


COVID-19-Related Anxiety and Cognition in Middle-Aged and Older Adults: Examining Sex as a Moderator

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Abstract

Aging populations experience disproportionate risk for cognitive decline, which may be exacerbated by coronavirus (COVID-19) illness, particularly among women. This study tested sex as a moderator of associations between COVID-19 state anxiety and cognition in middle-aged/older adults. Adults aged 50+ ($N = 275$; 151 men/124 women) completed the Coronavirus Anxiety Scale and Cognitive Failures Questionnaire online from remote locations in July/August 2020. A subset of participants ($n = 62$) completed an objective cognitive task (Stroop). Multiple regressions determined whether sex moderated associations between COVID-19 anxiety and cognitive outcomes. Sex was a significant moderator, such that for women (not men), greater COVID-19 anxiety was associated with more memory failures and blunders (subjective measures) and

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worse processing speed (objective measure). COVID-19 state anxiety is linked to everyday cognition and processing speed in women, but not men. Consistency across subjective and objective measures promotes the need for sex-specific understanding of the pandemic's behavioral and cognitive effects in mid-to-late life.

Keywords

Cognition, coronavirus, anxiety, sex differences, middle-aged adults, older adults

Introduction

Coronavirus 2019 disease (COVID-19) is a highly contagious acute respiratory illness that began spreading worldwide in late 2019. COVID-19 led to an international pandemic that has negatively and severely impacted individual health, community health, and the medical community (Choi et al., 2020; Lima et al., 2020; Van Bavel et al., 2020). Thus, the global scientific community has been called to advance understanding not only of the physiological symptoms of the disease but also of the behavioral and psychological impact of the pandemic. The majority of research has focused on physiological outcomes and risk factors for COVID-19, with sex differences identified for both the morbidity and mortality related to physical COVID-19 symptoms (Klein et al., 2020). Psychological factors, such as anxiety, have also been examined in the context of the COVID-19 pandemic, with sex differences showing greater state anxiety (transitory state of psychological and physiological reactions directly related to adverse situations in a specific moment [Leal et al., 2017]) and trait anxiety (generally stable tendency to become anxious [Leal et al., 2017]) in younger women relative to men (Bigalke et al., 2020; Özdin & Bayrak Özdin, 2020). The association between non-COVID-19-specific state anxiety and cognitive functioning has also been studied (Vytal et al., 2012), but whether state anxiety such as that experienced in response to COVID-19 information is linked to various aspects of cognitive function (e.g., subjective everyday functioning, objective cognition) and whether these associations depend on sex in aging populations is unclear. Better understanding of the cognitive and emotional consequences of the pandemic—and the extent to which those differ among men and women—is expected to inform efforts to prevent long-term sequelae of COVID-19 across the lifespan.

In the United States, approximately 50% of Americans report being acutely anxious about COVID-19 infection (Canady, 2020). A recent study among middle-aged adults living in China also observed that those in quarantine endorsed higher state anxiety scores than individuals not in quarantine (Chen et al., 2021). Studies in a range of countries have also reported sex differences in state anxiety (i.e., overall feelings/experience of anxiety, not specifically linked to COVID-19 information/situations) during the COVID-19 pandemic. In a sample of mostly younger adults in the United States, during the COVID-19 stay-at-home orders (April–May 2020), relative to men,

women endorsed greater state anxiety symptoms, as assessed via the State-Trait Anxiety Inventory (STAI)–State subscale (Spielberger et al., 1983), not specifically related to COVID-19 but rather overall acute reactions to everyday stressful situations (Bigalke et al., 2020). Another study (Frontini et al., 2021) found sex differences for both state and trait anxiety (again via the non-COVID-19-specific STAI scale) among adults living in Portugal during the COVID-19 pandemic, with females scoring higher in both types of anxiety. Similarly, findings from China have observed that, in adults of a variety of ages, women were at greater risk than men of experiencing state anxiety (Liu et al., 2020; Yan et al., 2021). Additionally, findings were observed in a Turkish population of mostly younger adults, with women endorsing greater general (not tied to COVID-19) and health-related state anxiety symptoms than men (Özdin & Bayrak Özdin, 2020). However, the differential impact of COVID-19-specific state anxiety and cognitive performance (known to be associated with state [Vytal et al., 2012] and trait [Bishop, 2009] anxiety not tied to COVID-19) among men and women, particularly in aging populations, has not been established. This information could help inform sex-specific identification and treatment efforts for mitigating the negative impacts of the pandemic (e.g., cognitive disruption) across the lifespan.

Studies examining the impact of COVID-19 among middle-aged and older adult populations are especially important for several reasons. First, lack of spousal and social support as well as increased medical comorbidities may make middle-aged and older adults most vulnerable to negative immediate psychological consequences of COVID-19 (Satre et al., 2020). These age groups are also at a greater risk of morbidity and mortality related to COVID-19 (Nanda et al., 2020), and are more likely than younger adults to experience cognitive decline and/or impairment in general (Salthouse, 2009).

