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Critical Review

Subjective versus objective cognition during menopause: A systematic review and meta-analysis

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Abstract

Objective: This systematic review and meta-analysis aimed to review existing measures of subjective cognition during menopause and to estimate the correlation between subjective and objective cognition in perimenopausal and postmenopausal women. **Method:** Eligible studies reported scores for at least one subjective and objective measure of cognition for perimenopausal or postmenopausal women. EMBASE, Medline, and PsycINFO were searched for eligible studies on November 22nd 2024. The risk of bias in individual studies was evaluated using a modified QUADAS-2 form. The results of the review were summarized in narrative form. Studies that reported correlations between subjective and objective cognition were synthesized using a multilevel meta-analysis. **Results:** The sample included 5629 participants over 24 studies, including 295 perimenopausal women, 5086 postmenopausal women, and 248 women across mixed peri- and post-menopausal samples. Twelve measures of subjective cognition were used across studies. Six studies were included in the meta-analysis. A small significant correlation was observed between subjective cognition and objective measures of learning efficiency ($r = .12$; CI = .02 to .23). Correlations across other cognitive domains were non-significant. **Conclusions:** Our findings suggest subjective cognition may be associated with performance on measures of learning efficiency, offering a starting point for further research on menopausal brain fog. The present findings highlight the need for a reliable measure of subjective cognitive symptoms associated with menopause. Additionally, a better characterization of the neuropsychological profile of menopausal brain fog is needed to progress research in this field and ultimately improve clinical support for women experiencing these symptoms.

Keywords: Brain fog; menopause; perimenopause; cognition; neuropsychological tests; aging (normal)

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Statement of Research Significance

Research Question(s) or Topic(s): This study examined whether cognitive difficulties during menopause, often described as "brain fog," are associated with measurable changes in cognitive performance. It also reviewed the tools currently used to assess subjective cognition in this population. **Main Findings:** A small but significant correlation was found between subjective cognition and learning efficiency, or the ability to learn and retain new information. No significant correlations were observed between subjective complaints and other cognitive domains. Across studies, 12 different tools with varying psychometric properties were used to assess subjective cognition. **Study Contributions:** This study is the first to synthesize correlations between subjective and objective cognition during menopause using meta-analysis. Findings highlight a need for more reliable and standardized tools to assess menopause-related cognitive concerns and suggest that reduced learning efficiency may underlie self-reported menopausal brain fog. Findings inform future research and may improve clinical recognition and support for cognitive concerns during menopause.

Introduction

Menopause, which is defined as the day of the final menstrual period and is diagnosed retrospectively after 12 consecutive months of amenorrhea, has a median age of 51 years and results from an age-related diminished supply of ovarian follicles. Perimenopause, the transitional phase around the menopause, spans approximately four to 10 years leading up to menopause and ends a year after the final menstrual period (Harlow et al., 2012). Perimenopause is associated with fluctuating and declining levels of sex hormones, including estradiol and progesterone. For many women, perimenopause is also accompanied by a range of physical, behavioral, and cognitive changes, including hot flushes, night sweats, sleep disturbance, and depression, all of which can have adverse impacts on a woman's quality of life (Harlow et al., 2012).

It is estimated that between 62 and 67% of women experience cognitive symptoms during perimenopause, with common symptoms including difficulty concentrating, losing their train of thought, forgetfulness, and challenges with multi-tasking (Reuben et al., 2021). Many report that these cognitive symptoms impact their

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daily lives, affecting work performance, social interactions, and overall quality of life (Woods et al., 2023). For some, the cognitive symptoms raise concerns about early-onset dementia or reflect underlying ADHD symptoms (Epperson et al., 2015; Maki & Jaff, 2024).

Colloquially, the term "brain fog" has become synonymous with cognitive symptoms during menopause. Although brain fog is not a recognized clinical syndrome, it provides a meaningful way for women to describe their experience of subjective cognitive symptoms during the menopause transition years. Additionally, the term has been increasingly utilized in research and clinical practice (Maki & Jaff, 2022). Hence, we define "menopausal brain fog" as subjective cognitive symptoms related to menopause and will use these terms interchangeably. As the neuropsychological profile of brain fog during menopause remains unclear, the aim of this systematic review and meta-analysis is to provide an overview of current research that has examined the relationship between subjective cognitive symptoms and objective cognitive performance during the menopause transition years.

There is currently no formal measure of menopausal brain fog. Research studies that aim to identify or measure subjective cognitive decline during menopause typically use self-report questionnaires assessing symptoms of forgetting or other memory-related complaints, such as the Memory and Cognitive Confidence Scale (MACCS; Ballantyne et al., 2021), Memory Functioning Questionnaire (MFQ; Maki et al., 2007), Attentional Functional Index (AFI; Grummisch et al., 2023), or the Multifactorial Memory Questionnaire (MMQ; Unkenstein et al., 2016). It is also unclear whether menopausal brain fog represents an objective change in cognition that can be reliably detected by neuropsychological tests (Weber & Mapstone, 2009). Studies that have examined this question often find that other menopausal symptoms, such as fatigue, mood disturbances, and vasomotor symptoms, may better predict subjective cognitive decline than measures of objective cognition, implying that reducing or treating these symptoms could improve cognitive functioning (Triantafyllou et al., 2016; Unkenstein et al., 2016; Weber et al., 2012). However, there is also contrasting evidence pointing to a subtle decline in objective measures of verbal memory and attention (Armeni et al., 2018; Drogos et al., 2013; Greendale et al., 2010; Grummisch et al., 2023; Schaafsma et al., 2010; Weber & Mapstone, 2009; Weber et al., 2013), as well as a potential association between subjective cognitive complaints and decreased hippocampal volume (Conley et al., 2020). Furthermore, some research has suggested that cognitive changes can occur in the absence of other menopausal symptoms (Maki et al., 2021).

It is crucial to characterize the typical neuropsychological profile of menopausal brain fog in relation to established cognitive constructs to facilitate an evidence-based assessment of its symptoms and severity. As a multifactorial syndrome, clinical presentations of menopausal brain fog are likely heterogeneous, meaning that two women reporting brain fog may be experiencing different types of symptoms, with the degree of diminishment in each construct varying from person to person (Grewal et al., 2023; Maki & Jaff, 2022).

Even though brain fog or cognitive symptoms during menopause may not reach established thresholds for statistical or clinical significance using neuropsychological tests, it is important to characterize the neuropsychological profile of brain fog for several reasons. First, up to 67% of women report a substantial impact of brain fog on work and quality of life (Harper et al., 2022). Hence, it is crucial that we better understand how it relates to objective cognitive performance, measurable by neuropsychological tests. Second, there is a need to untangle the individual factors that contribute to subjective cognitive decline during menopause to identify effective interventions to alleviate symptoms tailored to individual needs. Third, given that subjective cognitive concerns in adulthood are a risk factor for later-life dementia (Pike et al., 2022), it is important to better understand the nature of the subjective cognitive symptoms or brain fog in menopause and characterize the associated neuropsychological profile. Finally, understanding the neuropsychological profile of brain fog is essential for research focused on understanding the direct effects of menopause-related changes on cognition.

In this study, we used objective cognitive performance, assessed using neuropsychological tests, as a proxy for brain health and aimed to determine the extent to which existing measures of subjective cognition correlate with neuropsychological outcomes. By synthesizing the current literature, we sought to identify the subjective measures currently used in menopausal populations and assess whether any patterns emerge in their correlation with objective cognitive performance. Accordingly, this study aimed to review the available measures for assessing brain fog, evaluate their quality, and examine how they relate to neuropsychological test performance. Specifically, this study aimed to systematically review and meta-analyze correlations between subjective and objective cognitive measures in perimenopausal and postmenopausal women.

Method

Preregistration and protocol

This study was preregistered on PROSPERO (Study ID: CRD42024541330). All human data included in this manuscript was obtained in compliance with the Helsinki Declaration.

Eligibility criteria

Eligible studies met the following criteria: (a) reported outcomes for at least one subjective measure of cognition and at least one neuropsychological test score in a perimenopausal or postmenopausal cohort of women, and (b) were in English, or an English version of the study could be accessed via Google Translate. Exclusion criteria included (a) studies involving participants with current comorbid neurological or psychiatric conditions known to impact cognition, (b) participants with a history of chemotherapy, and (c) studies not published in English. Specifically, we excluded studies that focused exclusively on clinical populations (e.g., major psychiatric, neurodevelopmental, or neurodegenerative disorders), but retained community-based samples that screened for these conditions. Studies that included individuals who had undergone surgical menopause as part of a larger sample were retained but noted for later sensitivity analyses if they were included in the meta-analysis. However, studies that exclusively examined cohorts of women with surgical menopause were excluded, as their findings may not generalize to the natural menopause transition, which was the primary focus of the review.

Search strategy

Search databases included MEDLINE, EMBASE, and PsycINFO, accessed via the Ovid interface. Three terms were used in the search strategy, including (a) neuropsychological assessment or cognition, (b) menopause, and (c) subjective cognitive decline. The full search strategy is available in Supplementary Table 1. The reference lists of eligible studies identified were also searched to identify any additional studies meeting the eligibility criteria. The final search date was November 22nd 2024.

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Study selection

Search records were imported into Covidence screening (Veritas Health Innovation, 2024). Title and abstract screening was completed independently by the first author (R.F.). A total of 155 studies were retained for full-text screening and were independently reviewed by the first author (R.F.). The last author (C.G.) reviewed a subset of 55 studies. There was substantial agreement for inclusion between reviewers (agreement = 94.5%, Cohen's kappa = .77), and disagreements were resolved by consensus.

Data extraction

Data extraction was completed independently by the first author (R.F.), with the last author (C.G.) reviewing accuracy in a subset of studies. No automation tools were used in the data extraction process. For longitudinal studies or randomized controlled trials (RCTs), the baseline estimates were recorded.

