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Review

Mental fatigue in older adults: A narrative review of subjective, behavioral, neurophysiological, and physical changes

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HIGHLIGHTS

- **Distinct neurophysiological signatures of mental fatigue in older adults**Older adults exhibit delayed information processing rather than decreased task engagement, as seen in younger adults. This suggests age-specific brain adaptations to mental fatigue.
- **Postural balance is impaired despite preserved functional performance**Mental fatigue increases postural sway and alters gait mechanics in older adults, especially during dual-task conditions, without affecting standard functional tests. This indicates that subtle balance deficits may go undetected by traditional clinical assessments.
- **The loss of muscular strength after the fatiguing task appears to be associated with cortical mechanisms**Reduced maximal strength following mentally fatiguing tasks in older adults primarily results from changes in cortical inhibition rather than muscle contractility.
- **Physical and cognitive training may attenuate the effects of mental fatigue**Brain endurance training, which combines cognitive and physical exercises, reduces the negative effects of mental fatigue on both cognitive and physical performances in sedentary older adults.

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ABSTRACT

Mental fatigue is a frequently reported symptom in older adults, affecting their daily functional abilities. It is a psychobiological state induced by prolonged or intense cognitive tasks, characterized by a subjective feeling of exhaustion and lack of energy. While mental fatigue effects are well-documented in young adults, its influence on older adults remains unclear. This narrative review investigated the effects of mental fatigue on subjective, behavioral, neurophysiological, and physical parameters in older people. A literature search was conducted in PubMed, Web of Science and PsycINFO databases, and 28 studies met eligibility criteria. The results indicated that subjective mental fatigue increases after a mentally fatiguing task, regardless of task and duration. Meanwhile, behavioral performance evolution is relatively heterogeneous depending on the studies. Neuromuscular and neurophysiological results suggest an involvement of cortical mechanisms in the onset of mental fatigue, explaining either the decrease in physical or cognitive performance or the emergence of compensatory strategies related to aging. Mental fatigue affects postural balance by increasing postural sway and altering gait biomechanics, especially during dual-tasking, without significantly impacting functional tests such as the Timed Up and Go or the 6-min Walking Test. Observed changes in brain activity suggest a slowing of information processing in older adults, contrasting with a more pronounced cognitive disengagement in young adults after fatigue tasks. These results highlight the importance of studying the neurophysiological mechanisms of mental fatigue in older adults, and mitigation strategies, such as physical and cognitive training, to limit mental fatigue effects in this population.

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1. Introduction

The current global population is increasingly aging. The number of people aged 65 and over is expected to rise from 703 million in 2019 to 1.549 billion in 2050, an increase of 120 % (Sandron, 2020), making aging a real public health issue. Aging is a progressive and irreversible process of biological, physiological, and functional changes that occur with age, leading to a decrease in adaptive capacities and an increase in vulnerability to diseases and the risk of mortality. The physical and cognitive effects of aging are well documented in the literature. Aging leads to a decrease in maximal strength, a reduction in muscle mass, and a decline in cardiorespiratory capacities (Aoyagi & Shephard, 1992; Betik & Hepple, 2008; Hunter et al., 2016). Cognitive declines associated with aging include reduced processing speed (Salthouse, 1987), impaired working memory (Salthouse & Babcock, 1991), and diminished executive functions—higher-order cognitive processes that govern goal-directed behavior, such as inhibition, planning, and decision-making (West, 1996). Despite these declines, aging may also involve adaptive neural reorganization mechanisms (Reuter-Lorenz & Park, 2010).

In older adults, mental fatigue is one of the most frequently reported symptoms that significantly impacts daily well-being (Meng et al., 2010). Mental fatigue is defined as a psychobiological state induced by prolonged and/or intense cognitive task performance, characterized by a subjective feeling of exhaustion and lack of energy (Boksem & Tops, 2008; Rozand & Lepers, 2017). Identifying the presence of mental fatigue has become a primary focus of studies addressing this topic. It is mainly assessed through subjective measures (e.g., analog scales, questionnaires), behavioral measures (e.g., reaction time, accuracy, eye movements), and/or physiological measures such as electroencephalography (EEG), functional magnetic resonance imaging (fMRI), neuromuscular measures (e.g., maximal voluntary contraction [MVC], endurance strength, muscle activity), near-infrared spectroscopy (NIRS) and oculometric measures (e.g., pupil diameter).

The detrimental effects of mental fatigue on cognitive and physical performances are well-known in young adult people. Cognitively, mental fatigue can lead to decreased attention (Boksem et al., 2006), impaired emotion regulation (Grillon et al., 2015), less effective decision-making (Guo et al., 2018), and disruptions in executive functions such as inhibition and planning (Kato et al., 2009). Physically, mental fatigue can reduce muscular and cardiorespiratory endurance, impair motor control, and negatively affect technical skills in sports (Pageaux & Lepers, 2018; Rozand & Lepers, 2017; Van Cutsem et al., 2017). These cognitive and physical deficits can have significant consequences in daily life, such as increasing the risk of road accidents (Dignes, 1995), medical errors (Tawfik et al., 2018), and reduced productivity at work (Ricci et al., 2007). Although the effects of mental fatigue in young adults are well-documented, they are less well-understood in older adults.

Studies on mental fatigue in older adults have aimed to better understand its impact on cognitive and physical capacities, with particular attention to balance in this population. This topic has attracted growing interest in recent years, as evidenced by an increasing number of publications. However, while the effects of mental fatigue are well documented in young adults, their impact on older individuals remains less well understood. Therefore, the objective of this review is to synthesize current knowledge on this topic by examining how mental fatigue affects the cognitive, physical, and balance-related capacities of older adults. Specifically, this review seeks to answer the following research question: How does mental fatigue influence these capacities in older adults, as assessed through subjective, behavioral, physiological, and balance-specific measurements? Addressing this question will provide a comprehensive understanding of the effects of mental fatigue in the aging populations and inform potential interventions to mitigate their impact.

2. Method

2.1. Eligibility criteria

To be included in this narrative review, the selected studies had to include an experimental protocol inducing mental fatigue in old participants (≥ 55 years). Studies exclusively on young populations (< 55 years) were excluded from this review, but those comparing the effects of mental fatigue between young and older participants were included. Although we included studies comparing young vs. older participants, the present review is not interested in this comparison per se but by the results obtained on the effects of mental fatigue on the aging population only. The studies had to be published in scientific journals written in French or English. No gender restrictions were applied.

2.2. Information sources and search strategy

The sources used in this review were the PubMed (Medline), Web of Science, and PsycINFO databases (all databases searched). The literature search included all works published up to January 2025. The complete search strategy for the three databases is shown in Table 1.

2.3. Study selection

In this review, we used PRISMA guidelines to select relevant articles. All articles were collected from all databases, and duplicates were eliminated using the open-source Mendeley software. All studies identified through these keyword searches were screened based on their titles and abstracts. After this initial filtering, the selected articles were thoroughly reviewed by the first author. As a result of this selection process, 28 articles were included in this review. The full study selection process is presented in Fig. 1.

2.4. Data extraction

The information extracted from the selected studies was divided into two parts: i) data encompassing the study design, participant demographics, methods used to induce mental fatigue, and the control task, and ii) the results of the effects of mental fatigue measured in each study, such as subjective data (perceived mental fatigue), behavioral data (reaction time, accuracy), neurophysiological data (electroencephalogram, prefrontal cortex activity), as well as physical measures (muscle strength, balance).

Table 1
Number of hits for the complete search strategy for the PubMed (Medline), Web of Science, and PsycINFO databases.