Research shows associations between both state and trait anxiety and cognitive performance. Although the focus of the present study is on state anxiety specific to reaction to COVID-19 information/situations (emotional and physiological responses to seeing/hearing COVID-19 information), given that state and trait anxiety are associated (Leal et al., 2017), it is important to discuss findings related to both types of anxiety regarding their impact on cognitive functioning. Aging populations tend to demonstrate strong positive relationships between both state and trait anxiety and subjective cognitive performance. For instance, in a sample of middle-aged adults, greater trait anxiety (assessed via the German version of the Penn State Worry Questionnaire [Glöckner-Rist & Rist, 2014]) was associated with more subjective complaints in attention and memory function (Mascherek et al., 2020). Another study in older adults showed that individuals with subjective memory complaints endorsed greater trait anxiety (assessed via the STAI; [Balash et al., 2013]). Prior research findings (although limited) also point to a relationship between state anxiety (albeit not specific to COVID-19) and trait anxiety and objective cognitive performance in aging populations. One study in healthy older adults found that greater self-reported trait anxiety (assessed via the Symptoms Checklist-90 Revised scale [Derogatis, 1994]) was associated with worse global and visuospatial cognitive functioning (Stillman et al., 2012).

Another study found that, in community-dwelling older adults, greater trait anxiety (assessed via the Depression Anxiety and Stress Scale [Akin & Çetm, 2007]) was associated with worse global cognitive function, but not specific domains of cognitive function (Del Brutto et al., 2015). Longitudinal studies have also linked increased anxiety to cognitive decline, and have noted sex differences in the cognitive domains affected. For instance, increased trait anxiety (assessed via the Symptoms Checklist-90 scale) has been associated with worse verbal memory in older adults (aged 65+ years, regardless of sex), with associations between increased anxiety and decline in executive function and processing speed observed only in women (Gulpers et al., 2019). Another study in younger adults found sex-specific associations between induced state anxiety and spatial memory, with increased anxiety leading to worse performance in women, but not men (Ruginiski et al., 2018). Similarly, a study in younger adults showed that in women (not men), higher state anxiety was associated with worse executive function (risk tasking behavior; [Panno et al., 2018]).

To date, no studies have examined the impact of sex on associations between COVID-19-related state anxiety and everyday subjective cognition, or objective cognition. As previously noted, recent research suggests sex differences in non-COVID specific state anxiety (but assessed during timepoints within the COVID-19 pandemic) in younger adults (Bigalke et al., 2020). Additional research is needed to evaluate COVID-19-related state anxiety (i.e., specific emotional and physiological responses to COVID-19 information/situations) and cognition amongst specific vulnerable age groups of middle-aged and older adults. Finding from such investigations will reveal important information for understanding the psychological impact of a pandemic on various aspects of cognitive function in aging adults. Ultimately, a more thorough understanding of sex-specific patterns regarding risks of state anxiety relating to COVID-19 may help not only with immediate care for individuals during the ongoing pandemic but also help inform prevention efforts for ongoing mental health problems.

Aims and hypotheses

Overall, the goal of this study was to examine whether sex moderates the association between COVID-19-related state anxiety and subjective cognitive function (everyday cognition, as assessed by the Cognitive Failures Questionnaire (CFQ)) as well as objective cognitive function in middle-aged and older adults in the United States. Based upon the extant research showing worse state and trait anxiety in women (assessed during the COVID-19 pandemic) as well as sex differences in the impact of state anxiety on cognitive function (several studies outlined earlier showing worse impact of non-COVID-19-specific anxiety in women), we hypothesized that sex would moderate the association between COVID-19-related state anxiety and cognition. Specifically, we hypothesized that women would show stronger associations than men regarding the relationship between greater COVID-19-related anxiety and worse subjective everyday cognition (assessed via the CFQ; [Broadbent et al., 1982]) and objective cognitive function (assessed via the Stroop task [Stroop, 1935]; chosen due its consideration the

golden standard assessment for a range of cognitive functions including processing speed, attention and inhibition). Assessing associations between COVID-19 state anxiety and performance across a range of both subjective cognitive function (through the CFQ) and objective cognitive function (through indices of performance across multiple objective cognitive domains in the Stroop task) will allow us to more comprehensively evaluate the potential impact of pandemic-related emotional responses and anxiety-related physiological responses on daytime functioning in mid-to-late life.

Methods

Participants

A sample of middle-aged and older adults ($N = 275$; 151 men/124 women, $M_{age} = 64.66$, $SD = 7.87$) living in the United States was recruited through Qualtrics survey panels in July and August 2020. Those who met inclusion criteria read and documented informed consent prior to completing the online survey and objective cognitive tasks. Participants were included in the study if they (i) were aged 50 years or older, (ii) resided in the United States, (iii) reported no cognitive impairment or major neurological disorder (no diagnoses of mild cognitive impairment, dementia, or other neurological disorder, including Parkinson's Disease, Amyotrophic Lateral Sclerosis, Epilepsy, etc.), and (iv) reported normal or corrected-to-normal vision and/or hearing (i.e., glasses, hearing aid). Participants were excluded from the study if they were receiving pharmacological and/or non-pharmacological treatment for cognition, substance use, fatigue, or mood concerns, or were participating in non-pharmacological treatment for sleep (sleep medication use was recorded and examined as a covariate in analyses). Participants were compensated \$6.50 for completing the online survey and \$10.00 for completing the online cognitive tasks. All study procedures were approved by the University of Missouri Institutional Review Board.