Study characteristics

Data items extracted for study characteristics included author information, publication year, the primary objective of the study, and the country where the study was conducted. The dates and setting of data collection were also recorded.

Participant characteristics

For participant characteristics, extracted data items included the sample size, mean age and education, and menopause stage for each group (classified as perimenopause, postmenopause, or combined). The criteria used to define the stage of menopause were also recorded. Any reported estimates of hormone levels, including estradiol, progesterone, testosterone, follicle-stimulating hormone (FSH), luteinizing hormone (LH), and use of menopausal hormone therapy, were also recorded for each group.

Measures of subjective cognition

The measure of subjective cognition used in each study was recorded. The number of items, scoring scale, test–retest reliability, and validation method were also recorded for each measure. If this information was not reported in the included study, it was sought from the original publication of the measure.

Measures of objective cognition

The names and outcomes of neuropsychological tests administered in each study were recorded. Following data extraction, tests were categorized into broad cognitive domains following the Cattell-Horn-Carroll (CHC) model of cognitive abilities (Schneider & McGrew, 2018). This model was selected because it is the most comprehensive and empirically supported model of cognition and is the basis for the most updated neuropsychological test batteries such as the Fifth Edition of the Wechsler Adult Intelligence Scale (WAIS-5; Wechsler et al., 2024). These cognitive domains included learning efficiency (*Gl;* the ability learn and store information over time), working memory (*Gwm;* the ability to maintain and manipulate information in the mind), retrieval fluency (*Gr; the efficiency with which information can be retrieved from long-term memory*), processing speed (*Gs;* the ability to control attention to perform simple cognitive tasks quickly and fluently), fluid reasoning (*Gf;* the ability to solve novel problems without the use of previously learned information), and acquired knowledge (*Gc;* the ability to understand and communicate culturally relevant knowledge) (Schneider & McGrew, 2018). Additionally, general intelligence (*G*), or general cognitive ability, is a higher-order domain that underpins performance across all broad cognitive ability domains and reflect shared variance across distinct cognitive abilities. For each test administered, the mean score for each group reported in each study was recorded in the format used, including mean raw scores, z-scores, or t-scores.

Measures of other menopause symptoms

Any administered measures of mood, sleep or fatigue, and vasomotor symptoms were documented, with the names and outcomes of each recorded. Mood measures included those assessing overall mood, depressive symptoms, anxiety symptoms, or stress symptoms. These were grouped under a single category of mood.

Correlations between measures

Any reported Pearson's correlation coefficients (Pearson's *r*) or beta regression coefficients (beta estimates) between measures of objective and subjective cognition, subjective cognition and menopausal symptoms, and objective cognition and menopausal symptoms were recorded. Beta estimates are considered appropriate substitutions for Pearsons's *r*, with evidence supporting the relative accuracy and stability of results in meta-analyses using both types of estimates (Peterson & Brown, 2005).

Quality evaluation

The risk of bias and applicability concern for each study was evaluated using a modified QUADAS-2 form (Whiting, 2011). The risk of bias was evaluated for four domains, including patient selection, the measure of subjective cognition, the measure of objective cognition, and timing and flow. Applicability concerns were evaluated for three domains, including patient selection, the measure of subjective cognition, and the measure of objective cognition. Signalling questions for each domain were answered as *yes*, *unclear*, or *no*, and the risk of bias for each domain was then determined as *low*, *high*, or *unclear*. A list of signalling questions and completed ratings for each included study are shown in Supplementary Table 2. The quality evaluation was completed independently by the first (R.F.) and last (C.G.) authors, with agreement between reviewers assessed using Cohen's kappa (κ). There was a substantial agreement across domains, including patient selection (agreement = 95.5%, κ = .65), objective measure (agreement = 1, κ = 1), subjective measure (agreement = 1, κ = 1), and timing and flow (agreement = 91.1%, κ = 82.1). Disagreements were resolved by consensus.

Data synthesis

Studies that reported correlations between any measures were included in the meta-analyses. Meta-analyses were completed when three or more relevant outcomes were reported (Higgins et al., 2023). Three meta-analyses were planned a priori, including synthesizing correlations between objective and subjective measures of cognition (Model 1), subjective cognition and menopausal symptoms (Model 2), and objective cognition and menopausal symptoms (Model 2). All analyses were multilevel random-effect meta-analyses conducted using the *meta* package in R Studio (RStudio: Integrated Development for R, 2020; Schwarzer, 2024). The multilevel approach was used to account for dependent effect sizes, where level one represents the study level and level two represents the effect level, with results to be displayed visually using forest plots.

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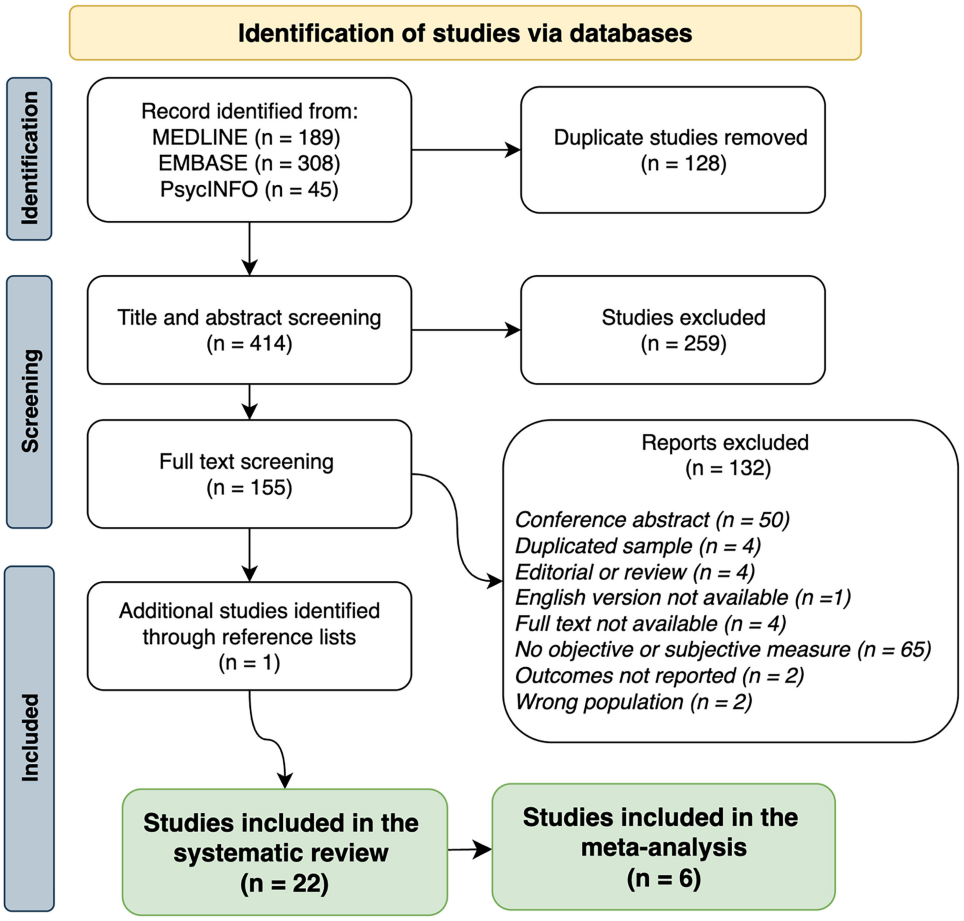


Figure 1. PRISMA flowchart of study selection.

Effect measure

For all analyses, the effect measures were Pearson's correlation coefficients (r). Heterogeneity was evaluated using Cochran's Q with its associated degrees of freedom, tau-squared, and I-squared values (Higgins & Thompson, 2002). Pearson's correlation coefficients were interpreted according to Cohen (1988) as small ($r = .10$), moderate ($r = .30$), or large ($r = .50$).

Subgroup and meta-regression analyses

Subgroup analyses planned a priori included examining the effect of the menopause stage (all models), the cognitive domain of the objective tests (Models 1 and 3), and menopausal symptoms type (Models 2 and 3). Meta-regressions were used to examine sources of within- and between-study heterogeneity on an exploratory basis.

Sensitivity analyses

Two sensitivity analyses were planned. The first was to evaluate the effect measure (Pearson's r or beta estimate) on the results of any meta-analysis. The second was to examine the effect of studies rated as having a high risk of bias in any QUADAS-2 domain.

Results

Study characteristics

A flowchart of the study selection process is shown in Figure 1. Twenty-two eligible studies were included in the systematic review, including 16 cross-sectional studies, six RCTs, and two longitudinal studies. A summary of the study characteristics is displayed in Table 1.

Sample characteristics

Overall, there were 5007 participants, including 512 perimenopausal women, 4352 postmenopausal women, and 143 women across combined samples. The mean age for the perimenopausal group was 49.50 years ($SD = 0.98$), while the postmenopausal group had a mean age of 55.87 years ($SD = 4.25$). The combined group had a mean age of 53.46 years ($SD = 0.49$). The perimenopausal group had an average of 16 years of education ($SD = 0.30$), compared to 13.19 years ($SD = 2.58$) for the postmenopausal group and 15.75 years ($SD = 0.92$) for the combined group. Only eight studies reported estradiol, testosterone, follicle-stimulating hormone (FSH), or luteinizing hormone (LH) levels. No studies reported progesterone. A summary of these details, including studies with missing data, is available in Supplementary Table 3.