Database	Complete search strategy	Hits (01/01/2025)
PubMed (Medline)	(((((("mental fatigue") OR "cognitive fatigue") OR "mental exertion") OR "cognitive exertion") OR "mental exhaustion")) AND (((((("age") OR "aging") OR "old") OR "senior") OR "elderly"))	877
Web of Science	TS=(("mental fatigue" OR "cognitive fatigue" OR "cognitive exertion" OR "mental exertion" OR "mental exhaustion") AND ("age" OR "aging" OR "old" OR "senior" OR "elderly"))	826
PsycINFO	(((((("mental fatigue") OR "cognitive fatigue") OR "mental exertion") OR "cognitive exertion") OR "mental exhaustion")) AND (((((("age") OR "aging") OR "old") OR "senior") OR "elderly"))	650

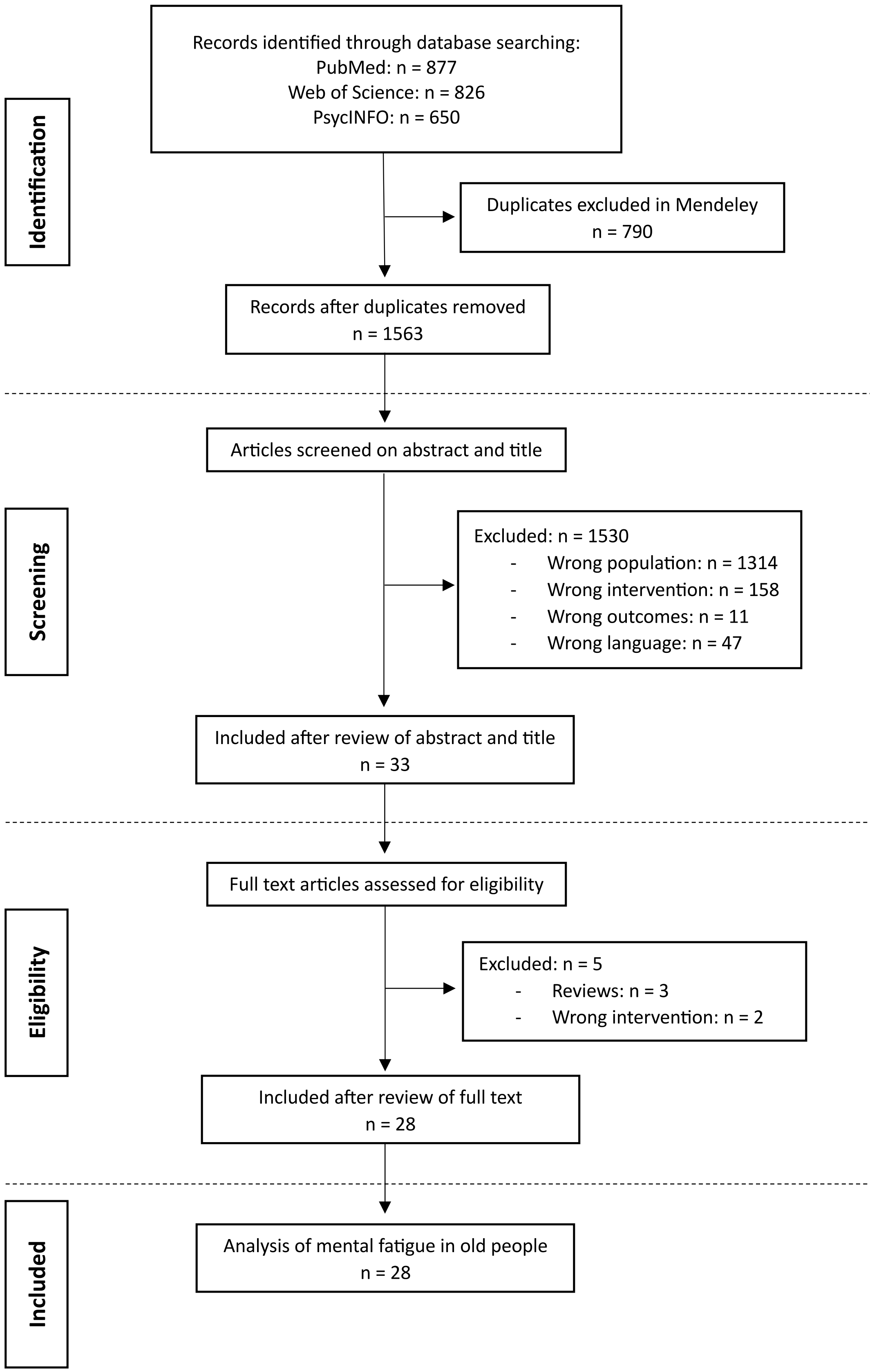

Fig. 1. Flow diagram of the reviewing method based on Prisma guidelines.

3. Results

3.1. Study characteristics

3.1.1. Participant characteristics

Table 2 synthesizes all information pertaining to participant characteristics. The study presenting the lowest mean age in older adults is de Jong et al., 2018 (57.8 ± 6.0 years) and the study presenting the higher mean age is Holtzer et al., 2011 (80.6 ± 4.9 years).

Whereas the lowest mean age of younger participants is 21.0 ± 1.0 years (Fletcher & Osler, 2021) and the higher mean age is 25.2 years (21–34; Pergher et al., 2019). Among the studies, 60 % conducted comparisons between older and younger participants, while 40 % focused exclusively on older participants.

3.1.2. Mental-fatigue task characteristics

Tables 2 and 3 synthesizes all information pertaining to the selected studies. The duration of mental fatigue protocols exhibited significant heterogeneity, ranging from 7 min (Shelton et al., 2011) to 180 min (Arnau et al., 2017; Babu et al., 2019). However, in a study, a large part of young and older participants could not complete the intended 180-min Stroop task (Babu et al., 2019). This suggests that a cognitively demanding task of 3 h may be excessively challenging, irrespective of age. Consequently, most studies have opted for task durations ranging from 60 to 90 min. The cognitively demanding tasks performed by participants varied across studies, predominantly involving the Stroop task ($n = 13$; Anderson et al., 2019; Babu et al., 2019; Burke et al., 2018; Faria et al., 2024; Fletcher & Osler, 2021; Gilsoul et al., 2022, 2024; Nikooharf Salehi et al., 2022; Ren et al., 2019; Santos et al., 2025; Shelton et al., 2011; Shortz et al., 2015; Shortz & Mehta, 2017), the N-back task ($n = 6$; Anderson et al., 2019; Pergher et al., 2019, 2021; Ren et al., 2019; Shortz & Mehta, 2017; Shortz et al., 2015), the Go/No-go task ($n = 2$; Falkenstein et al., 2002; Terentjeviene et al., 2018), the Psychomotor Vigilance Task (PVT; $n = 3$; Morris & Christie, 2020a, 2020b; Santos et al., 2025), the stop signal task ($n = 2$; Behrens et al., 2017; Varas-Diaz et al., 2020) or the typewriting-computer task ($n = 2$; de Jong et al., 2018; Marandi et al., 2018). Some other tests have also been used less frequently, such as left-or-right task (Arnau et al., 2017), red-or-blue task (Löffler et al., 2023), flanker task (Faria et al., 2024), visual stimuli task (Wascher & Getzmann, 2014), the attentional network test (Holtzer et al., 2011) or another mental fatigue protocol (Boolani et al., 2020).