Measures

Demographics. Participants reported their age, sex (1 = male, 2 = female), race, highest level of education, and total household income (considered a measure of socioeconomic status in the present study, categorized as: below \$19,999, \$20,000–\$39,999, \$40,000–\$59,999, \$60,000–\$79,999, \$80,000–\$99,999, above \$100,000). Additionally, participants reported their number of medical conditions from a list of common age-related disorders (e.g., heart disease, cancer, diabetes, chronic pain conditions such as fibromyalgia, arthritis, and urinary tract problems) and responded with a “yes” or “no” regarding whether they used sleep or pain medications. Participants were also asked to best describe their COVID-19 infection status (herein referred to as COVID-19 status, coded as a categorical variable with three levels: 1 = diagnosed with COVID-19,

still recovering; 2 = previously diagnosed with COVID-19 but now fully recovered; 3 = never diagnosed with COVID-19).

COVID-19-related anxiety

COVID-19-related anxiety was measured using the Coronavirus Anxiety Scale (CAS; [S. A. Lee, 2020]). This scale is considered a measure of state anxiety related to COVID-19, as questions pertain to current anxiety symptoms. Participants were asked to rate on a scale from 0 (not at all) to 4 (nearly every day) the degree to which they experienced five-items specifically related to the COVID-19 pandemic (e.g., “I felt dizzy, lightheaded, or faint, when I read or listened to news about the coronavirus,” “I felt nauseous or had stomach problems when I thought about or was exposed to information about the coronavirus,” etc.) over the last 2 weeks. The total score was computed as the variable of interest. Total scores ranged from 0 to 20, with higher scores representing greater COVID-19-related state anxiety. The CAS has demonstrated high internal consistency (alpha coefficient of 0.93) and validity and is able to discriminate well between people with and without dysfunctional anxiety (S. A. Lee, 2020).

Subjective cognition

Everyday cognition—cognitive failures. The (CFQ; Broadbent et al., 1982) measures self-reported everyday cognitive failures. Participants provide ratings from 0 (never) to 4 (always) indicating the degree to which they experience failures in 25 everyday cognitive tasks (e.g., “Do you find you forget appointments?”; “Do you read something and find you haven’t been thinking about it and must read it again,” “Do you have trouble making up your mind?” etc.) over the past month. The CFQ-total score was computed, ranging from a possible 0 to 100, with higher scores indicating greater everyday cognitive failures (i.e., worse subjective everyday cognition). Subscores representing cognitive failures in four main domains were also computed (Wallace et al., 2002): CFQ-memory (measures general memory failures and forgetfulness across eight questionnaire items; possible scores range from 0 to 32), CFQ-distractibility (measures perceptual aspects of divided attention tasks across 9 questionnaire items; possible scores range from a possible 0 to 36), CFQ-blunders (measures errors in task execution across 7 questionnaire items; possible scores range from 0 to 28), CFQ-names (measures specific memory for proper names across 2 questionnaire items; possible scores range from 0 to 8). The CFQ has excellent psychometric properties, with high internal consistency (alpha coefficient of .91; [Wallace et al., 2002]).

Objective cognition

Stroop task. Participants were invited to complete an online version of the color-word Stroop task (Stroop, 1935) via Inquisit web (“Inquisit Web,” 2020). In this task,

participants are shown one of four color words or colored rectangles (red, green, blue, black) in the center of the computer screen and are instructed to indicate the color (not the name) of the word or rectangle via a designated keyboard press. Participants are instructed to respond as quickly and accurately as possible. Trials consist of three possibilities: *control trials* (i.e., colored rectangles; measures processing speed [Spreeen & Strauss, 1998; Stroop, 1935]), *congruent trials* (i.e., words presented in which the color of the word matches the name of word; measures processing speed and attention [Spreeen & Strauss, 1998; Stroop, 1935]), *incongruent trials* (i.e., the color of the word is not the same as the name of the word; measures inhibition, an executive function [Spreeen & Strauss, 1998; Stroop, 1935]). Each color word and colored rectangle (out of four possible colors) is presented seven times for each trial type (control, congruent, incongruent), for a total of 84 trials. Color word/colored rectangle stimuli stay on the screen until a response is made. Intertrial interval time is 200 ms and trials are presented in random order. Error feedback is provided for a duration of 400 ms when participants answer incorrectly (a red “X” is displayed at the center of the screen). Average reaction time (RT; measured from color word/color rectangle stimuli onset until a response is made) on correct trials for each trial type (control trials, congruent trials, incongruent trials) were computed as the outcomes of interest. Higher RTs indicate worse performance.

Statistical analyses

Independent sample t-tests and chi-square analyses were conducted to evaluate differences between men and women continuous and categorical variables, respectively, (evaluated at an alpha level of $p < .05$). Multiple regressions were conducted using the PROCESS macro (model 1) in SPSS (Version 26). Criterion variables for subjective cognition included: CFQ-total, CFQ-memory, CFQ-distractibility, CFQ-blunders, CFQ-names and objective cognitive outcomes (Stroop Task RT on control trials [processing speed], Stroop Task RT on congruent trials [processing speed and attention], Stroop Task RT on incongruent trials [inhibition]). Independent variables included CAS, sex, and the CAS x sex interaction. Analyses for the subjective cognitive outcomes controlled for age, education, total household income (considered a measure of socioeconomic status), number of medical conditions, and COVID-19 status. Due to the known association between cognitive function and sleep medications (Hanlon et al., 1998) and pain medications (Finan et al., 2013), analyses also controlled for current use of sleep or pain medication.