Quality evaluation

The assessment of risk of bias across studies was conducted across four domains, with ratings of low, high, or unclear risk for each. Individual study scores for each signalling question are available in Supplementary Table 2. In the patient selection domain, 9% of studies were rated as having a low risk of bias, 54.5% as high risk, and 36.5% as unclear. Those rated as having high risk typically used convenience sampling to recruit participants rather than random or consecutive recruitment. In contrast, those with unclear risk typically did not report how participants were recruited. For the objective measure domain, 4.5% of studies were classified as low risk, 22.7% as high risk, and 72.7% as unclear. Bias in this domain

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Table 1. Characteristics of included studies

Study	Study design	Sample	Sample details as describing in primary studies	N	Surgical menopause	Hormone therapy use	Time since meno-pause	Measure of subjective cognition	Measures of objective cognition						
									Gl	*Gwm*	*Gr*	*Gs*	*Gc*	*Gf*	*Gv*
Armeni et al. (2018)	Cross-sectional	Postmenopausal	Healthy postmenopausal women with subjective memory complaints	44	Not reported	Excluded	10.2 (6.9) years (mean, SD); range 1 – 33 years	"Do you have any memory problems compared to the past?"	x	x					
Ballantyne et al. (2021)	Longitudinal	Combined	Women aged 40 – 65 years who were perimenopausal or postmenopause, including surgical menopause, with any subjective cognitive complaint, and experiencing at least one vasomotor symptom	27	Included	Included (if stable)	Not reported	MACCS	x	x	x	x	x	x	
Barnhart et al. (1999)	RCT	Perimenopausal	Perimenopausal women aged 45 – 55 years, with symptoms of fatigue, lack of energy, anxiety, tension, irritability, depression, insomnia, forgetfulness, concentration difficulties, decreased libido, or global reports of a decreased sense of well-being	60	Excluded	Past only, ≥ 6 months washout)	5.0 (3.8) years (median, SD); range 2 – 16 years	DSR - Forgetfulness and Concentration				x			x
Conley et al. (2020)	Cross-sectional	Postmenopausal	Postmenopausal women aged between 50 – 60 years	44	Partial (excluding full surgical menopause)	Past only, ≥ 1 year washout)	3.6 (2.9) years (mean, SD)	CCI	x	x					
Drogos et al. (2013)	Cross-sectional	Combined	Women with last menstrual period 6 months to 10 years before recruitment, with a minimum of 35 hot flashes per week as indicated by diaries completed over a minimum of 2 weeks, and intact uterus and ovaries.	68	Excluded	Past only, ≥ 6 months washout)	6.4 (4.3) years (cognitive complainers)	MFQ - Current Memory Rating	x	x	x				x
Dumas et al. (2013)	Cross-sectional	Postmenopausal	Healthy, cognitively normal, not depressed, postmenopausal women	23	Not reported	"Prior" only (6/23) washout period not reported	7.3 (3.5) years (non-complainers)	CCI	x	x					
Epperson et al. (2011)	RCT	Combined	Women aged 45 – 60 years who were "worried about their memory and concentration"	16	Excluded (One participant had a partial hysterectomy)	Past only, ≥ 1 year washout)	29.3 (20.5) years (mean, SD); range 2 – 60 years	BADDS - Attention-Concentration and Working Memory-Recall	x	x	x	x			
Epperson et al. (2015)	RCT	Combined	Women aged 45 – 60 who reported the onset of executive function difficulties during the menopause transition and were within 5 years of their final menstrual period.	32	Not reported	Past only, ≥ 6 months washout)	2.1 (1.6) years (mean, SD; converted from months)	BADDS - Attention-Concentration	x	x					
Gorenstein et al. (2011)	RCT	Postmenopausal	Healthy hysterectomized women, aged 40 – 59 years, who were undergoing treatment at the Department of Gynaecology, School of Medicine, University of São Paulo	53	Included (5/65 had a full oophorectomy)	Current users at baseline excluded, prior users not reported	3.2 (1.5) years (estrogen group)	Subjective memory questionnaire	x	x		x			

(*Continued*)

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Table 1. (*Continued*)

Study	Study design	Sample	Sample details as describing in primary studies	N	Surgical menopause	Hormone therapy use	Time since menopause	Measure of subjective cognition	Measures of objective cognition						
									Gl	*Gwm*	*Gr*	*Gs*	*Gc*	*Gf*	*Gv*
Grummisch et al. (2023)	Longitudinal	Perimenopausal	Perimenopausal women aged 45 – 55 years	43	N/A	Current users at baseline excluded, prior users not reported	4.0 (2.7) years (placebo group)	MFQ-FOF and AFI	x	x		x			
Hogervorst et al. (1999)	Cross-sectional	Postmenopausal	Perimenopausal women aged 45 – 55 years	341	N/A	Current users at baseline excluded, prior users not reported	Not applicable	"Do you consider yourself forgetful?"	x			x			
Jenkins et al. (2008)	RCT	Postmenopausal	Postmenopausal women at increased risk of developing breast cancer	207	Not reported	Included	Not reported	CFQ	x	x	x	x			
Karossy et al. (2007)	Cross-sectional	Postmenopausal	Postmenopausal women	52	Included - 6/52 "uterectomy"	Current users at baseline excluded, prior users not reported	8.62 (2.31) years (mean, SD)	WHQ-M	x	x		x			
Li et al. (2022)	Cross-sectional (Case–control)	Postmenopausal	Postmenopausal women	3218	Not reported	Not reported	1.7 (0.8) years (placebo); 1.8 (0.7) years (HT group)	"How would you rate your memory at the present time? "	x						
Maki et al. (2007)	RCT	Postmenopausal	Generally healthy postmenopausal women with intact uteri	108	Excluded	Past only at baseline, ≥ 1 year washout	Not reported	MFQ-FOF	x	x	x				x
Pang & Kim, 2021)	Cross-sectional (Cohort)	Postmenopausal	Menopausal women over 50 years of age	42	Not reported	Not reported	10.2 (6.7) years (mean, SD); range 1 – 33 years (converted from months)	SCF - Subjective Cognitive Questionnaire	x	x	x	x			
Schaafsma et al. (2010)	Cross-sectional	Perimenopausal and	Postmenopausal (results reported seperately)		Women aged between 45 – 60 years covered the pre-, peri- and		postmenopausal stages of menopause	86							
Included	Included, but results reported	separately	Not reported	"Do	you have problems with your memory?"	x	x	x	x						
Triantafyllou et al. (2016)	Cross-sectional	Postmenopausal	Healthy postmenopausal women with subjective memory complaints	39	Excluded	Not reported	7.0 (5.0) years (mean, SD)	"Do you have any memory problems compared to the past?"	x						
Unkenstein et al. (2016)	Cross-sectional	Perimenopausal	Women aged 40 to 60 years	94	Excluded	Not reported	Not applicable	MMQ - Ability and MemCo	x	x	x	x	x		
Vega et al. (2016)	Cross-sectional	Postmenopausal	Postmenopausal women aged 50 – 60	31	Excluded	Past only, ≥ 6 months washout	Not applicable	CCI	x						

Table 1. (*Continued*)

Study	Study design	Sample	Sample details as describing in primary studies	N	Surgical menopause	Hormone therapy use	Time since menopause	Measure of subjective cognition	Measures of objective cognition						
									Gl	*Gwm*	*Gr*	*Gs*	*Gc*	*Gf*	*Gv*
Weber et al. (2012)	Cross-sectional	Perimenopausal	Perimenopausal women	75	Excluded	Past only, ≥ 3 months washout	10.2 (6.9) years (mean, SD); range 1 – 33 years	MFQ-FOF and MFQ-Total	x	x	x				x
Zhu et al. (2024)	Cross-sectional	Perimenopausal	Perimenopausal women who were experiencing menopausal-related symptoms, such as cognitive (i.e. brain fog), vasomotor, psychosocial, sexual and physical symptoms.	232	N/A	Included	Not reported	EMQ-R	x	x	x	x			
Total									21	18	10	12	2	1	4

was assessed based on whether objective cognition measures were interpreted without knowledge of the results of the subjective measure of cognition. The high number of studies rated as unclear in this domain was due to a lack of available information in the report. Similarly, in the subjective measure domain, 13.6% of studies demonstrated low risk, 22.7% high risk, and 63.6% unclear risk of bias. Again, the high number of studies rated as unclear was due to insufficient information about whether the subjective test was scored and interpreted without knowledge of objective test results. Lastly, the timing and flow domain included 45.5% of studies rated as low risk, 13.6% as high risk, and 40.9% as unclear. This domain assessed bias regarding whether there were any gaps between the administration of the objective tests and subjective measures of cognition (ideally, these measures should be administered during the same session). A summary of the risk of bias across included studies is displayed in Figure 2.

Applicability concern was assessed for patient selection, measures of objective cognition, and measures of subjective cognition. For patient selection, 45.5% of studies were rated as having low applicability concern, 22.7% as high concern, and 31.8% as some concerns. In the objective measures domain, 86.4% of studies had low applicability concerns, 4.5% were rated as high concerns, and 9.1% had some concerns. The subjective measures domain showed 90.9% of studies with low applicability concern and 9.1% with some concerns. A summary of applicability across included studies is displayed in Figure 3.

Measures of subjective cognition

Twelve different measures of subjective cognition were used across the included studies. As expected, these measures varied considerably regarding psychometric quality and the aspect of subjective cognitive functioning each questionnaire measures. A summary of all measures, including scale details and test–retest reliability estimates, is shown in Table 2. For organizational purposes, the measures were grouped into broad themes based on face validity and apparent alignment with cognitive symptoms commonly reported by experiencing menopausal brain fog including general cognitive concerns, attention and concentration, and memory (Harper et al., 2022). This categorization was intended solely to aid interpretation and does not imply theoretical distinctions. Currently, there is limited construct validity evidence and no established factor structure to support the assumption that these self-report measures map onto distinct cognitive constructs in a manner consistent with objective cognitive domains, such as those defined in CHC theory. Specifically, confirmatory factor analysis (CFA) is considered the gold standard approach for evaluating construct validity, as it tests whether the data fit a hypothesized measurement model based on theoretical expectations (Strauss & Smith, 2009). The absence of such analyses during scale development limits confidence in the distinctiveness and theoretical validity of the self-report cognitive domains purportedly assessed. Without a measurement model, it is difficult to determine whether total scores and subscale scores meaningfully reflect discrete constructs, which in turn undermines attempts to evaluate convergent and discriminant validity, both between self-report measures and in relation to objective cognitive performance.