3.1.3. Outcome characteristics

In these studies, mental fatigue was measured using four types of assessment. It was measured subjectively, where participants reported their perceived fatigue before and after the fatiguing task using scales or questionnaires (activation-deactivation adjective checklist [AD ACL], Karolinska sleeping scale [KSS], modified fatigue impact scale [MFIS], Piper fatigue scale [PFS], profile of mood states [POMS], visual analogue scale [VAS], NASA task load index [NASA-TLX], 18-item state cognitive fatigue, 9-point Likert scale). Behavioral data collected during the fatiguing task, such as reaction time (RT) or accuracy, were also used to quantify mental fatigue. RT is the latency time between the presentation of a stimulus (e.g., auditory, visual) and the response to that stimulus. Accuracy corresponds to the correctness of the response given after each stimulus by the participant during the task. The shorter the reaction time, the faster the response. Some researchers examined neurophysiological responses induced by mental fatigue during or after the task, such as brain EEG activity (Arnau et al., 2017; Babu et al., 2019; de Jong et al., 2018; Falkenstein et al., 2002; Löffler et al., 2023; Pergher et al., 2019; Wascher & Getzmann, 2014), prefrontal cortex activity by NIRS (Shortz et al., 2015; Terentjeviene et al., 2018) or motor evoked potentials (MEP) by transcranial magnetic stimulation (TMS; Morris & Christie, 2020b). Some researchers also analyzed physical responses induced by mental fatigue, such as handgrip strength (Shortz & Mehta, 2017; Shortz et al., 2015; Terentjeviene et al., 2018), handgrip endurance time (Shortz & Mehta, 2017; Shortz et al., 2015), muscle electromyographic (EMG) activity (Morris & Christie, 2020a; Santos et al., 2025; Shortz & Mehta, 2017; Shortz et al., 2015). Notably, researchers focused on balance parameters such as postural sway (Morris & Christie, 2020a; Nikooharf Salehi et al., 2022; Varas-Diaz et al., 2020), gait performance (Behrens et al., 2017; Fletcher & Osler, 2021; Santos et al., 2025) or functional balance (Boolani et al., 2020; Fletcher & Osler, 2021).

3.2. The effects of mental fatigue

3.2.1. Subjective mental fatigue steadily increases

Table 4 shows the effects of a cognitively demanding task on the subjective perception of mental fatigue. In all the studies that measured it, participants perceived an increase in mental fatigue after the cognitively fatiguing task, whether in pre/post comparisons (Anderson et al., 2019; Arnau et al., 2017; Burke et al., 2018; de Jong et al., 2018; Gilsoul et al., 2022, 2024; Marandi et al., 2018; Morris & Christie, 2020b; Ren et al., 2019; Santos et al., 2025) or compared to a control session (Behrens et al., 2017; Boolani et al., 2020; Faria et al., 2024; Fletcher & Osler, 2021; Morris & Christie, 2020a; Nikooharf Salehi et al., 2022; Shortz & Mehta, 2017; Shortz et al., 2015; Varas-Diaz et al., 2020).

However, most studies did not find a significant difference in subjective mental fatigue between young and older participants (Arnau et al., 2017; Behrens et al., 2017; Fletcher & Osler, 2021; Gilsoul et al., 2022; Morris & Christie, 2020a; Santos et al., 2025; Shortz & Mehta, 2017; Shortz et al., 2015). Only two out of the 19 studies evaluating subjective mental fatigue showed that perceived subjective mental fatigue increased more in young participants than older ones (Morris & Christie, 2020a, 2020b). Young participants also showed a greater decrease in intrinsic motivation to complete the task compared to older participants (Terentjeviene et al., 2018). For older individuals, perceived mental fatigue could increase less for the same task when performed in blocks with breaks (Gilsoul et al., 2022). Within the older population, there is greater interindividual variability in the subjective mental fatigue perception induced by the mentally fatiguing tasks than within young people. In other words, some older individuals would experience significant subjective fatigue, while others would perceive low fatigue for the same task (Ren et al., 2019).

3.2.2. Behavioral outcomes

Table 4 shows the behavioral outcomes of the effects of a cognitively demanding task in older adults. During a mentally fatiguing task, the evolution over time of behavioral data (RT, accuracy) varies across studies. Some authors have demonstrated either a maintenance (Falkenstein et al., 2002; Faria et al., 2024; Pergher et al., 2021) or an increase (Arnau et al., 2017; Burke et al., 2018; Pergher et al., 2019; Nikooharf Salehi et al., 2022; Shelton et al., 2011) in RT among older adults. Interestingly, some interventions have shown potential to mitigate these effects. For example, one study applied transcranial alternating current stimulation (tACS) using two electrodes positioned at Cz and Oz on the EEG cap and found that this technique significantly reduced the increase in RT during a mentally fatiguing task (Löffler et al., 2023). This suggests that tACS may be a promising method to modulate behavioral effects of mental fatigue in older population, but this effect has to be replicated. Moreover, (Gilsoul et al., 2022) suggested that segmenting a fatiguing mental task into shorter time blocks, rather than performing it continuously, can also reduce the onset or intensity of mental fatigue, possibly by allowing partial recovery of cognitive resources between segments. These approaches may therefore represent promising strategies for modulating the behavioral consequences of mental fatigue in older adults. Furthermore, it appears that the efficiency of exploring new stimuli in the environment was reduced following a mentally fatiguing task in older adults (Wascher & Getzmann, 2014).

Table 2
Description of study protocols used in the literature to analyze mental fatigue effects in old people.

Authors	Study design	Population (n)	Gender	Age mean (SD or range)	Cognitive task	Control task	Task duration (min)	Measure time	Measure characteristics
Anderson et al. (2019)	Within group design	Healthy older adults (52)	$W = 36$; $M = 16$	71.0 (5.1)	Stroop + Dual 1-back task	Ø	30	Pre-post and ToT	18-item state CF, fMRI
Arnau et al. (2017)	Within group design	Healthy older adults (14) Healthy young adults (13)	$W = 6$; $M = 8$ $W = 8$; $M = 5$	64.0 (56–70) 24.0 (20–30)	Visual stimuli task	Ø	180	Pre-post and ToT	9-pt Likert scales, RT, accuracy, EEG
Babu et al. (2019)	Within group design	Healthy older adults (18) Healthy young adults (16)	$W = 7$; $M = 11$ $W = 9$; $M = 7$	(60–87) (18–33)	Stroop task	Ø	180	ToT	RT, CVRT, error rate, EEG
Behrens et al. (2017)	Within group design	Healthy older adults (16) Healthy young adults (16)	N.A.	N.A.	Stop signal task	Watching documentary	90	Pre-post	MFIS, POMS, Balance
Boolani et al. (2020)	Within group design	Healthy older adults (11)	$W = 7$; $M = 4$	62.8 (4.6)	CPT + RVIP + FTT + TMT	Rest	30	Pre-post	POMS, 30 s CST, TUG, BBS
Burke et al. (2018)	Within group design	Healthy older adults (35)	$W = 21$; $M = 14$	73.8 (5.9)	Stroop task	Ø	160	Pre-post and ToT	PFS, MFIS, RT, accuracy, pupil diameter
de Jong et al. (2018)	Within group design	Healthy middle aged (24) Healthy young adults (24)	$W = 13$; $M = 11$ $W = 16$; $M = 8$	57.8 (6.0) 22.4 (3.4)	Typewriting + mouse targeting task	Ø	120	Pre-post and ToT	AD ACL, RT, accuracy, EEG
Falkenstein et al. (2002)	Within group design	Healthy older adults (12) Healthy young adults (12)	$W = 6$; $M = 6$ $W = 6$; $M = 6$	58.3 (54–65) 22.5 (19–25)	Go/Nogo task	Ø	2 × 30	ToT	RT, error rate, EEG
Faria et al. (2024)	Within group design	Healthy older adults (35)	$W = 26$; $M = 9$	N.A.	Flanker test + Stroop task	Watching documentary	30 + 10 + 10	Pre-post and ToT	VAS, enjoyment, 10RM leg press, 6MWT, TUG
Fletcher and Osler (2021)	Within group design	Healthy older adults (10) Healthy young adults (10)	$W = 6$; $M = 4$ $W = 4$; $M = 6$	74.0 (6.0) 21.0 (1.0)	Incongruent Stroop task	Reading	25	Pre-post	MF, Balance ST and DT
Gilsoul et al. (2024)	Within group design	Healthy older adults (17) Healthy middle aged (17) Healthy young adults (21)	$W = 8$; $M = 9$ $W = 10$; $M = 7$ $W = 13$; $M = 8$	65.1 (3.2) 50.5 (6.4) 22.4 (2.0)	Stroop task	Ø	160	Pre-post and ToT	KSS, VAS, RT ex-gaussian distribution: μ and τ
Gilsoul et al. (2022)	Between group design	Healthy older adults (36) Healthy middle aged (36) Healthy young adults (42)	$W = 18$; $M = 18$ $W = 20$; $M = 16$ $W = 22$; $M = 20$	67.5 (3.7) 50.4 (6.1) 22.3 (2.2)	Stroop task with or without break	Ø	160 or 4 × 40	Pre-post and ToT	VAS, KSS, RT ex-gaussian distribution: τ
Holtzer et al. (2011)	Within group design	Healthy older adults (228)	$W = 139$; $M = 89$	80.6 (4.9)	Attentional network test	Ø	35	ToT	RT
Löffler et al. (2023)	Between group design	Healthy older adults (48) SHAM = 15, 5 Hz = 15, 40 Hz = 18	$W = 23$; $M = 25$	72.1 (5.1)	Red-or-blue task with brain stimulation	Red-or-blue task without brain stimulation	30 + 30	Pre-post and ToT	RT, EEG
Marandi et al. (2018)	Within group design	Healthy older adults (18) Healthy young adults (20)	$W = 11$; $M = 7$ $W = 9$; $M = 11$	58.0 (7.0) 23.0 (3.0	Prolonged functional computer task	Ø	40	ToT	Eye tracking
Morris and Christie (2020a)	Within group design	Healthy older women (16) Healthy young women (16)	$W = 16$ $W = 16$	72.6 (1.6) 22.4 (0.9)	PVT	Watching nature video	20	Pre-post	MFIS, EMG, Postural sway
Morris and Christie (2020b)	Within group design	Healthy older women (16) Healthy young women (9)	$W = 16$ $W = 9$	74.1 (6.3) 22.4 (2.9)	PVT	Ø	20	Pre-post and ToT	SF, RT, accuracy, MVC, EMG, TMS
Nikooharf Salehi et al. (2022)	Between group design	Experimental: Healthy older adults (20)	$W = 10$; $M = 10$ $W = 10$; $M = 10$	66.6 (3.4) 64.1 (4.6)	Stroop task	Watching documentary	30	Pre-post and ToT	VAS, RT, BBSy