Given the smaller subset of individuals who completed the online cognitive tasks ($N = 62$, 33 men/29 women) and the general rule of thumb in regression analyses to examine one independent variable per every 10 cases (Harrell, 2015), we reduced the number of covariates for regression analyses of objective cognitive outcomes. In these analyses, we controlled for common covariates associated with cognitive aging and age-related health conditions: age, education and number of medical conditions.

In the case of a significant interaction in regression models, follow-up tests of simple slopes were used to examine the strength and significance of the association between CAS and cognitive outcomes among men and women. All regression results were evaluated at an alpha level of $p < .05$.

Results

Participant characteristics

Participant demographics and descriptive values for cognition and sleep variables are provided in [Table 1](#). A total of 544 participants initially responded to the survey (completed screening questions), with 325 participants meeting inclusion criteria. Missing data for variables examined in the present study were as follows (missing data percentage pertains to of those individuals who met inclusion criteria, how many did not complete the survey items): age ($n = 0, 0\%$), sex ($n = 0, 0\%$), education ($n = 0, 0\%$), race ($n = 0, 0\%$), number of medical conditions ($n = 0, 0\%$), sleep medication usage ($n = 0, 0\%$), pain medication usage ($n = 0, 0\%$), CAS ($n = 43, 13\%$), COVID-19 status ($n = 0, 0\%$), and CFQ ($n = 50, 15\%$). A final sample of 275 participants (151 men/124 women) completed all survey items related to variables of interest in the present study and were included in regression analyses regarding COVID-19-related anxiety and subjective cognition (CFQ-total and subscores). A subset of 62 participants ($M_{age} = 63.40, SD = 1.70$; 33 men/29 women) also completed the online cognitive task (Stroop task), and these participants were included in regression analyses regarding COVID-19-related anxiety and objective cognitive performance. For CFQ-blunders and CFQ-names, men had significantly higher values than women. For all other variables, there were no significant differences on mean values (for continuous variables, t-tests) or frequency of categories (for categorical variables, chi-square tests) between men and women ($ps > .05$).

Regression results

COVID-19-related anxiety and CFQ

CFQ-total. The full regression model was significant and explained approximately 18% of variation in CFQ-total scores ($F(10, 264) = 5.67, p < .001, R^2_{\text{adjusted}} = 0.18$). However, as shown in [Table 2](#), CAS and sex were not independently associated with CFQ-total scores. Additionally, the interaction between CAS and sex was not associated with CFQ-total scores.

CFQ-memory. The full regression model was significant, and explained approximately 16% of variation in CFQ-memory scores ($F(10, 264) = 5.12, p < .001, R^2_{\text{adjusted}} = 0.16$). As shown in [Table 2](#), CAS and sex were not independently associated with CFQ-memory. However, CAS and sex interacted in their association with CFQ-memory, accounting for 2% unique variance [$F(1, 264) = 4.89, p = .028, R^2$

Table 1. Participant characteristics.

Variable	Total (N = 275)			Men (N = 151)			Women (N = 124)		
	Mean (SD)	Range		Mean (SD)	Range		Mean (SD)	Range	
Age	64.66 (7.87)	50.00–85.00		64.30 (8.07)	50.00–85.00		65.10 (7.62)	50.00–83.00	
Race (n, %)									
White/European American	(243, 89%)	—		(131, 87%)	—		(112, 90%)	—	
Black/African American	(19, 7%)	—		(12, 8%)	—		(7, 6%)	—	
Asian/Asian American	(8, 3%)	—		(5, 3%)	—		(3, 2%)	—	
American Indian/Alaskan Native	(1, 0%)	—		(1, 1%)	—		(0, 0%)	—	
Other	(4, 1%)	—		(2, 1%)	—		(2, 2%)	—	
Education (n, %)									
Some high school	(3, 1%)	—		(2, 1%)	—		(1, 1%)	—	
Graduate of high school	(55, 20%)	—		(30, 20%)	—		(25, 20%)	—	
Some college	(98, 35%)	—		(55, 36%)	—		(43, 35%)	—	
Graduated college	(80, 29%)	—		(39, 26%)	—		(41, 33%)	—	
Graduate or professional school	(38, 14%)	—		(25, 17%)	—		(13, 10%)	—	
Other	(1, 1%)	—		(0, 0%)	—		(1, 1%)	—	
Household income (n, %)									
Below \$19,999	(35, 13%)	—		(18, 12%)	—		(17, 14%)	—	
\$20,000-\$39,999	(75, 27%)	—		(40, 27%)	—		(35, 28%)	—	
\$40,000-\$59,999	(68, 25%)	—		(39, 26%)	—		(29, 23%)	—	
\$60,000-\$79,999	(36, 13%)	—		(23, 15%)	—		(13, 11%)	—	
\$80,000-\$99,999	(26, 9%)	—		(17, 11%)	—		(9, 7%)	—	
Above \$100,000	(35, 13%)	—		(14, 9%)	—		(21, 17%)	—	
# of medical conditions	2.22 (2.16)	0.00–11.00		2.44 (2.20)	0.00–11.00		1.98 (2.09)	0.00–9.00	
Use of sleep medications (n, %)									
Yes	(64, 23%)	—		(38, 25%)	—		(98, 79%)	—	
No	(211, 77%)	—		(113, 75%)	—		(26, 21%)	—	