General cognition

Three measures conceptualized subjective cognition in terms of task failures, complaints, or perceived cognitive decline. Three studies used the Cognitive Complaint Index (CCI; Conley et al.,

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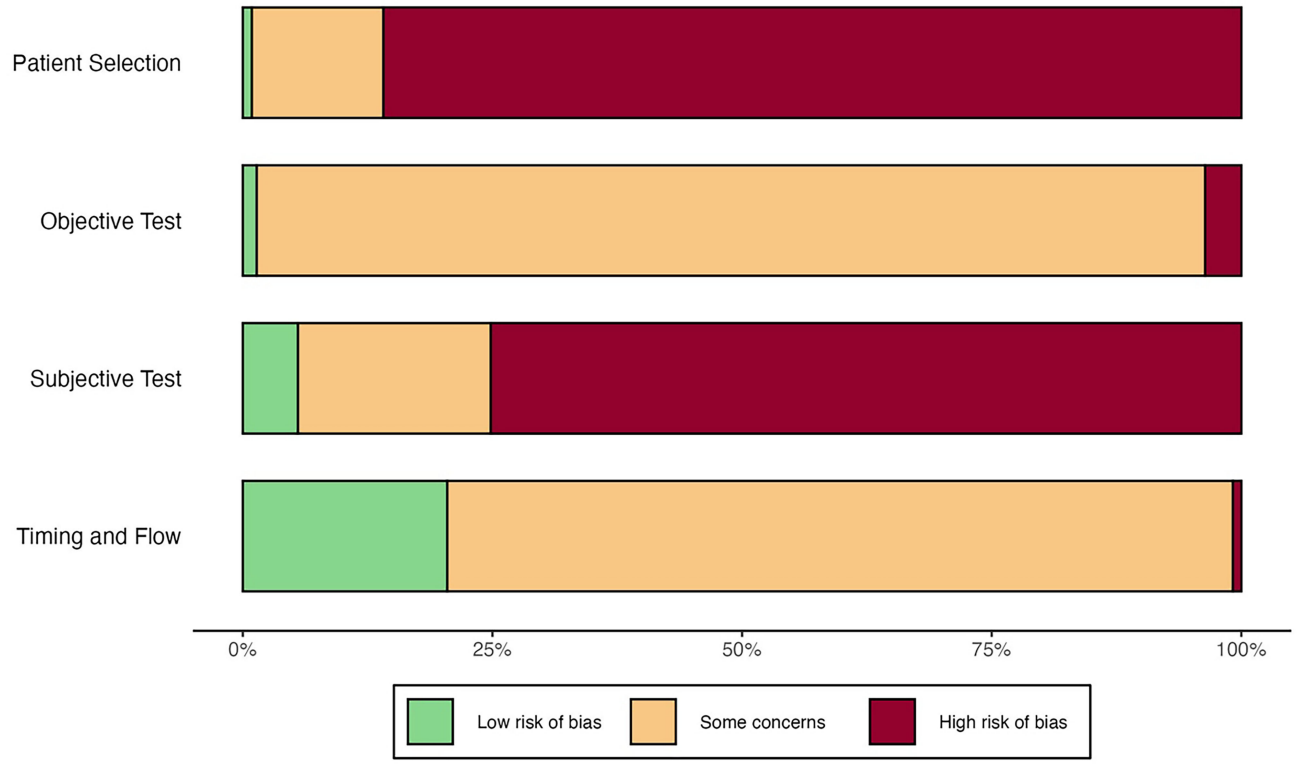


Figure 2. Risk of bias for patient selection, objective measures, subjective measures, and timing and flow using a modified QUADAS-2 form.

2020; Dumas et al., 2013; Saykin et al., 2006; Vega et al., 2016). The total score provides an "index" reflecting general cognitive complaints across various areas of functioning and is a compilation of 114 items from different existing measures (see Saykin et al., 2006). Although the total score is estimated to have high test–retest reliability (Rattanabannakit et al., 2016), this index has not been validated as a measure of subjective cognition.

The Cognitive Failures Questionnaire (CFQ), a 25-item measure of self-reported "failures" across everyday tasks such as absent-mindedness, forgetfulness, and clumsiness, was used in one study (Broadbent et al., 1982; Jenkins et al., 2008). The total score has been validated in a university sample and has moderate test–retest reliability but has not been validated in a menopausal sample (Craig Wallace, 2004; Rast et al., 2009).

The Subjective Cognitive Decline Questionnaire (SCDQ), a 24-item measure of self-perceived cognitive decline, was used in one study (Pang & Kim, 2021; Rami et al., 2014). The scale includes questions about perceived decline in several cognitive domains, including memory, language, and executive function. The measure has moderate test–rest reliability and has been validated in a sample of individuals with mild cognitive impairment and Alzheimer's disease (Rami et al., 2014). However, dimensionality, or construct validity, was assessed using principal components analysis (PCA), which is a method of item reduction rather than factor analysis (Floyd & Widaman, 1995). As such, construct validity was not evaluated according to established guidelines (Strauss & Smith, 2009).

Attention and concentration

Two measures focused on attention, including the 13-item Attentional Functional Index (AFI) (Cimprich et al., 2011), which was used in one study, and the 5-item attention and concentration subscale of the Brown Attention Deficit Disorder Scale (BADDS), which was used in two studies (Epperson et al., 2011, 2015). The AFI has high test–retest reliability, but construct validity was evaluated using PCA (Cimprich et al., 2011). The Brown Attention-Deficit Disorder Scales are also reported to have adequate reliability and have been validated in an adult sample (Brown, 1996; Davenport & Davis, 2011).

Memory functioning

Six scales were used to assess memory functioning, each with varying reliability and validity evidence. The Everyday Memory Questionnaire-Revised (EMQ-R), a 13-item scale measuring attentional and retrieval difficulties, was used in one study (Royle & Lincoln, 2008; Zhu et al., 2024). While the original scale demonstrated moderate test–retest reliability, this has not been evaluated in the revised scale (Efklides et al., 2002). Moreover, the construct validity of the EMQ-R is questionable, again assessed using PCA, which identified a third factor (or component) with two unrelated items that were retained in the scale (Royle & Lincoln, 2008).

Similarly, the Memory and Cognitive Confidence Scale (MACCS) is a 28-item scale that assesses various aspects of memory confidence, including general memory, decision-making, concentration ability, and cognitive perfectionism (Ballantyne et al., 2021; Nedeljkovic & Kyrios, 2007). Test–rest reliability varies across subscales, with high reliability for the total score and decision-making scale but moderate to poor for the other subscales (Nedeljkovic & Kyrios, 2007). Validation efforts have focused on individuals with obsessive–compulsive disorder (Nedeljkovic & Kyrios, 2007).

The Memory Functioning Questionnaire (MFQ) includes four subscales, namely, Frequency of Forgetting (32 items), Seriousness of Forgetting (18 items), Mnemonics Usage (8 items), and

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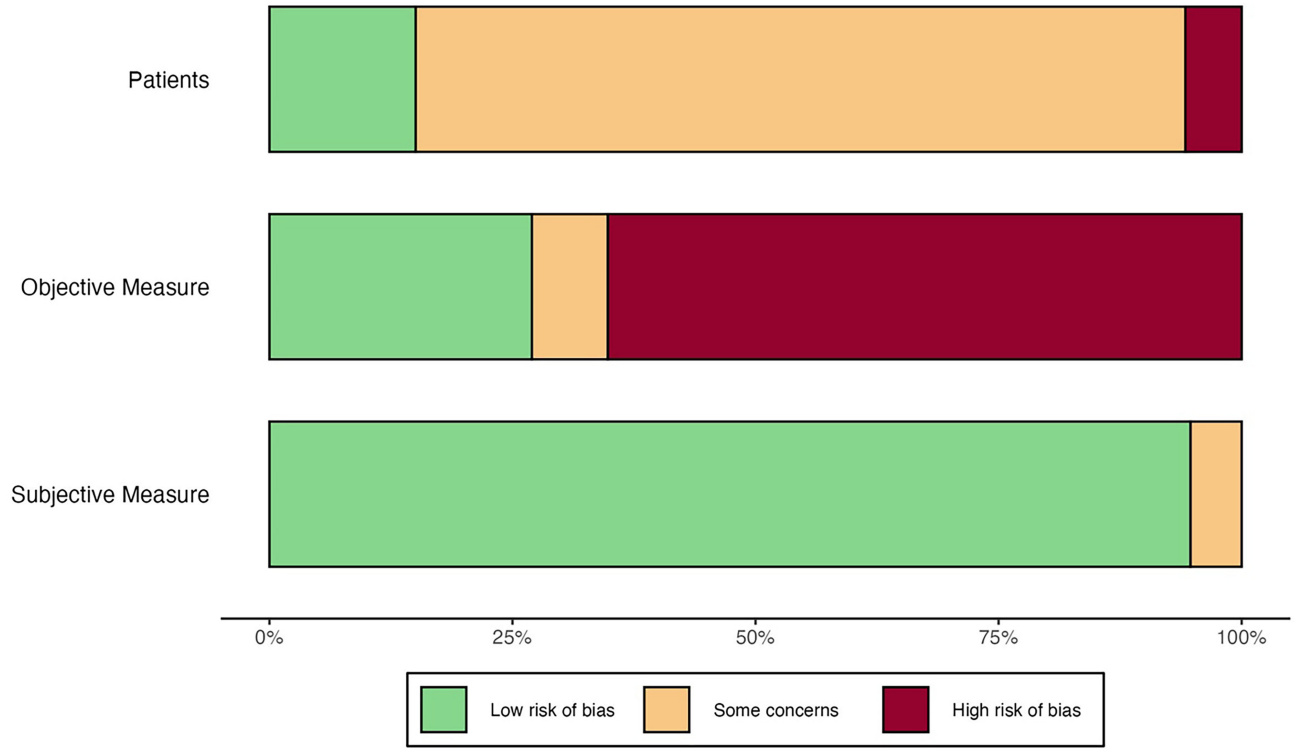


Figure 3. Applicability concern for patient selection, objective measures, and subjective measures using a modified QUADAS-2 form.