(continued on next page)

Table 2 (*continued*)

Authors	Study design	Population (n)	Gender	Age mean (SD or range)	Cognitive task	Control task	Task duration (min)	Measure time	Measure characteristics
		Control: Healthy older adults (20)							
Pergher et al. (2021)	Within group design	Healthy older adults (16) Healthy young adults (23)	$W = 8$; $M = 8$ $W = 14$; $M = 9$	62.1 (52–69) 24.8 (19–34)	N-back task	Ø	60	ToT	RT, accuracy
Pergher et al. (2019)	Within group design	Healthy older adults (18) Healthy young adults (20)	$W = 12$; $M = 6$ $W = 12$; $M = 8$	60.4 (54–69) 25.2 (21–34)	N-back task	Ø	60	Pre-post and ToT	RT, accuracy, EEG
Ren et al. (2019)	Within group design	Healthy older adults (46)	$W = 31$; $M = 15$	71.5 (5.3)	Dual 1-back + Stroop task	Ø	30	Pre-post and ToT	VAS, IIVRT, fMRI
Santos et al. (2025)	Within group design	Healthy older adults (12) Healthy young adults (12)	$W = 5$; $M = 7$ $W = 5$; $M = 7$	71.0 (3.76) 22.5 (1.7)	PVT + AX-CPT + Stroop task	Ø	30	Pre-post and ToT	VAS, RT, accuracy, EMG, balance gait
Shelton et al. (2011)	Within group design	Healthy older adults (91)	$W = 61$; $M = 30$	71.9 (60–85)	Stroop task	Ø	7	Pre-post and ToT	RT, accuracy
Shortz and Mehta (2017)	Within group design	Healthy older women (10) Healthy young women (10)	$W = 10$; $M = 0$ $W = 10$; $M = 0$	75.9 (7.8) 24.1 (1.8)	Stroop + Dual 1-back or concurrent mental task during exercises	Watching documentary	60	Pre-post and ToT	POMS, NASA TLX, MVC, endurance, EMG
Shortz et al. (2015)	Within group design	Healthy older women (11)	$W = 11$; $M = 0$	78.8 (7.4)	Stroop task + Dual 1-back task	Watching documentary	60	Pre-post and ToT	POMS, MVC, endurance time, PFC activity
Terentjeviene et al. (2018)	Within group design	Healthy older women (15) Healthy young women (15)	$W = 15$; $M = 0$ $W = 15$; $M = 0$	72.7 (5.7) 22.2 (2.7)	Go/Nogo task	Ø	120	Pre-post and ToT	NASA TLX, IIVRT, accuracy, TMS, strength, PFC activity
Varas-Diaz et al. (2020)	Between group design	Experimental: Healthy older adults (30) Experimental = 15, control = 15	$W = 19$; $M = 11$	67.6 (7.1)	Stop signal task	Watching documentary	60	Pre-post	NASA TLX, postural sway, HRV
Wascher and Getzmann (2014)	Within group design	Healthy older adults (12) Healthy young adults (12)	N.A.	62.2 (54–66) 24.0 (22–28)	Visual stimuli task	Ø	80	ToT	RT, error rate, EEG

AD ACL = activation-deactivation adjective checklist; AX-CPT = AX continuous performance task; BBS = Berg balance scale; BBSy = Biodex balance system; CF = cognitive fatigue; CPT = continuous performance task; CVRT = coefficient of variation of reaction time; DT = double task; EEG = electroencephalography; EMG = electromyography; fMRI = functional magnetic resonance imaging; FTT = finger tapping task; HRV = heart rate variability; IIVRT = intraindividual variation of reaction time; KSS = Karolinska sleeping scale; MF = mental fatigue; MFIS = modified fatigue impact scale; MVC = maximal voluntary contraction; N.A. = not available; NASA TLX = NASA task load index; PFC = prefrontal cortex; PFS = Piper fatigue scale; POMS = profile of mood states; PVT = psychomotor vigilance task; RM = repetition maximum; RT = reaction time; RVIP = rapid visual input processing; SF = subjective fatigue; ST= single task; TMS = transcranial magnetic stimulation; TMT = trail-making test; ToT = time on task; TUG = timed up and go; VAS = visual analogue scale; 30 s CST = 30-s chair stand test; 6MWT = 6-min walking test.

Comparative analyses of RT performance between young and older adults have yielded varying results. Some studies reported an equivalent increase in RT (Santos et al., 2025) or an equivalent stagnation (Morris & Christie, 2020b) between young and older participants. Some studies have reported a greater increase in RT among older adults compared to younger adults (de Jong et al., 2018; Gilsoul et al., 2024; Marandi et al., 2018), while others have observed no change in older adults and an increase in younger adults (Babu et al., 2019; Morris & Christie, 2020a), particularly in the intraindividual variability of RT (IIVRT; Terentjeviene et al., 2018), which is correlated with mental fatigue (Ren et al., 2019).