(continued)

Table 1. (continued)

Variable	Total (N = 275)		Men (N = 151)		Women (N = 124)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Use of pain medication (n, %)						
Yes	(160, 58%)	—	(87, 58%)	—	(73, 59%)	—
No	(115, 42%)	—	(64, 42%)	—	(51, 41%)	—
COVID-19 status (n, %)						
Diagnosed, still recovering	(1, 0%)	—	(0, 0%)	—	(1, 1%)	—
Previously diagnosed, fully recovered	(2, 1%)	—	(2, 1%)	—	(0, 0%)	—
Never diagnosed	(272, 99%)	—	(149, 99%)	—	(123, 99%)	—
Coronavirus Anxiety Scale (CAS)	0.83 (2.09)	0.00–16.00	0.77 (2.02)	0.00–16.00	0.90 (2.18)	0.00–15.00
CFQ-total	29.83 (14.35)	1.00–79.00	30.46 (14.46)	1.00–79.00	29.07 (14.24)	5.00–79.00
CFQ-memory	6.69 (4.63)	0.00–26.00	6.74 (4.58)	0.00–25.00	6.64 (4.72)	0.00–26.00
CFQ-distractibility	12.09 (5.63)	1.00–30.00	11.85 (5.72)	1.00–28.00	12.37 (5.54)	2.00–30.00
CFQ-blunders ^a	8.27 (4.62)	0.00–22.00	8.76 (4.47)	0.00–22.00	7.66 (4.74)	0.00–22.00
CFQ-names ^a	3.74 (1.94)	0.00–8.00	4.01 (2.02)	0.00–8.00	3.41 (1.78)	0.00–8.00
Stroop task- RT (ms)						
Control trials ^b	1438.55 (518.42)	746.71–3768.74	1484.94 (573.69)	746.71–3768.74	1385.77 (451.61)	813.46–2802.96
Congruent trials ^b	1530.80 (618.14)	790.21–4330.93	1595.48 (698.10)	794.26–4330.93	1457.20 (514.71)	790.21–3015.85
Incongruent trials ^c	1853.77 (572.42)	971.96–3688.52	1948.29 (658.51)	971.96–3688.52	1745.74 (442.08)	1057.64–2853.50

Note. CFQ = Cognitive Failures Questionnaire.

^aSignificant differences between men and women ($p < .05$).

^bBased on subset of sample that completed tasks: Total ($n = 62$), Men ($n = 33$), Women ($n = 29$).

^cTwo participants obtained an accuracy of 0% on incongruent trials; therefore, no RT could be calculated (for correct trials). Therefore, this subsample is based on 60 participants. Men ($n = 32$), Women ($n = 28$).

Table 2. Associations between COVID-19-related anxiety and subjective everyday cognition in middle-aged and older adult men and women (N = 275).

Cognitive Outcome	B	SE B	t	p
CFQ-total				
CAS	-0.95	1.27	-0.75	.46
Sex	-1.53	1.77	-0.87	.39
CAS × sex	1.36	0.84	1.62	.11
Age	-0.16	0.10	-1.56	.12
Education	0.68	0.86	0.79	.43
Income	-0.40	0.55	-0.73	.47
# of medical conditions	1.84	0.44	4.22	.00
Sleep med use	3.17	2.03	1.56	.12
Pain med use	1.09	1.82	0.60	.55
COVID-19 status	3.31	6.22	0.53	.59
CFQ-memory				
CAS	-0.62	0.42	-1.49	.14
Sex	-0.28	0.58	-0.49	.63
CAS × sex	0.61	0.27	2.21	.028
Age	-0.05	0.03	-1.44	.15
Education	0.17	0.28	0.62	.54
Income	-0.05	0.18	-0.29	.77
# of medical conditions	0.59	0.14	4.17	.00
Sleep med use	1.10	0.66	1.66	.10
Pain med use	0.17	0.59	0.29	.77
COVID-19 status	1.08	2.03	0.53	.59
CFQ-distractibility				
CAS	0.15	0.51	0.30	.77
Sex	0.72	0.71	1.02	.31
CAS × sex	0.17	0.34	0.51	.61
Age	-0.05	0.04	-1.23	.22
Education	0.18	0.35	0.53	.60
Income	-0.07	0.22	-0.33	.74
# of medical conditions	0.67	0.17	3.82	.00
Sleep med use	1.23	0.81	1.51	.13
Pain med use	0.33	0.73	0.45	.65
COVID-19 status	0.47	2.49	0.19	.85
CFQ-blunders				
CAS	-0.53	0.41	-1.29	.20
Sex	-1.35	0.57	-2.37	.02
CAS × sex	0.62	0.27	2.29	.02
Age	-0.07	0.03	-2.02	.04
Education	0.25	0.28	0.89	.37

(continued)