Retrospective Forgetting (5 items; Gilewski et al., 1990). No total score is calculated. Two studies used all four subscales (Maki et al., 2007; Weber et al., 2012), and one study focused solely on the Frequency of Forgetting (Grummisch et al., 2023). Evidence supporting the reliability and validity of these subscales is limited, with initial exploratory factor analysis providing some support for its stability (Gilewski et al., 1990).

The Multifactorial Memory Questionnaire (MMQ) has three subscales, including Memory Contentment (i.e., satisfaction with memory; 21 items), Memory Ability (i.e., perceived memory ability; 20 items), and Strategy Use (i.e., use of techniques to support memory; 20 items) (Troyer & Rich, 2002). No total score is calculated. All three subscales were used in one study (Unkenstein et al., 2016). There is evidence of moderate test–retest reliability for the strategy use subscale but poor reliability for the other subscales (Yang et al., 2023). Similar to the EMQ-R and the MFQ, the subscales were identified using PCA (Troyer & Rich, 2002).

Other scales include the Subjective Memory Questionnaire (SMQ), a 43-item measure used in one study (Gorenstein et al., 2011), with moderate test–retest reliability but limited evidence for construct validity (Bennett-Levy & Powell, 1980). The Memory and Concentration subscale of the Women's Health Questionnaire (WHQ) consists of three items and was used in one study (Hunter, 1992; Karossy et al., 2007). The scale was developed and validated in a sample of mid-life women aged 45 to 65, with reliability estimates ranging from moderate to high (Hunter, 2003).

Finally, the Daily Symptom Rating Scale (DSRS) is a 17-item measure that assesses mood, behavior, and pain symptoms related to menopause but also includes single items on forgetfulness and concentration (Taylor, 1979). This measure was used in one study (Barnhart et al., 1999).

Single-item measures

In addition, six studies assessed subjective cognition using a single question. For four of those studies, the question was rated on a Likert scale. For the other two studies, the question was rated on a binary scale, as "yes" or "no" (Drogos et al., 2013; Hogervorst et al.,1999; Li et al., 2022; Schaafsma et al., 2010; Triantafyllou et al., 2016). Further details are provided in Table 2.

Measures of objective cognition

A broad range of neuropsychological tests were used to measure objective cognition across included studies. The definition of each cognitive domain and a breakdown of the neuropsychological tests included in each domain are shown in Table 3. These tests were categorized into broad cognitive domains based on the CHC model. The cognitive domains assessed included learning efficiency, working memory, retrieval fluency, cognitive speed, fluid reasoning, and acquired knowledge. The most common cognitive domain tested was learning efficiency (21 studies), followed by working memory capacity (17 studies), processing speed (12 studies), and retrieval fluency (10 studies). Visual processing was measured in only four studies, comprehension knowledge was measured in two studies, and only one study measured fluid reasoning ability.

Measures of other menopause symptoms

Other menopausal symptoms assessed across studies included sleep or fatigue, overall mood, depression, anxiety, stress, and vasomotor symptoms. Supplementary Table 4 summarizes the measures used to assess these symptoms.

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Table 2. Characteristics of measures of subjective cognition across included studies

Measure of subjective cognition	Item and scale details	Test–retest reliability	Construct validity	Cognitive domain	Included studies
Scales					
Cognitive complaint index (CCI) (Saykin et al., 2006)	114 items rated as "yes" or "no." Higher scores represent a greater percentage of items endorsed.	High (r = .96; Rattanabannakit et al., 2016)		Unavailable	General cognition
Conley et al. (2020) Dumas et al. (2013) Vega et al. (2016)					
Cognitive failures questionnaire (CFI) (Broadbent et al., 1982)	25 items rated on a 5-point scale. Higher scores represent more cognitive failures.	Moderate (r = .80; Rast et al., 2009)	CFA – Four factors (Distractibility, Memory, Blunders, Names) (Craig Wallace, 2004)	Cognitive Failure	Jenkins et al. (2008)
Subjective cognitive decline questionnaire (SCDQ) (Rami et al., 2014)	24 items rated as "yes" or "no." Higher scores represent greater levels of perceived decline.	Moderate (r = .83; Youn et al., 2009)	PCA – One factor (Rami et al., 2014).	Cognitive decline	Pang & Kim, 2021)
Attentional function index (AFI) (Cimprich et al., 2011)	13 items rated from 0 to 100	High (r = .92; Cimprich et al., 2011)	PCA – Three factors (Effective Action, Attentional Lapses, Interpersonal Effectiveness) (Cimprich et al., 2011)	Directed attention and executive functioning	Grummisch et al. (2023)
Brown attention deficit disorder scale – attention and concentration scale (BADDS)	40 items rated on a 3-point scale	Moderate (r = .79; Kooij et al., 2008)		Attention	Epperson et al., (2011; 2015)
Everyday memory questionnaire-revised (EMQ-R) (Royle & Lincoln, 2008)	13 items rated on a 5-point scale. High scores represent more memory difficulties.	Moderate (r = .85; Efklides et al., 2002)	PCA – Three factors – Retrieval, Attentional Tracking, and "unknown" (Royle & Lincoln, 2008)	Retrieval and attention	Zhu et al. (2024)
Memory and cognitive confidence scale (MACCS) (Nedeljkovic & Kyrios, 2007)	28 items rated on a 5-point scale. Higher scores indicate less confidence.	High (r = .92; Nedeljkovic & Kyrios, 2007)	EFA – Four factors (subscales) (Nedeljkovic & Kyrios, 2007)	Memory	Ballantyne et al. (2021)
Confidence in general memory (MACCS-GEN)	15 items rated on a 5-point scale. Higher scores indicate less confidence.	Moderate (r = .89; Nedeljkovic & Kyrios, 2007)	EFA	Memory	Ballantyne et al. (2021)
Confidence in decision-making (MACCS-DEC)	5 items rated on a 5-point scale. Higher scores indicate less confidence.	High (r = .92; Nedeljkovic & Kyrios, 2007)	EFA	Memory	Ballantyne et al. (2021)
Confidence in concentration ability (MACCS- CON)	4 items rated on a 5-point scale. Higher scores indicate less confidence.	Poor (r = .74; Nedeljkovic & Kyrios, 2007)	EFA	Memory	Ballantyne et al. (2021)
Cognitive perfectionism (MACCS-PER)	4 items rated on a 5-point scale. Higher scores indicate less confidence.	Poor (r = .76; Nedeljkovic & Kyrios, 2007)	EFA	Memory	Ballantyne et al. (2021)
Memory functioning questionnaire (MFQ) (Gilewski et al., 1990)	No total score. Higher scores represent better memory functioning.	High (Goodness of fit index = .985; Gilewski et al., 1990)*	EFA – Four factors (subscales) (Gilewski et al., 1990)	Memory	
Frequency of forgetting subscale	33 items rated on a 7-point scale		EFA	Memory functioning	Maki et al. (2007) Weber et al. (2012) Grummisch et al. (2023)
Seriousness of forgetting	18 items rated on a 7-point scale		EFA	Memory functioning	Maki et al. (2007) Weber et al., (2012)
Mnemonics usage	8 items rated on a 7-point scale		EFA	Memory functioning	Maki et al. (2007) Weber et al., (2012)

(*Continued*)

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Table 2. (*Continued*)

Measure of subjective cognition	Item and scale details	Test–retest reliability	Construct validity	Cognitive domain	Included studies
Retrospective functioning	5 items rated on a 7-point scale		EFA	Memory functioning	Maki et al. (2007) Weber et al., (2012)
Multifactorial memory questionnaire (MMQ) (Troyer & Rich, 2002)	No total score.		PCA – Three factors (subscales) (Troyer & Rich, 2002)		
Contentment subscale	18 items rated on a 5-point scale. High scores represent greater contentment.	Poor (ICC = .72; Yang et al., 2023)	PCA	Memory	contentment
Unkenstein et al. (2016)					
Ability subscale	20 items rated on a 5-point scale. Higher scores represent stronger beliefs in memory ability.	Poor (ICC = .74; Yang et al., 2023)	PCA	Memory functioning	Unkenstein et al. (2016)
Strategy use subscale	19 items rated on a 5-point scale. Higher scores represent greater use of strategies.	Moderate (ICC = .77; Yang et al., 2023)	PCA	Memory functioning	Unkenstein et al. (2016)
Subjective memory questionnaire (SMQ) (Bennett-Levy & Powell, 1980)	43 items rated on a 5-point scale. Higher scores represent better perceived memory.	Moderate (r = .86; Bennett-Levy & Powell, 1980)	PCA – One factor (Behavioral organization)	Retrieval	Gorenstein et al. (2011)
Women's health questionnaire (WHQ) – memory/ concentration (Hunter, 1992)	37 items rated on a 4-point scale. Higher scores reflect poorer perceived health.	Moderate to high (r = .78 to .96; Hunter, 1992)	PCA – Nine factors (subscales). One factor represents memory and concentration	Memory and	concentration
Karossy et al. (2007)					
Daily symptom rating scale (DSRS) - forgetfulness (Taylor, 1979)	1 item rated on a 5-point scale.	Moderate to high (r = .83 to .92; Taylor, 1979)*	PCA – Four factors (mood, behavior, pain, physical) (Taylor, 1979)	Forgetfulness	Barnhart et al. (1999)
Single-item measures					
"Do you have problems with attention/ concentration?"	1 item rated on a 4-point scale		N/A	Attention	Schaafsma et al. (2010)
"Do you have problems with your memory?"	1 item rated on a 4-point scale		N/A	Memory	Armeni et al. (2018)
"How would you rate your memory at the present time? Would you say it is excellent, very good, good, fair or poor?"	1 item rated on a 5-point scale		N/A	Memory	Li et al. (2022)
"Do you have any memory problems compared to the past?"	1 item rated as "yes" or "no"		N/A	Memory	Triantafyllou et al. (2016)
"Do you consider yourself forgetful?"	1 item rated as "yes," "no," or "don't know"		N/A	Memory	Hogervorst et al. (1999)
"How would you rate your memory in terms of the kinds of problems that you have?"	1 item rated on a 7-point scale		N/A	Memory	Drogos et al. (2013)

Note: Pearson's r test–retest coefficients and ICC values between below .75 are considered poor, .75 to .90 are considered moderate, and above .90 are considered high (Nunnally & Bernstein, 1994; Portney & Watkins, 2009).
*Test–retest reliability estimate is for the overall scale.