Four distinct behavioral patterns (RT and accuracy combined) have been observed in older adults during the mental fatigue task. In some studies, the increase in RT was accompanied by a decrease in accuracy (Arnau et al., 2017; Burke et al., 2018; Pergher et al., 2019; Shelton et al., 2011) or maintenance of accuracy (de Jong et al., 2018; Gilsoul et al., 2024; Santos et al., 2025). In other studies, the maintenance of RT was accompanied by maintenance of accuracy (Falkenstein et al., 2002; Faria et al., 2024; Morris & Christie, 2020b) or a decrease in accuracy (Pergher et al., 2021; Terentjeviene et al., 2018).

3.2.3. *Physiological outcomes*

Table 5 shows the physiological outcomes of the effects of a cognitively demanding task. The analysis of brain activity using the EEG system allows for the measurement of event-related potentials (ERPs). ERPs are electrical responses of the brain triggered by a specific stimulus, such as a sound, an image, or a tactile stimulation. ERPs are measurable brain activities that reflect the sensory, cognitive, or motor processing of the stimulus. ERPs are defined by their amplitude (the magnitude of the electrical signal) and their latency (the delay between the onset of stimulus presentation and the appearance of the ERP). In older adults, no variation of ERP amplitude in the late period of stimulation processing (300-1000 ms) was observed during the mentally fatiguing task (Babu Henry Samuel et al., 2019). During a cognitively fatiguing task, two studies have reported a decrease in P3 amplitude only in young adults (Wascher & Getzmann, 2014), while no change—or only a modest reduction—was observed in older adults (Falkenstein et al., 2002). P3 (or P300) is an event-related potential (ERP) component

Table 3
Mental fatigue tasks used in mental fatigue research among older adults.

Task name (studies number)	Description	Purpose
Stroop Incongruent or mixed congruent/ incongruent trials (13)	Participants are asked to name the ink color of words that may denote a conflicting color (e.g., the word "red" printed in blue ink).	Assesses cognitive inhibition and sustained attention.
N-back task (6)	A sequence of stimuli (e.g., letters, shapes) is presented and participants must indicate when the current stimulus matches one presented "n" items before (commonly 2- or 3-back).	Taxing working memory, cognitive updating, and sustained attention over time.
Go/No-go task (2)	Respond to frequent "Go" signals and withhold response on infrequent "No-go" trials.	Measures response inhibition and attentional flexibility; aims to fatigue inhibitory control.
Psychomotor vigilance task (3)	Visual stimuli appear at random intervals (2–10 s), and participants respond as quickly as possible.	Tests sustained attention and vigilance over time; sensitive to fatigue-related performance decline.
Stop task signal (2)	Participants initiate a response to a "Go" signal but must try to inhibit the action when a stop signal appears after a variable delay.	Evaluates reactive inhibition and control processes under fatigue-inducing conditions.
Typewriting-computer task (2)	Participants perform continuous typing tasks (e.g., copying text) or mouse targeting task.	Engages motor-attentional coordination and cognitive effort over time, promoting mental fatigue through repetitive processing.
Left-or-right task (1)	Simple decision-making task where directional stimuli require a left or right button press, delivered rapidly and repeatedly.	Assesses decision-making speed and sustained response accuracy under fatigue.
Red-or-blue task (1)	Visual task involving rapid color discrimination with repeated red or blue stimuli.	Targets visual discrimination and attentional consistency during prolonged effort.
Flanker task (1)	A central target (e.g., <) is flanked by congruent (e.g., <) or incongruent stimuli (e.g., >), requiring inhibition of irrelevant information.	Measures selective attention and interference control under sustained load.
Visual stimuli task (1)	Participants respond to specific visual cues or shapes over multiple trials, often with variable timing or embedded targets.	Evaluates visual processing speed and sustained perceptual engagement.
Attentional network test (1)	Combines cueing, Flanker, and Go/No-go components to assess alerting, orienting, and executive control networks.	Differentiates which attention networks are most impacted by mental fatigue.
Combined protocol (1)	Integrates two or more cognitive tasks (e.g., Stroop + Flanker) performed back-to-back or simultaneously.	Explores cumulative fatigue effects across multiple cognitive domains and interaction effects.

that typically occurs around 300 ms following stimulus onset and is associated with attentional resource allocation and working memory updating. In younger adults, a decline in P3 amplitude over time-on-task (ToT) has been interpreted as a reduced cognitive engagement and a diminished allocation of attentional resources (de Jong et al., 2018), potentially reflecting a strategic withdrawal from effortful processing when the cost-benefit ratio becomes unfavorable (Boksem & Tops, 2008; Hopstaken et al., 2016). This modulation suggests that young adults may disengage from cognitively fatiguing tasks to conserve cognitive

Table 4
Subjective and behavioral outcomes after mental fatigue task (time effect or interaction effect × age).

Authors	Subjective outcomes	Behavioral outcomes	
	Subjective mental fatigue	Reaction time	Accuracy
Anderson et al. (2019)	↗		
Arnau et al. (2017)	↗	↗	↘
Babu et al. (2019)		≈ (old); ↗ (young)	≈
Behrens et al. (2017)	↗		
Boolani et al. (2020)	↗		
Burke et al. (2018)	↗	↗	↘
de Jong et al. (2018)	↗	↗ (old); ≈ (young)	≈ (old); ↘ (young)
Falkenstein et al. (2002)		≈	≈
Faria et al. (2024)	↗	≈	≈
Fletcher and Osler (2021)	↗		
Gilsoul et al. (2024)	↗	μ: ↗ (more for old) τ: ↗ (middle-aged)	≈
Gilsoul et al. (2022)	↗ more with no break	τ: ↗ (young and middle-aged)	
Holtzer et al. (2011)		2 groups detected: RT ↘ and RT ↗	
Löffler et al. (2023)		Less ↗ with BS	
Marandi et al. (2018)	↗	↗ (old); ≈ (young)	
Morris and Christie (2020a)	↗	≈ (old); ↗ (young)	
Morris and Christie (2020b)	↗ (but MF old < MF young)	≈	≈
Nikooharf Salehi et al. (2022)	↗	↗	
Pergher et al. (2021)		≈	↘ (old)
Pergher et al. (2019)		↗	↘
Ren et al. (2019)	2 groups detected low MF + high MF	IIVRT positively correlated with MF	
Santos et al. (2025)	↗ (but no age × time interaction)	↗ (but no age × time interaction)	≈
Shelton et al. (2011)		≈	≈
Shortz and Mehta (2017)	↗		
Shortz et al. (2015)	↗		↘
Terentjeviene et al. (2018)		IIVRT ↗ (young)	↘
Varas-Diaz et al. (2020)	↗		
Wascher and Getzmann (2014)		IOR ↘ (old)	≈

IIVRT = intraindividual variation of reaction time; IOR = inhibition of return; MF = mental fatigue; RT = reaction time; μ = mean; τ = overall skewness of the distribution.

resources for more rewarding contexts.

In contrast, P3 amplitude remains relatively stable in older adults, despite increased mental fatigue, suggesting either a reduced capacity for dynamic resource reallocation or a sustained task engagement strategy. Wascher and Getzmann (2014) proposed that older adults may lack efficient compensatory mechanisms during prolonged cognitive effort, which could account for their reduced neural adaptability over time. However, this interpretation contrasts with findings from Falkenstein et al. (2002), who reported preserved performance and inhibitory control in older adults despite prolonged task engagement, suggesting a more conservative but stable cognitive control strategy, possibly reflecting a resistance to fatigue-induced decline.

With respect to P3 latency, older adults consistently exhibited longer latencies compared to their younger counterparts (de Jong et al., 2018), reflecting age-related slowing in stimulus evaluation and decision-making processes. This increased latency may indicate reduced processing speed, which becomes more pronounced under fatigue. De Jong et al. (2018) interpreted the dissociation between age groups—namely, the reduction in P3 amplitude among younger adults and the latency increase in older adults—as evidence for age-dependent fatigue effects. Specifically, mental fatigue in younger adults may lead to a qualitative reduction in attentional processing efficiency, whereas in older adults, the primary impact may be a general slowing of cognitive operations.