Table 2. (continued)

Cognitive Outcome	B	SE B	t	p
Income	-.17	0.18	-0.95	.24
# of medical conditions	0.49	0.14	3.50	.00
Sleep med use	0.75	0.66	1.14	.26
Pain med use	0.50	0.59	0.85	.40
COVID-19 status	2.20	2.01	1.10	.27
CFQ-names				
CAS	-0.02	0.18	-0.12	.90
Sex	-0.53	0.25	-2.10	.04
CAS × sex	0.02	0.12	0.19	.85
Age	0.00	0.01	0.24	.81
Education	0.11	0.12	0.88	.38
Income	-0.10	0.08	-1.33	.18
# of medical conditions	0.16	0.06	2.54	.01
Sleep med use	0.30	0.29	1.00	.32
Pain med use	0.09	0.26	0.37	.71
COVID-19 status	-0.42	0.89	-0.47	.64

Note. CAS = Coronavirus Anxiety Scale; Med = medication. Income reflects total household income (considered a measure of socioeconomic status in the present study).

change = 0.02). As shown in [Figure 1](#), in women, higher CAS scores were associated with higher CFQ-memory scores (i.e., more everyday memory failures; $B = 0.59$, $SE = 0.21$, $p = .004$). In men, CAS was not associated with CFQ-memory scores ($B = -0.01$, $SE = 0.18$, $p = .95$).

CFQ-distractibility. The full regression model was significant and explained approximately 15% of variation in CFQ-distractibility scores ($F(10, 264) = 4.52$, $p < .001$, $R^2_{\text{adjusted}} = 0.15$). However, as shown in [Table 2](#), CAS and sex were not independently associated with CFQ-distractibility scores. Additionally, the interaction between CAS and sex was not associated with CFQ-distractibility.

CFQ-blunders. The full regression model was significant, and explained approximately 17% of variation in CFQ-blunder scores ($F(10, 264) = 5.59$, $p < .001$, $R^2_{\text{adjusted}} = 0.17$). As shown in [Table 2](#), CAS was not independently associated with CFQ-blunders. Sex was independently associated with CFQ-blunders scores, in that men tended to have a higher CFQ-blunders score than women. Additionally, CAS and sex interacted in their association with CFQ-blunders, accounting for 2% unique variance ($F(1, 264) = 5.26$, $p = .02$, $R^2_{\text{change}} = .02$). As shown in [Figure 2](#), in women, higher CAS scores were associated with higher CFQ-blunders scores (i.e., more everyday blunders;

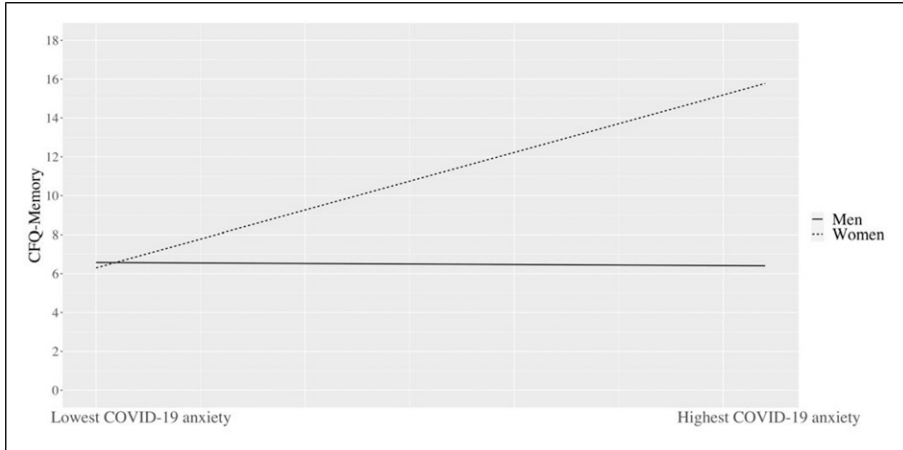


Figure 1. Association between COVID-19 anxiety and Cognitive Failures Questionnaire-memory, as moderated by sex, in middle-aged and older adults.

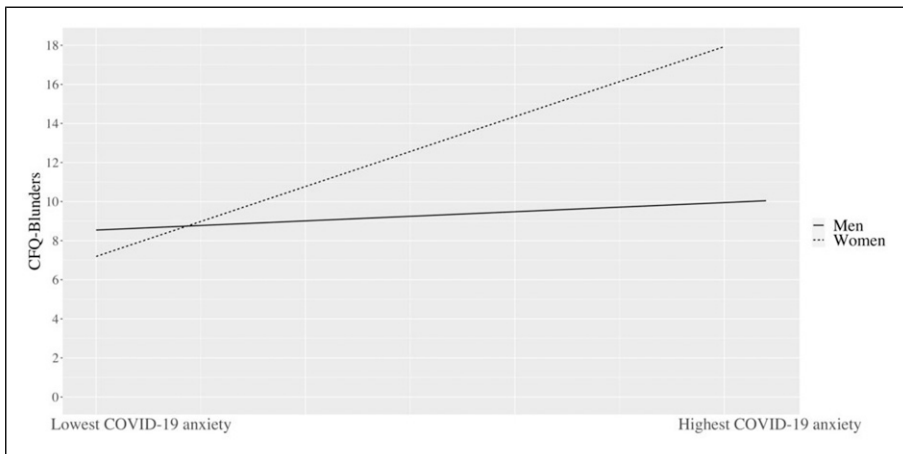


Figure 2. Association between COVID-19 anxiety and Cognitive Failures Questionnaire-blunders, as moderated by sex, in middle-aged and older adults.