Results of the meta-analyses

Studies that reported Pearson's correlation or beta coefficients between measures were retained for meta-analysis. Three main meta-analyses were conducted to pool correlations, including between subjective and objective cognition (Model 1), subjective cognition and other menopausal symptoms (Model 2), and objective cognition and other menopausal symptoms (Model 3).

Model 1: subjective versus objective cognition

Higher levels of subjective cognitive complaints were expected to be associated with poorer performance on objective measures. The correlation sign for subjective measures where higher scores represent better performance was inverted to maintain consistency. As such, negative correlations reflect that higher subjective scores (representing worse subjective cognition) are associated with lower objective scores (representing worse test performance).

A forest plot of the overall model organized by objective cognitive domain is shown in Figure 4. Six studies reported a total of 24 correlations between subjective and objective cognition. A multilevel random effects meta-analysis revealed that the overall correlation was non-significant (r = .06; CI = −.06 to .19; t = 1.05; p = .303). Heterogeneity was non-significant, including for the overall model (Q = 23.74, df = 23, p = .418), within-studies ($\tau^2 < 0.001$; CI < 0.01

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Table 3. Characteristics of measures of objective cognition classified using Cattell-Horn-Carroll (CHC) theory

Cognitive domain	Relevant narrow domains	Definition	Neuropsychological tests
Learning efficiency (*Gl*)	Associative memory (MA) Meaningful memory (MM) Free recall (M6)	The ability to learn, store, and consolidate new information over periods of time.	Word lists (CVLT, RAVLT, HVLT) Story recall (LM) Visual memory (RCFT, BVMT)
Working memory capacity (*Gwm*)	Auditory short-term storage (Wa) Visual–spatial short-term storage (Wv) Attentional control (AC)	The ability to maintain and manipulate information with active attention.	Digit Span Forward Digit Span Backwards Spatial Span VSPAN N-back Statement Verification Test Letter–Number Sequencing Spatial Span Continuous Performance Task Trail-Making Test A
Processing speed (*Gs*)	Switching (Sw)	The ability to control attention automatically, quickly, and fluently perform simple, repetitive cognitive tasks.	Symbol Digit Modalities Symbol Digit Search Digit Symbol Coding Trail-Making Test B D-KEFS Trails A and B Letter–Number Cancellation Stroop (Sw) Korean Color-Word Stroop Test (Sw)
Retrieval fluency (*Gr*)		The rate and fluency at which individuals can produce and selectively and strategically retrieve information from long-term memory.	COWAT D-KEFS Verbal Fluency Letter Fluency
Visual processing (*Gv*)		The ability to make use of simulated mental imagery to solve problems.	Block Design Card Rotation Hooper Visual Organization Test Symbol Copying Test
Comprehension-knowledge (*Gc*)		The ability to comprehend and communicate culturally valued knowledge.	Vocabulary Boston Naming Test
Fluid reasoning (*Gf*)		The use of deliberate and controlled procedures to solve novel problems.	Matrix Reasoning

to 0.01), and between-studies (τ^2 = 0.01; CI < 0.01 to 0.14) was minimal (I^2 = 3.1%), suggesting the effect was relatively consistent across studies. However, a subgroup analysis looking at the correlation between subjective cognition and different objective cognitive domains, as this analysis was planned a priori.

There were 12 measures of learning efficiency and nine measures of working memory capacity. In addition, there were three measures of general cognition. A small significant correlation was observed between cognition and learning efficiency (r = .12; CI = .02 to .23). The correlation between subjective cognition and working memory capacity was non-significant (r = .05; CI = −.17 to .26), as was the correlation between subjective cognition and general cognitive ability (r = .05; CI = −.24 to .33). Heterogeneity statistics for each subgroup analysis are displayed in Table 4.

Model 2: subjective cognition versus menopause symptoms

Higher levels of subjective cognitive complaints were expected to be associated with more severe menopausal symptoms. The correlation sign for subjective measures where higher scores represent better performance was inverted to maintain consistency. As such, positive correlations reflect that higher subjective scores (representing worse cognition) are associated with higher scores on measures of menopausal symptoms (representing worse symptoms).

Six studies reported a total of 26 correlations between subjective cognition and menopause symptoms. Positive correlations indicated that higher reports of subjective cognitive decline were associated with more menopausal symptoms. A multilevel random effects meta-analysis revealed that the overall correlation was non-significant (r = .11; CI = -.27 to .47; t = 0.60; p = .551). There was significant heterogeneity in the overall model (Q = 688.93, df = 25, p < .001), as well as significant within-study heterogeneity (τ^2 = 0.38; CI = 0.21 to 0.77) and between-study variability (τ^2 = 0.10; CI = 0.00 to 0.93; I^2 = 96.4%).

A subgroup analysis was conducted to investigate whether the type of menopause symptom was a significant source of heterogeneity. The correlation was non-significant across all symptom subgroups, including overall mood (r = −.19; CI = −.46 to .12), sleep or fatigue symptoms (r = .01; CI = −.57 to .59), and vasomotor symptoms (r = .63; CI = −.43 to .96), suggesting that heterogeneity in the overall model was not due to symptom type. Similarly, a subgroup analysis was conducted to investigate whether the menopause stage was a significant source of heterogeneity. The correlation was also non-significant across all subgroups, including perimenopause (r = .15; CI = −.56 to 0.74), post-menopause (r = .27; CI = −.46 to .78), and combined samples (r = −.24; CI = −.88 to .70). Heterogeneity statistics for both subgroup analyses are displayed in Table 4. A forest plot of the overall model organized by symptom type is shown in Supplementary Figure 1.

Model 3: objective cognition versus menopause symptoms

Higher levels of menopausal symptoms were expected to be associated with poorer performance on objective measures. As such,

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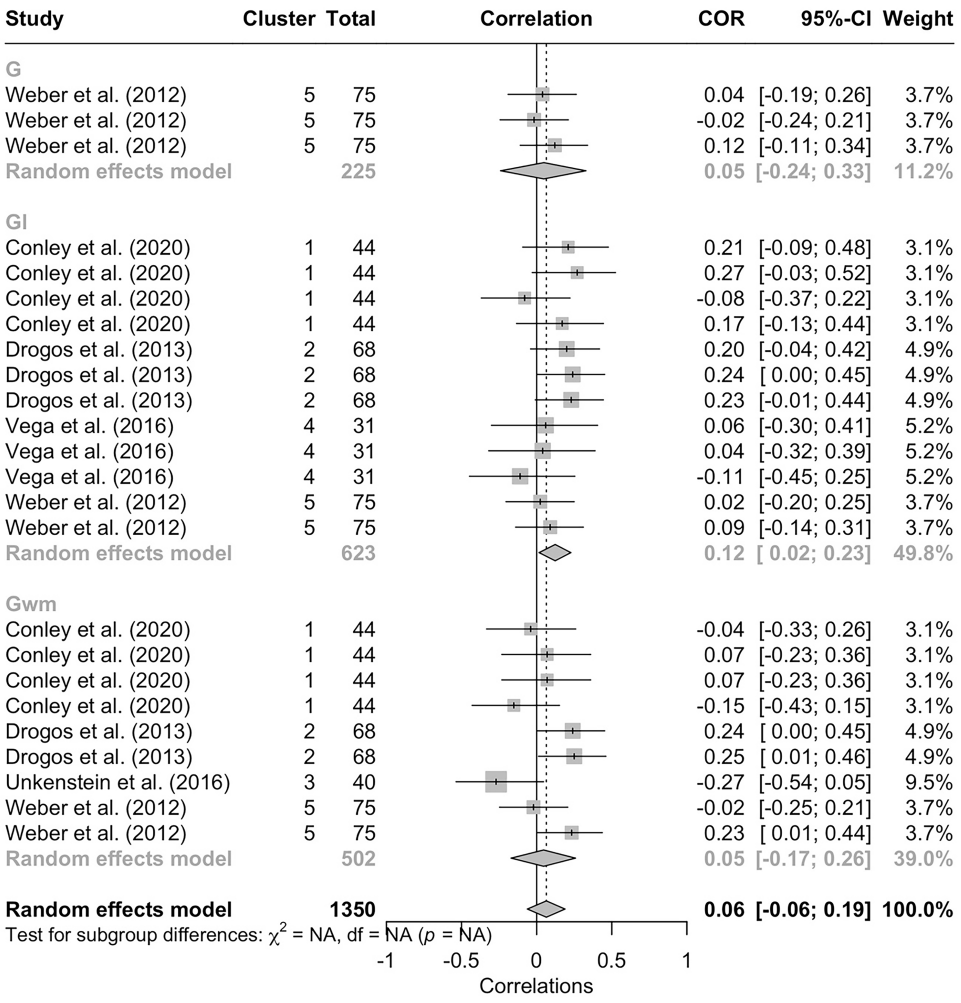


Figure 4. Forest plot of correlations between subjective and objective measures of cognition (model 1) categorized by cognitive domain.

negative correlations reflect that higher scores on measures of menopausal symptoms (representing worse cognition) are associated with lower objective scores (representing worse performance).