In studies observing band power, the mentally fatiguing task also induced a systematic increase in alpha power in the frontal region for both young (Arnau et al., 2017) and older adults (Arnau et al., 2017; Pergher et al., 2019). However, the variation in occipital alpha band power is less clear. One study showed an increase only in young people after 180 min of a left-or-right task (Arnau et al., 2017), while another showed an increase only in older adults after 60 min of an N-back task (Pergher et al., 2019). Additionally, a 30-min red-or-blue task protocol increased alpha band power in older adults (Löffler et al., 2023). In this case, using a brain stimulation protocol did not influence the variations in alpha band power. Theta band power also significantly increased during the fatiguing task, mainly for older adults (Arnau et al., 2017).

Two studies used fMRI, and one used TMS to understand the impact of mental fatigue on brain networks. The variation in connectivity of the right hemisphere insula and putamen appears to reflect mental fatigue (Anderson et al., 2019). When mental fatigue is significant, a decrease in corticostriatal network connectivity has been observed (Ren et al., 2019). Although these results showed a decrease in brain connectivity with mental fatigue, the latter does not seem to impact the amplitude of MEP or the cortical silent period after 20 min of PVT (Morris & Christie, 2020b). Two other studies showed a decrease in prefrontal cortex activity by NIRS (Shortz et al., 2015; Terentjeviene et al., 2018) after the fatiguing mental task.

In addition to its effects on brain function, performing a cognitively fatiguing task may also affect older adults at a neuromuscular level. Studies showed that mental fatigue tasks induced a decrease in the MVC force of handgrip in older adults (Shortz & Mehta, 2017; Terentjeviene et al., 2018) or of dorsiflexion foot in young and older adults (Morris & Christie, 2020b). After 60 min of a fatiguing task (Stroop + Dual 1-back), the decrease in MVC handgrip was greater in young individuals compared to older adults (Shortz & Mehta, 2017). Moreover, the impact

Table 5
Neurophysiological outcomes after mental fatigue task (time effect or interaction time × age).

	EEG					fMRI
Authors	P3 amplitude	P3 fractional area latency	Alpha band power	Theta band power	Late period of stimulation processing	Connectivity
Anderson et al. (2019)						Right hemisphere insula putamen connectivity reflects MF
Arnau et al. (2017)			Frontal: ↗ (old, young) Occipital: ↗ (young)	Frontal: ↗ more with aging Occipital: ↗ (old)		
Babu et al. (2019)					Occipito-temporal: ↘ (young) Centro-frontal: ↗ (young)	
de Jong et al. (2018)	↘ more for young than old with ToT	↗ more for old than young with ToT				
Falkenstein et al. (2002)	≈					
Löffler et al. (2023)			↗ (No stimulation effect)			
Pergher et al. (2019)			Occipital and prefrontal: ↗ (old)			
Ren et al. (2019)						Corticostriatal network connectivity ↘ with high MF
Wascher and Getzmann (2014)	↘ (young)					

	Neuromuscular outcomes			Other physiological outcomes		
	MVC	Endurance strength	Muscle activity	Prefrontal cortex activity (NIRS)	Pupil diameter	Cardiovascular responses
Burke et al. (2018)					↘	
Faria et al. (2024)		≈				
Marandi et al. (2018)					↗	
Morris and Christie (2020a)			EMG onset time MG ↗			
Morris and Christie (2020b)	↘ (but no age × time interaction)		≈			
Santos et al. (2025)			Wavelet-based time frequency intermuscular β band coherence ↗ (but no age effect)			
Shortz and Mehta (2017)	↘ more for young than old	≈ (MF) Old: ↘ (concurrent task)	ECR/FCR ratio ↗			HR ↗ (concurrent task)
Shortz et al. (2015)	≈	≈	EMG FCR ↗	↘		HR ↗
Terentjeviene et al. (2018)	↘			↘		HF power ↘

ECR = extensor carpi radialis; EMG = electromyography; FCR = flexor carpi radialis; fMRI = functional magnetic resonance imaging; HF = high frequency; HR = heart rate; MF = mental fatigue; MG = medial gastrocnemius; NIRS = near-infrared spectroscopy; ToT = time on task.

of mental fatigue on handgrip strength endurance time is well-known in older people. Two studies showed that handgrip strength endurance time was similar following 60 min of Stroop + Dual 1-back in older adults (Shortz & Mehta, 2017; Shortz et al., 2015). A decrease in handgrip strength endurance time appears only when a concurrent task is used (Shortz & Mehta, 2017). The authors found an increase in flexor carpi radialis (FCR) EMG (Shortz et al., 2015), extensor carpi radialis (ECR)/ FCR ratio (Shortz & Mehta, 2017), and medial gastrocnemius (MG; Morris & Christie, 2020a) following the mentally fatiguing task. To complement this EMG data, a study showed an increase in wavelet-based time-frequency intermuscular beta-band coherence with the onset of mental fatigue (Santos et al., 2025). An increase in this data suggests a greater involvement of supraspinal structures (cortical and subcortical) in gait control after mental fatigue (Santos et al., 2025).

3.2.4. Balance outcomes

We decided to dedicate an entire section to balance parameters because eight of twenty-eight studies (28.6 %) have investigated the impact of mental fatigue on postural balance and gait. Table 6 shows the balance outcomes of the effects of a cognitively demanding task. Three of these studies found an increase in postural sway in older adults (Morris & Christie, 2020a; Nikooharf Salehi et al., 2022; Varas-Diaz et al., 2020), with no significant difference between single task (ST)—participant is focused on the walking task, with no additional cognitive demands—and dual-task (DT) conditions—participant walks while simultaneously performing an additional cognitive task (Morris & Christie, 2020a). However, the DT increased the coefficient of variation of speed and stride length in older adults (Behrens et al., 2017). An increase in sway path length (+32 %) was also observed after 25 min of an incongruent Stroop task in older adults (Fletcher & Osler, 2021). However, the biomechanical changes observed during the treadmill gait analysis after a 30-min PVT were similar between young and older participants, as a decrease in stand time and stride length, but an increase in cadence and variability of stride length has been observed (Santos et al., 2025). Mental tasks did not induce variations in the 30-s chair stand test (30 s CST), 6-min walking test (6MWT) and timed up and go (TUG) tests in older adults but has led to a decrease in the Berg balance scale (BBS; Boolani et al., 2020; Faria et al., 2024).

Table 6
Balance outcomes after mental fatigue task (time effect or age × time interaction).

	Balance outcomes		
	Postural sway	Gait performance	Functional balance
Behrens et al. (2017)		DT: ↗ coefficient of variation of speed and stride length (old)	
Boolani et al. (2020)			30 s CST and TUG: ≈ BBS: ↘
Faria et al. (2024)			6MWT and TUG: ≈
Fletcher and Osler (2021)	Sway path length: +32 % (old)		≈
Morris and Christie (2020a)	↗ (ns between ST and DT)		
Nikooharf Salehi et al. (2022)	↗		
Santos et al. (2025)		↘ stance time, ↘ stride length, ↗ cadence, ↗ variability of stride length (but no age × time interaction)	
Varas-Diaz et al. (2020)	↗		

BBS = Berg balance scale; DT = double task; ns = not significant; ST = single task; TUG = timed up and go; 30 s CST = 30-s chair stand test; 6MWT = 6-min walking test.