$B = .72$, $SE = .20$, $p < .001$). In men, CAS was not associated with CFQ-blunders scores ($B = 0.09$, $SE = 0.18$, $p = .60$).

CFQ-names. The full regression model was significant and explained approximately 8% of variation in CFQ-names scores ($F(10, 264) = 2.37$, $p = .01$, $R^2_{\text{adjusted}} = 0.08$). However, as shown in Table 2, CAS was not independently associated with CFQ-names and CAS did not interact with sex in its association with CFQ-names

scores. Sex was independently associated with CFQ-names scores in that men tended to have higher CFQ-names scores than women.

COVID-19-related anxiety and objective cognition (Stroop task)

Control trials (processing speed). The full regression model for analyses regarding performance on control trials was significant and explained approximately 31% of variation in performance ($F(6, 55) = 4.15, p = .002, R^2_{\text{adjusted}} = 0.31$). As shown in Table 3, CAS and sex were not independently associated with RT on control trials. However, CAS and sex interacted in their association with RT on control trials, accounting for 6% unique variance [$F(1, 55) = 4.87, p = .03, R^2 \text{ change} = 0.06$]. As shown in Figure 3, higher CAS (more COVID-19-related anxiety) was associated with higher

Table 3. Associations between COVID-19-related anxiety and objective cognition in middle-aged and older adult men and women ($N = 62$).

Cognitive Outcome ^a	B	SE	t	p
Stroop: RT control trials				
CAS	-202.89	106.91	-1.90	.06
Sex	-249.81	133.18	-1.87	.07
CAS × sex	166.78	75.57	2.21	.03
Age	31.29	7.93	3.94	.00
Education	1.13	63.35	0.02	.99
# of medical conditions	21.84	33.85	0.65	.52
Stroop: RT congruent trials				
CAS	-181.16	133.29	-1.36	.18
Sex	-271.08	166.03	-1.63	.11
CAS × sex	122.17	94.21	1.30	.20
Age	35.11	9.89	3.55	.00
Education	6.83	78.97	0.09	.93
# Of medical conditions	25.28	42.20	0.60	.55
Stroop: RT incongruent trials ^b				
CAS	-94.68	125.89	-0.75	.46
Sex	-254.32	157.57	-1.61	.11
CAS × sex	79.56	88.83	0.90	.37
Age	29.23	9.32	3.14	.00
Education	43.76	75.78	0.58	.57
# of medical conditions	53.28	39.73	1.34	.19

Note. RT = reaction time; CAS = Coronavirus Anxiety Scale.

^aDue to the higher (albeit non-significant) percentage of women than men reporting sleep medication use (see Table 1), sleep medication was also investigated as a potential covariate in regression models. However, sleep medication was found to be a non-significant covariate across all models and did not change strength of associations between the independent variable and dependent variable. Thus, regression models are reported without sleep medication use as a covariate.

^bTwo participants obtained an accuracy of 0% on incongruent trials; therefore, no RT could be calculated (for correct trials). Therefore, this subsample is based on 60 participants, Men ($n = 32$), Women ($n = 28$).

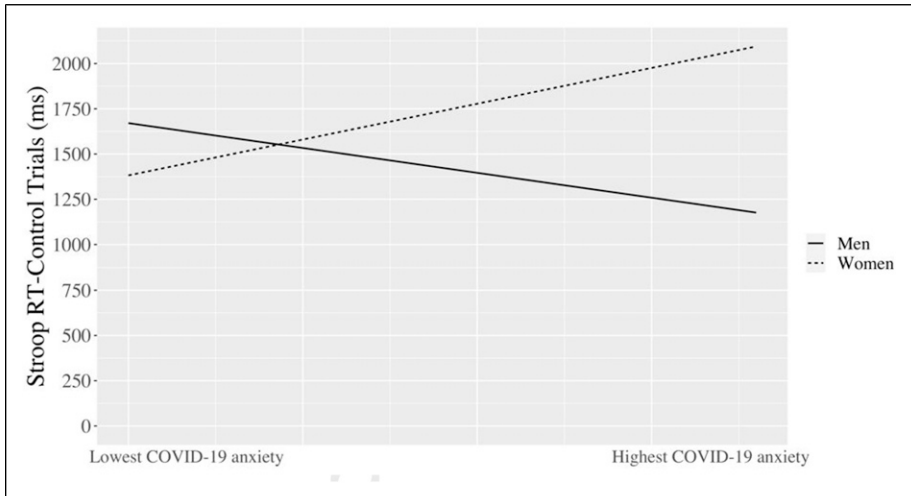


Figure 3. Association between COVID-19 anxiety and Stroop reaction time on control trials (measuring processing speed), as moderated by sex, in middle-aged and older adults.

RT on control trials (worse processing speed performance) among women ($B = 134.49$, $SE = 64.46$, $p = .04$), but not men ($B = -39.11$, $SE = 45.17$, $p = .39$).

