al., 2024). This novel training method, where demanding cognitive tasks are added to standard exercise tasks, further helps (when compared to standard physical activity training) people deal with mental fatigue. Its beneficial effects have been explained by the adaptations caused by the higher cognitive load (i.e., larger stimulus) associated with combined training. Similarly, older adults who perform habitual physical activity can be expected to experience movement-related cognitive demands than sedentary people. This may explain why Study 2 found that active older adults were more resilient against mental fatigue and its effects compared with sedentary older adults. However, research is needed that replicates these findings and extends them with process measures to identify the underlying mechanism(s).

Limitations

Our studies yielded some novel and important findings that can help understand older adults' cognitive and physical performance. Their interpretation should consider potential methodological issues. First, only men were tested in Study 1. Future studies should replicate the findings in older sedentary women. Second, Study 1 did not test performance under control (rested) conditions on a separate session/day. Instead, we evaluated performance under control (rested) and mentally fatigued conditions in the same session. We adopted this single session design for convenience. Future studies should adopt a double session cross-over design like Study 2. Third, we assessed mental fatigue using subjective ratings. Future studies should include other markers of mental fatigue such physiological responses to better capture changes in mental fatigue. Finally, we examined relatively few tasks that were performed in the same fixed order for all participants. Future studies could assess batteries of tasks, with the order of testing counterbalanced across participants.

Practical Applications

The present studies demonstrate that mental fatigue can impair cognitive and physical performance in older adults. A state of mental fatigue may increase their risk of falls and accidents therefore we suggest countermeasures to mitigate the detrimental effects of mental fatigue. Short-term options include the consumption of caffeine and music (Proost et al., 2022). Long-term options include regular physical activity and combined cognitive and exercise training, such as brain endurance training. This combined cognitive and exercise training method can help develop mental fatigue resilience and tackle the detrimental effects of mental fatigue on cognitive and physical performance in young adults (Dallaway et al., 2021; Díaz-García et al., 2023; Staiano et al., 2022). The beneficial effects of brain endurance training have recently been confirmed in sedentary older adults (Díaz-García et al., 2025).

Conclusions

The present studies provide evidence confirming that performance of a broad range of classic cognitive and exercise tasks deteriorates with aging in older adults. They also provide novel evidence that mental fatigue impairs cognitive and physical performance in older adults, and, moreover, that these impairments increase with age and decrease with habitual physical activity. Taken together, the findings suggest that cognitive and/or exercise training interventions could help mitigate age-related deterioration in performance.

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