4. Discussion

This narrative review aimed to synthesize knowledge on the effects of a cognitively fatiguing task on subjective fatigue and behavioral, physiological, and physical components in older adults. Mental fatigue induced by prolonged cognitive tasks increases subjective fatigue in older adults. Its impact on behavioral and physiological parameters varies with aging. While maximal strength decreases after demanding cognitive tasks, muscle endurance generally seems preserved in old adults. This maximal strength reduction appears primarily linked to changes in cortical mechanisms rather than alterations in muscle contractile properties. Additionally, observed changes in brain activity indicate a slowing of information processing in older adults, contrasting with a more pronounced cognitive disengagement in younger adults.

4.1. Methods used to induce mental fatigue

In the 28 studies included in this review, the task used to induce mental fatigue primarily involved the Stroop task (n = 13) and the N-back task (n = 6). The Stroop task mainly included a combination of both congruent and incongruent trials (72.3 %) or exclusively incongruent trials (27.7 %). The latter is an effective method for inducing mental fatigue in older adults. In the incongruent Stroop task, participants see color words written in ink colors different from the color words. This task is more challenging than when the word and ink color are congruent. It requires response inhibition, making it cognitively demanding and requiring significant selective attention. The incongruent Stroop induces more mental fatigue in older adults because it involves executive functions, which decline significantly with age, mainly due to changes in brain connectivity (Fjell et al., 2017). Some protocols also used a combination of two tasks (n = 6; 21.4 %) or more tasks (n = 2; 7.1 %) to induce mental fatigue. The main combination of the two tasks consists of the Stroop task and the N-back task (n = 4; 66.7 %; Anderson et al., 2019; Ren et al., 2019; Shortz & Mehta, 2017; Shortz et al., 2015). Meanwhile, two other combinations have been used, such as the "Flanker task + Stroop task" (Faria et al., 2024) and the "Mouse target task + Typing task" (de Jong et al., 2018). One protocol used three tasks to induce mental fatigue, including "PVT + AX CPT + Stroop", while another combined four different cognitive tasks, including "Continuous performance task + rapid visual input processing task + finger tapping task + trail-making test" (Boolani et al., 2020).

To provide a basis for comparison, many studies (n = 9; 32.1 %) included a control session designed not to induce any mental fatigue, lasting the same duration as the fatiguing task. This session most often involved watching a nature documentary on television (n = 7; 25.0 %), reading (n = 1; 3.6 %), or resting (n = 1; 3.6 %). The control session helps isolate the specific effects induced by the task, ensuring that the results can be attributed only to the onset of mental fatigue.

4.2. Subjective and behavioral effects of mental fatigue

All studies that measured the subjective level of mental fatigue observed an increase in older adults, regardless of the duration and type of protocol used. Fatigue in older adults is considered a major public health concern, as it ultimately compromises their quality of life over time (Doris et al., 2010). It could be reduced by breaking the task into several intervals to incorporate rest periods (Gilsoul et al., 2022). Subjective fatigue also tends to alter task perception by increasing the mental workload required for its completion, particularly during concurrent tasks (Shortz & Mehta, 2017; Varas-Diaz et al., 2020). Subjective fatigue is also associated with decreased cognitive functions, such as executive attention (Holtzer et al., 2011) and prospective memory

(Shelton et al., 2011). Executive attention refers to cognitive processes that allow for planning and decision-making, primarily involving prefrontal circuits (Fan et al., 2002, 2005). Executive attention appears to be negatively affected by cognitively fatiguing tasks. Meanwhile, prospective memory declines with mental fatigue, especially when the task demands high attentional capacity, particularly in older adults (Shelton et al., 2011). The reduction in cognitive abilities following a mentally fatiguing task can also be observed through the evolution of behavioral performance during the task. However, performance changes vary significantly across studies.

Many studies report a decline in behavioral performance at the end of a cognitively demanding task in older adults, with different patterns: an increase in RT only (de Jong et al., 2018; Gilsoul et al., 2022, 2024; Holtzer et al., 2011; Löffler et al., 2023; Marandi et al., 2018; Nikooharf Salehi et al., 2022; Santos et al., 2025), a decrease in accuracy only (Pergher et al., 2021; Shortz et al., 2015; Terentjeviene et al., 2018), or both (Arnau et al., 2017; Burke et al., 2018; Pergher et al., 2019).

On the other hand, some studies found no change in performance for older adults throughout the task (Babu et al., 2019; Falkenstein et al., 2002; Morris & Christie, 2020a, 2020b; Shelton et al., 2011). The heterogeneity in these findings may be due to protocol variations, including task type and duration. For example, studies using protocols lasting 20 min or less did not report behavioral changes (Morris & Christie, 2020a, 2020b; Shelton et al., 2011).

Additionally, it is essential to note that for protocols lasting 120 to 180 min, a significant decrease in motivation was observed among participants (Arnau et al., 2017; Gilsoul et al., 2024; Terentjeviene et al., 2018). The onset of increased demotivation could be a confounding factor in the evolution of behavioral performance, as participants may become less engaged in the task. To better analyze the effects of mental fatigue, protocols should therefore be limited to durations of less than 120 min for mentally fatiguing tasks.

4.3. Physiological effects of mental fatigue

The maximal strength capacity of older individuals with foot dorsi flexion and handgrip appears to decrease with mental fatigue compared to control sessions (Morris & Christie, 2020b; Terentjeviene et al., 2018). One study showed a significant ~32 % decrease in handgrip maximal strength for both mental fatigue and control sessions (Shortz et al., 2015). Therefore, the author did not conclude that mental fatigue influences handgrip strength capacity. When it is present, the decline in maximal strength capacity is not explained by changes in muscle contractile properties or neuromuscular excitability (Morris & Christie, 2020b) but is rather attributed to supraspinal mechanisms (Gandevia, 2001). A change in cortical functions is a strong hypothesis, particularly because following a mentally fatiguing protocol, the cortical silent period increases (Morris & Christie, 2020b; Terentjeviene et al., 2018), indicating increased cortical inhibition.

Muscle endurance time after mental fatigue showed no significant change in older adults for handgrip (Shortz & Mehta, 2017; Shortz et al., 2015) and leg extension movement (Faria et al., 2024). Meanwhile, in young adults, performing a demanding cognitive task induces a decrease in lower limb strength endurance (Alix-Fages et al., 2022). However, under DT conditions, one of these studies reported a significant reduction in handgrip muscular endurance (Shortz & Mehta, 2017). Cognitive processes, particularly those related to executive functions, decline with age, making it increasingly difficult to perform two tasks simultaneously (Verhaeghen et al., 2003). Previous studies have highlighted the role of the prefrontal cortex in regulating DT performance, which requires both cognitive and motor processing (Dietrich & Audiffren, 2011; Mehta & Parasuraman, 2013). A reduction in prefrontal cortex activation has been associated with early failures in submaximal upper limb tasks that involve additional cognitive demands (Mehta, 2016; Shortz et al., 2015). This decrease in prefrontal cortex activity has also been observed following mental fatigue tasks (Shortz et al., 2015; Terentjeviene et al., 2018), supporting the hypothesis that the mental fatigue phenomenon induces cortical modifications.

The two studies using fMRI have highlighted that brain network connectivity is affected by the presence of high mental fatigue. Mental fatigue seems reflected by right hemisphere insula-putamen connectivity (Anderson et al., 2019) and induces a decrease in corticostriatal network connectivity (Ren et al., 2019). It also appears that the cognitive processes of young and older adults are affected differently when mental fatigue occurs. EEG studies have shown that P3 amplitude does not significantly decrease throughout the task in older adults (de Jong et al., 2018; Falkenstein et al., 2002; Wascher & Getzmann, 2014), whereas it significantly decreases in younger adults (de Jong et al., 2018; Wascher & Getzmann, 2014). The decrease in P3 amplitude is correlated with an increase in task response error rate (de Jong et al., 2018) and is linked to attentional capacity and memory operations (Polich, 2007). Young adults seem to adopt a disengagement strategy, reducing the quality of task processing to preserve their cognitive resources during a mentally fatiguing task. In contrast, older adults show an increase in P3 fractional area latency (de Jong et al., 2018), which indicates a slower processing speed. Analysis of alpha band power during the mental fatigue task supports this hypothesis. Alpha band power increases at the frontal level regardless of age (Arnau et al., 2017; Löffler et al., 2023; Pergher et al., 2019), while its increase is much more pronounced in younger adults at the occipital level (Arnau et al., 2017). A higher alpha power in occipital regions has been associated with an internally oriented brain state (Hanslmayr et al., 2011). Thus, these findings could reflect a greater attentional disengagement in the younger adult group.