Two studies reported a total of 60 correlations between objective cognition and menopause symptoms. Positive correlations indicated that poorer performance on objective measures was associated with more menopausal symptoms. A multilevel random effects meta-analysis revealed the overall correlation was non-significant ($r = -.11$; CI = −.29 to .08; $t = -1.12$; $p = .265$), with significant within-study heterogeneity ($\tau^2 = 0.02$; CI = 0.01 to 0.05) and some between-study variability ($\tau^2 = 0.08$; CI = 0.00 to 0.60; $I^2 = 51.8\%$). Overall heterogeneity in the model was significant ($Q = 122.32$, $df = 59$, $p < .001$). As such, subgroup analyses were subsequently conducted to investigate potential sources of heterogeneity.

Subgroup analyses were conducted to examine whether the cognitive domain was a significant source of heterogeneity in the model. There was a significant negative correlation between menopause symptoms and tests of general intellectual ability ($r = -0.25$; CI = −0.43 to −0.05) and learning efficiency ($r = -.19$; CI = −.26 to −.12). In contrast, the correlation was non-significant for tests of visuospatial ability ($r = -.04$; CI = −.25 to .16) and working memory capacity ($r = .13$; CI = −.06 to .32, respectively). A forest plot of the overall model organized by objective cognitive domain is shown in Supplementary Figure 2. Heterogeneity statistics for both subgroup analyses are displayed in Table 4.

Sensitivity analyses

Sensitivity analyses were conducted to examine whether the difference in effect size measures was a significant source of heterogeneity. For Model 1, the effect size measure was a significant source of heterogeneity in the overall model ($F_{1,\ 22} = 8.64$, $p = .008$). Upon further inspection in a subgroup analysis, beta effect sizes appeared to be driving the effect. Therefore, we reran the cognitive domain subgroup analysis without the beta effects ($n = 1, k = 5$). The resulting model showed non-significant correlations across all domains, including learning efficiency. Whilst this finding indicates that the results of this subgroup analysis should be interpreted with caution, considering that only one study used beta estimates, the results of this sensitivity analysis may be due to other study-specific effects.

To be comprehensive, sensitivity analyses were also conducted for Models 2 and 3. The results indicated that the effect size measure was not a significant source of heterogeneity in Model 2 ($F_{1,\ 33} = 0.57$, $p = .457$) or Model 3 ($F_{1,\ 58} = 1.54$, $p = .219$), suggesting that the inclusion of beta coefficients did not have a significant impact on the results.

Risk of bias analyses

Risk of bias analyses were conducted to assess whether studies rated as having a high risk of bias in any domain significantly impacted the results of Model 1. The results showed that variance in the overall model was not related to the risk of bias in the patient

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Table 4. Heterogeneity statistics for subgroup analyses for all meta-analytic models

Model and subgroup analysis	k	r	95% CI	tau^2	Q	I^2
Model 1: objective vs. subjective measures						
Cognitive domain subgroup analysis						
General intellectual ability	3	.05	[−0.24; 0.33]	< 0.001	0.70	0.0%
Learning efficiency	12	.12	[0.01; 0.23]	0.003	7.86	0.0%
Working memory	9	.05	[−0.17; 0.26]	0.026	13.81	42.1%
Model 2: subjective measures vs. menopause symptoms						
Symptom type subgroup analysis						
Mood	12	−.19	[−0.46; 0.12]	0.22	105.49	89.6%
Sleep or fatigue	4	.01	[−0.57; 0.59]	0.11	15.99	81.2%
Vasomotor	10	.63	[−0.43; 0.96]	1.37	34.41	98.0%
Menopause stage subgroup analysis						
Combined	2	−.24	[−0.88; 0.70]	< 0.0001	0.03	0.0%
Perimenopause	16	.15	[−0.56; 0.73]	1.37	606.90	97.5%
Postmenopausal	8	.27	[−0.46; 0.78]	0.31	67.19	89.6%
Model 3: objective measures vs. menopause symptoms						
Cognitive domain subgroup analysis						
General intellectual ability	5	−0.25	[−0.43; −0.05]	< 0.0001	1.42	0.0%
Learning efficiency	45	−0.19	[−0.26; −0.12]	0.0317	95.26	53.8%
Visuospatial ability	5	−0.04	[−0.25; 0.16]	< 0.0001	0.55	0.0%
Working memory	5	0.13	[−0.06; 0.32]	< 0.0001	1.60	0.0%

selection domain ($F_{1,\ 22} = 1.12$, $p = .301$), the objective measure domain ($F_{1,\ 22} = 0.01$, $p = .920$), or the timing and flow domain ($F_{1,\ 22} = 1.05$, $p = .316$). However, variance was significantly associated with the risk of bias in the subjective measure domain ($F_{1,\ 22} = 8.64$, $p = .008$). One of the signalling questions, which are prompts or items on quality evaluation tools to guide evaluation of the risk of bias, in this domain was whether subjective cognition was assessed using a single question. Two studies using single-item measures recruited participants based on their reported subjective cognitive decline, which may have contributed to the risk of bias in this domain.

Discussion

The current study aimed to systematically review and meta-analyze correlations between subjective and objective measures of cognition in perimenopausal and postmenopausal women. Previous research has suggested that cognitive complaints during menopause are associated with subtle declines in verbal memory, attention, and processing speed (Armeni et al., 2018; Drogos et al., 2013; Greendale et al., 2010; Grummisch et al., 2023; Schaafsma et al., 2010; Weber & Mapstone, 2009; Weber et al., 2013). The results of the meta-analyses revealed a small but significant correlation between subjective cognition and performance on measures of learning efficiency. Correlations between subjective cognition and all other cognitive domains were non-significant. Additionally, although subjective cognition and objective cognitive performance were expected to correlate with other menopausal symptoms, the meta-analyses did not support this prediction.

Measures of subjective cognition used in menopause research

A key finding of this study was the considerable heterogeneity in the measures of subjective cognition used across studies. To highlight current limitations in existing measures, subjective cognition was quantified in 21 different ways across the 22 included studies, including self-report questionnaires and subscales. Whilst the included studies all purported to assess "subjective cognition," the measurement tools used in these studies varied considerably in the conceptualization of subjective cognition. For example, whilst most questionnaires provided scores aiming to quantify memory functioning in some way, this included different aspects of memory functioning, such as perceptions of the frequency of forgetting, confidence in memory ability, memory strategy use or seriousness of forgetting. Other questionnaires or scores aimed to capture related abilities, such as attention or concentration, while others aimed to capture cognition more broadly, such as those with scores reflecting cognitive complaints or cognitive failures.

Additionally, whilst most scales were validated as part of the development procedure, the method used by some researchers was PCA, which is appropriate for item reduction but is not a method of construct validation (Floyd & Widaman, 1995). Only one scale, the CFQ, used a confirmatory factor analysis, which is considered the gold standard approach for evaluating construct validity (Strauss & Smith, 2009). Measures of subjective cognition are intended to capture perceptions of cognition in day-to-day life as well as functioning and, as such, should not be expected to map neatly onto objective cognitive domains. However, the lack of consistency raises the question of whether "subjective memory" in these studies is comparable. In terms of whether any existing measure may be appropriate for use as a scale for menopausal brain fog, the measures also varied considerably in terms of age of publication, with publication dates ranging from 1979 to 2014. Items conceptualized and validated several decades ago may be less relevant to capture functioning in the context of modern day social and occupational demands, particularly digital-based platforms, communication, and multi-tasking. Additionally, measures varied in their test–retest reliability ($r = .72$ to $.96$), ranging from poor to high reliability. While reliability estimates of .90 or above are considered acceptable for clinical decision-making, several measures fell below this threshold, suggesting limited clinical utility as potential measures of menopausal brain fog. As a result, findings from individual studies may only apply to their specific samples.

Overall, these findings emphasize the variability in the existing literature on subjective cognition in menopause, limiting the comparability of findings. In addition, the lack of validation of scales in a menopausal sample, except the EMQ-R (Zhu et al., 2024), means it remains unclear whether current research can capture the experience of "brain fog" or even a consistent concept of subjective cognition. It is uncertain to what extent these measures reflect women's experiences of brain fog, especially as

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none of the studies in this review explicitly used this term. Therefore, the following findings regarding the correlations between subjective and objective cognition should be interpreted with these limitations in mind.

Subjective versus objective cognition in menopause

Despite the variability in subjective, a meta-analysis was conducted to assess whether the existing research findings provide evidence to support a correlation between objective and subjective cognition in menopause. Based on previous research suggesting that menopausal brain fog may be related to reduced attention, learning efficiency, and processing speed, it was anticipated that a small correlation would be observed between subjective and objective cognition, at least in these cognitive domains. The results of the meta-analysis were partially consistent with expectations, demonstrating a small correlation between subjective cognition and measures of learning efficiency. This finding suggests that subjective cognition during the menopause transition may be linked to a subtle decline in learning efficiency, which involves the ability to learn, store, and consolidate new information over time (Schneider & McGrew, 2018). Of note, the measures of subjective cognition used in the studies in this meta-analysis were the Cognitive Complaints Index (CCI), the Memory Functioning Questionnaire (MFQ), and a single-item measure of memory functioning measured on a 7-point scale (i.e., "*How would you rate your memory in terms of the kinds of problems that you have?*"). Thematically, these measures appear to capture broader perceptions of cognitive functioning rather than being specific to perceived memory decline. However, due to the limited construct validity evidence supporting the interpretation of these measures in terms of specific cognitive domains, this interpretation remains speculative and is a direction for future research.