4.4. Balance effects of mental fatigue

Mental fatigue does not appear to impair performance on functional balance tests such as the 30 s CST, the 6MWT and the TUG in older adults (Boolani et al., 2020; Faria et al., 2024; Fletcher & Osler, 2021). However, two studies have shown that mental fatigue induces biomechanical changes in treadmill walking patterns (Behrens et al., 2017; Santos et al., 2025). These effects are exacerbated in a DT condition (Behrens et al., 2017) as it requires greater executive resources (Leone et al., 2017). Four studies have also found an increase in postural sway with the onset of mental fatigue in older adults (Fletcher & Osler, 2021; Morris & Christie, 2020a; Nikooharf Salehi et al., 2022; Varas-Diaz et al., 2020). One possible explanation is that the attention required for postural stability is compromised by mental fatigue. Some studies suggest that older adults are at a higher risk of falls when fewer attentional resources are available (Maki et al., 2001; Redfern et al., 2001; Woollacott & Shumway-Cook, 2002). The physiological cortical changes discussed could explain the reduction in these attentional resources.

4.5. Methodological limitations of the included studies

The findings of this review must be interpreted considering several methodological limitations across the included studies.

4.6. Sample size and population heterogeneity

Twenty studies out of the 28 studies included in this review featured small sample sizes for aging or experimental group (e.g., $N < 30$), reducing statistical power and generalizability. Additionally, participant populations varied widely in terms of baseline cognitive function, physical health, and frailty status, which may confound fatigue responses. Moreover, the number of studies investigating brain activity, balance or strength effects of mental fatigue is very limited, which prevents the extraction of generalizable concepts or robust theoretical frameworks.

4.7. Variability in fatigue-induction protocols

Concerning the task used to induce mental fatigue, while the Stroop and N-back tasks were predominant, their implementations differed (e.g., incongruent-only vs. mixed trials; duration ranging from 10 to 180 min). This variability complicates cross-study comparisons. Moreover, the relatively short duration of tasks in 10 studies may not have been sufficient to induce a measurable level of mental fatigue, particularly in older adults. Recent theoretical models suggest that cognitive fatigue requires prolonged and demanding tasks to emerge and may be best detected in paradigms involving sustained decision-making effort (Pessiglione et al., 2025). In this context, the absence of clear effects in some studies could be partly due to protocols that were not cognitively taxing enough or too brief to trigger fatigue-related changes.

In addition, a growing body of literature supports a motivational-metabolic model of mental fatigue (Pessiglione et al., 2025), in which both resource depletion and reduced willingness to exert mental effort contribute to fatigue onset. This model is especially relevant in explaining why some individuals, especially older adults, may not exhibit clear neurophysiological or behavioral signs of fatigue under short or externally paced tasks. The motivational-metabolic account suggests that cognitive effort investment is regulated by a cost-benefit evaluation process. As such, reduced P3 amplitude observed in younger adults may reflect strategic disengagement in response to perceived effort exceeding expected reward. Conversely, the stability of P3 responses in older adults may stem from reduced flexibility in adjusting effort allocation or diminished dopaminergic sensitivity to motivational cues with aging. This highlights the importance of considering individual differences in effort valuation when assessing fatigue markers, particularly in aging populations. Furthermore, the lower adherence typically observed in older participants when exposed to longer and more demanding tasks introduces practical limitations in study design. These motivational and methodological aspects should be considered when interpreting the heterogeneous results across studies.

Regarding the use of physiological measures, only two studies used fMRI, and EEG protocols varied in electrode placement and frequency-band analysis. No studies integrated multimodal assessments (e.g., combining EEG with muscle activity), missing opportunities to link neural and behavioral changes.

4.8. Recommendations for future research

To overcome these limitations, future research should aim to standardize fatigue-induction protocols through consensus on task duration and difficulty calibration. Studies should also recruit larger, stratified samples with thorough screening for health status and medication use. Integrating subjective, behavioral, and physiological assessments—such as combining fMRI with electromyography—would enhance the identification of the underlying mechanisms of the effects of mental fatigue on aging.

5. Conclusion and perspectives

This review confirms that mental fatigue induced by prolonged cognitive tasks is a robust phenomenon in older adults, leading to a systematic increase in subjective fatigue. However, its impact on behavioral and physiological performance is more heterogeneous. While some studies report a slowdown in reaction time and impaired attention, others show preserved behavioral capacities, suggesting compensatory strategies specific to aging. These compensatory strategies include modulations in neural activity to maintain task response efficiency, such as increased prefrontal cortex activity. For older adults, maximal strength seems to decrease after a cognitively demanding task, while muscular endurance time remains largely preserved, which differs from young adults. This decline in strength appears to be primarily linked to cortical mechanism modifications rather than alterations in muscle contractile properties. Moreover, mental fatigue affects postural balance in older adults, leading to increased postural sway and biomechanical changes in gait, particularly under DT conditions. However, these effects do not translate into reduced performance in functional tests such as the TUG or the 6MW. Finally, observed changes in brain activity indicate a slowdown in information processing in older adults, contrasting with a more pronounced cognitive disengagement in younger adults.

However, the role of physical and cognitive training in mitigating the effects of mental fatigue in older adults remains to be explored. A recent study examined the effects of a training protocol combining cognitive tasks (PVT and Stroop) and physical exercises (resistance and endurance training) on cognitive and physical performance in older adults, particularly in the presence of mental fatigue (Díaz-García et al., 2025). Sedentary older adults completed 65 min of Brain Endurance Training (BET; 20 min of the Stroop cognitive task, 20 min of resistance training, and 25 min of endurance training), three times per week for eight weeks. After the training protocol, cognitive and physical performance were less affected by mental fatigue compared to pretraining levels, demonstrating that BET can reduce the impact of mental fatigue in sedentary older adults.

Furthermore, to our knowledge, no study has compared the effects of mental fatigue based on physical activity levels in older adults. However, studies in young adults have shown that highly trained cyclists are significantly less affected by mental fatigue than untrained or minimally trained cyclists (Martin et al., 2016; Silva-Cavalcante et al., 2018), suggesting a possible benefit of long-term training. The neurophysiological mechanisms discussed in this review further support this potential role of physical activity. The observed changes in cortical inhibition (as indicated by increased cortical silent periods) and prefrontal cortex activity following mental fatigue suggest that enhancing neural efficiency through regular physical activity may mitigate the detrimental effects of mental fatigue. Evidence from young adults indicates that individuals with higher physical fitness levels experience less disruption in cortical functioning and executive control under mental fatigue. Moreover, recent findings on BET in older adults provide promising initial evidence that combined cognitive-physical interventions can enhance resilience to mental fatigue (Díaz-García et al., 2025). Therefore, promoting physical activity may not only improve general health but also help preserve cognitive, motor, and postural capacities under mentally fatiguing conditions in the aging population.

CRediT authorship contribution statement

Alain Bouche: Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Conceptualization. **Bénédicte Poulin-Charronnat:** Visualization, Validation, Supervision, Methodology. **Romuald Lepers:** Visualization, Validation, Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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