Although related to memory function, it is crucial to distinguish learning efficiency as a cognitive ability distinct from the neural processes and brain areas typically associated with memory. As clinical neuropsychologists are well aware, performance on measures of learning efficiency can be influenced by numerous factors, including other cognitive abilities such as working memory, attentional capacity, and fluid reasoning (i.e., executive functioning), all of which impact how well information is learned and subsequently retrieved. Additionally, performance can be affected by non-cognitive factors, such as fatigue, effort, and distractions like pain or other physical symptoms. Thus, our findings suggest that subjective cognitive concerns are associated with poorer performance on learning efficiency tasks. However, this finding does not necessarily indicate a direct relationship between menopause and primary memory difficulties. Instead, the results imply that subjective cognitive measures aiming to capture the experience of menopausal brain fog in a reliable and meaningful way should include items not only related to memory function but also to attention, concentration, and "executive functions," such as planning and organization. Including such items is important to ensure that subjective cognitive measures capture the full spectrum of cognitive changes experienced during menopause in order to be clinically useful and ecologically valid.

On the other hand, it is worth considering that some research findings do support an association between subjective cognitive decline during menopause and a primary memory impairment. Whilst subtle memory declines can be difficult to detect through neuropsychological tests alone due to limited sensitivity, neuroimaging studies indicate a potential link between subjective cognition and reduced grey matter volume in regions associated with memory functioning, such as the hippocampus (Conley et al., 2020). Other studies have reported associations between menopause stage and grey matter volume in various areas of the brain (for a review, see Ramli et al., 2023). However, findings are mixed. For instance, some studies report a decline in hippocampal volume during perimenopause that persists into postmenopause (Goto et al., 2011; Mosconi et al., 2018), while others suggest that hippocampal volume decreases during perimenopause but recovers postmenopause (Mosconi et al., 2021). Other studies have found minimal or no significant differences in grey matter volume across menopause stage groups (Seitz et al., 2019; Sullivan et al., 2005). These discrepancies may reflect methodological variability, such as differences in sample characteristics or menopause staging criteria. Nevertheless, the hippocampus remains a region of interest in understanding menopause-related cognitive changes and in identifying women who may be at increased risk for developing neurodegenerative disease. Given that subjective cognitive concerns are themselves a risk factor for later life dementia (Pike et al., 2022), it is important to better understand the nature of these symptoms and to characterize their associated neuropsychological profile. Future research should prioritize the development of a clear conceptual framework and cognitive characterization of menopausal brain fog, in conjunction with the creation of a reliable self-report measure that aligns with established cognitive domains. Such work would allow self-reported symptoms to be mapped onto objective cognitive functioning, as measured using validated neuropsychological tests. Improving the alignment between theoretical models, subjective and objective cognitive measures, and neuroimaging findings is essential to clarify the nature of menopause-related cognitive changes and, ultimately, identify women at greatest risk for ongoing cognitive decline.

Limitations of the evidence

The results of the meta-analyses were limited by the small number of included studies that reported correlation matrices. Although most included studies reported outcomes for subjective cognition, objective cognition, and various other measures to assess symptoms of menopause, only six of 22 studies in total reported correlations between these measures. Evaluating correlations between measures was not the primary aim of many of these studies. However, both the American Educational Research Association (AERA, 2006) and the American Psychological Association (2020) emphasize the need for correlation matrices in published reports to facilitate secondary analysis (Zientek & Thompson, 2009).

For instance, our study provides preliminary evidence supporting a correlation between subjective cognition and learning efficiency during menopause. Whilst this information may aid the development of a new scale, analyzing a broader array of correlations in the meta-analysis could enable an evaluation of which objective tests of learning efficiency may be more effective measures of menopausal brain fog. It has been suggested that associative memory, a narrow ability under learning efficiency describing the ability to form a link between previously unrelated stimuli, is closely related to hippocampal integrity (Saling, 2009). However, due to the limited number of correlations available, an analysis of task-specific abilities was not possible in the current study. The point of raising this possibility is not to speculate on a causal relationship between menopause and cognition but to

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highlight the importance of researchers reporting correlation tables in their published manuscripts, even in supplementary material, to facilitate the synthesis of findings such as those presented in this review.

Limitations of the analyses

Due to the few studies included in the meta-analysis, some evaluations of heterogeneity in the results were confounded with sample effects. For instance, although there were 60 correlations included in the meta-analyses between objective cognition and menopausal symptoms, those correlations were derived from only two studies, limiting the precision of estimates of between-study heterogeneity. Similarly, sensitivity analyses were also limited, as the risk of bias across domains was assessed per study rather than effect size, meaning there was limited variability in the risk of bias rating in each meta-analysis. However, notably, the meta-analysis between objective and subjective measures included 24 effect sizes from six different studies, including 12 effect sizes across four different studies for the learning efficiency subgroup analysis. Whilst there is no strict rule for the minimum number of studies or effect sizes required for subgroup analyses, most sources indicate that a minimum of four or five studies is adequate for findings to be meaningful (Borenstein, 2009; Higgins & Thompson, 2002).

Implications and future directions

A key finding of this study is the inadequacy of current measures of subjective cognition during menopause. The variability in the measures used across existing research limits the comparability of findings in this area and hinders the ability to draw meaningful inferences about the experience of menopausal brain fog, particularly since none of the studies explicitly used this term with their participants. This finding highlights two main research directions for cognition during menopause.

The first direction is the need to characterize menopausal brain fog in relation to established cognitive theory. Determining how menopausal brain fog manifests across established cognitive domains (e.g., working memory, learning efficiency, processing speed, etc.) is essential for understanding how brain fog differentiates from other psychological or cognitive conditions. This characterization should be broad, aiming to capture the cognitive profile of women across all stages of the menopause transition. The focus should be on examining the covariance of changes across cognitive domains at different stages of menopause to identify specific, narrow cognitive abilities that tend to be affected. For instance, one avenue to explore is whether there is a difference between associative memory and meaningful memory and whether there is evidence of a differential demand for visual processing. Additionally, research in this area needs to account for the potential indirect effects of other menopausal symptoms, ensuring that selected measures are validated in menopausal samples. This characterization would provide the necessary conceptual foundation to guide item generation for a targeted measure of menopausal brain fog, ensuring that any new subjective tool is grounded in theory and interpretable alongside objective test performance. It would also support the identification of objective neuropsychological tests that are likely to be sensitive to menopause-related cognitive changes.

The second direction is to develop a new measure of subjective cognition designed to assess cognitive complaints experienced by perimenopausal women who describe their symptoms as "brain fog." Currently, there is no validated measure of subjective cognition in this population. As awareness of the relationship between menopause and cognition grows, discussions of brain fog are becoming increasingly common in the community. Consequently, more women are presenting to general practitioners with complaints of "brain fog" due to menopause and are seeking treatment. Future research could be directed at developing validated scales to measure the degree of brain fog and provide a means of measuring how brain fog responds to different treatment options. In addition, clarity around the subjective and objective profile of menopause brain fog will aid discrimination between menopause-related cognitive concerns from early onset dementia as well as ADHD, which is increasingly being diagnosed in perimenopause. One final area of future research could be providing better clinical guidelines for primary care practitioners on how to assess brain fog.

Conclusion

Many women report experiencing some degree of cognitive symptoms during their menopause transition years. The severity appears to range from mild to problematic, with reports that cognitive symptoms impact work and life in general (Mitchell & Woods, 2001). The present findings emphasize the need for a stronger characterization of menopausal brain fog in relation to both subjective cognitive symptoms and objective cognitive performance. Research in this area cannot progress in an empirically robust manner without a good theoretical understanding of what brain fog looks like in relation to cognition and without a valid and reliable tool to assess brain fog in individuals presenting with concerns. Ideally, these two research goals should be pursued in tandem through an iterative process. A robust characterization of brain fog is essential to guide the development of a new measure, and a robust measure itself is necessary to map objective cognitive function to various presentations and severities of subjective brain fog. Like all good scientific theories, advances in this area would self-correct through an iterative process in which a theory of brain fog is established, which guides the development and validation of a new measure. As that measure is used to collect data from larger and more diverse samples, the theory can be refined.

The results of the present study provide a lead for further research on the assessment of menopausal brain fog, suggesting that future work may begin by focusing on the factors impacting learning efficiency during menopause, such as attention or concentration, and non-cognitive factors, such as anxiety and distractions. We recommend that future research prioritize using neuropsychological tests that capture narrow abilities within the broad domain of learning efficiency, including measures of both associative memory and meaningful memory (Schneider & McGrew, 2018). Suitable measures of these domains include the Verbal Paired Associates (VPA) and Logical Memory subtests from the Wechsler Memory Scale-Fourth Edition (WMS-IV). Tasks from the WMS-IV or the Wechsler Adult Intelligence Scales are grounded in cognitive theory and offer high ceilings, which is key for detecting subtle cognitive changes that may occur during the menopause transition. As such, long-format tasks with robust psychometric properties are recommended. For instance, the CVLT-3 Standard Form may be a suitable choice for a word list learning task (Delis et al., 2017). However, future research is needed to explore how people experiencing cognitive symptoms during menopause perform on these tasks. Although working memory and verbal fluency were not consistently associated with

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subjective complaints in our review, previous research has highlighted their potential relevance. Accordingly, future studies should apply the same criteria, prioritizing tests with established construct validity and high ceilings when selecting measures for these domains. Although this study did not seek to identify causal factors between menopause and cognitive decline, exploring these avenues would help guide future research to focus on the relationship between brain changes in menopause and factors related to learning efficiency.

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Data availability. The data and code used in this study will be available upon reasonable request.

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