Congruent trials (attention and processing speed). The full regression model was significant, accounting for 25% of variation in performance on congruent trials ($F(6, 55) = 3.02$, $p = .01$, $R^2_{\text{adjusted}} = 0.25$). However, as shown in Table 3, CAS, sex and CAS \times sex interaction were not associated with performance.

Incongruent trials (inhibition). The full regression model was significant, accounting for 24% of variation in performance on incongruent trials ($F(6, 53) = 2.77$, $p = .02$, $R^2_{\text{adjusted}} = 0.24$). However, as shown in Table 3, CAS, sex and CAS \times sex interaction were not associated with performance.

Discussion

The present study evaluated whether sex moderates the association between COVID-19-related anxiety (considered state anxiety) and subjective everyday cognitive function (i.e., cognitive failures) and objective cognition in middle-age and older adults living in the United States. Findings showed that sex moderated associations between COVID-19-related anxiety and certain aspects of subjective and objective cognition. In women, increased COVID-19-related anxiety was associated with worse everyday subjective cognition related to memory failures and blunders (task execution), as well

as worse performance on a task measuring processing speed. In men, COVID-19 anxiety was not associated with everyday cognition or objective cognitive performance.

Our hypothesis that greater COVID-19-related state anxiety would be associated with worse subjective everyday cognition and objective cognition, specifically in women, was generally supported. Sex moderated the association between COVID-19-related anxiety and specific aspects of cognitive function. We observed expected associations in women for everyday cognition (cognitive failures related to memory and blunders/task execution), and no association between COVID-19-related anxiety and everyday cognitive failures/objective cognition in men. These findings are in line with previous research showing stronger associations between trait anxiety and subjective cognitive function in women (Gulpers et al., 2019). Our findings extend these prior results by showing that state anxiety specifically related to a pandemic produces similar associations, and importantly shows that it is certain domains of functioning that are impacted. Findings for objective cognition are consistent with other investigations in older adults that showed associations between trait anxiety and other aspects of cognitive performance (global cognition; [Del Brutto et al., 2015; Stillman et al., 2012] and visuospatial functioning [Stillman et al., 2012]). However, importantly, this is the first study to show that women may be more vulnerable to specific aspects of objective cognition (i.e., longer processing speed on Stroop task control trials) in relation to COVID-19-related state anxiety, highlighting the need to consider sex in research evaluating the immediate impact of pandemic anxiety on objective cognitive performance.

State anxiety is thought to impact cognitive functioning through its demand of overlapping cognitive resources. That is, cognitive resources devoted to anxious thoughts can interfere with or reduce resources available for other cognitive tasks (Maloney et al., 2014). There is a debate as to whether increased state anxiety is more detrimental to cognitively demanding tasks, such as those mediated by executive functions (Eysenck & Calvo, 1992), or whether it negatively impacts lower order processes (e.g., processing speed and attention [Lo et al., 2019]). The present findings suggest that pandemic related state anxiety (at least anxiety related to COVID-19) may negatively impact lower order or less demanding objective cognitive tasks that measure processing speed, but only in women. Taken together, findings regarding subjective everyday cognition and objective cognition suggest that in women, COVID-19-related anxiety may have a broader impact across cognitive functions (including subjective evaluation of everyday function across several domains as well as objective evaluation of cognition) that vary in task demands.

It is important to note that gender roles may have contributed to the present findings. During the COVID-19 pandemic, women tended to spend more time at home than men, due to greater likelihood/opportunities for remote work and more housework/childcare duties (Power, 2020). Given the age of the present sample (middle-aged and older adults), it is also possible that the impact of anxiety on cognition was more severe in women due to other demands typically more prevalent in women in this age group, such

as unpaid caregiving for spouses and aging parents (National Research Council, 2010). The additional burden of these tasks during the pandemic may have contributed to the overall impact of COVID-19-related state anxiety on cognition. Thus, future work should examine traditional gender roles (hours spent remote working, childcare, informal caregiving) and how they may contribute to pandemic-related consequences such as disrupted cognitive functioning. Additionally, given the small subsample of participants who completed the objective cognitive task, as well as the lack of an extensive objective cognitive battery, it will be important to evaluate associations between COVID-19-related anxiety and objective cognitive performance on a wider range of cognitive tasks in order to more fully understand the potential impact of pandemic related state anxiety on cognitive function in mid-to-late life. Further, the present results are based on cross-sectional findings; therefore, prospective associations should be examined in future work in order to better understand temporal relationships between sex-specific patterns of COVID-19-related anxiety and subjective/objective cognition.

Although not a direct aim of the present study, it is noteworthy that we found the number of medical conditions (a covariate in our regression models) to be associated with subjective cognitive performance, but not objective cognitive performance. Research findings have generally observed that greater numbers of comorbid medical conditions in aging populations are associated with subjective cognitive concerns (Taylor et al., 2020; Taylor et al., 2007) and increased risk of objective cognitive decline (e.g., mild cognitive impairment, Alzheimer's disease, [Snowden et al., 2017]). Middle-aged and older adults with multiple medical conditions in the present study may not yet be experiencing significant objective cognitive dysfunction. In fact, our sample can be considered cognitively healthy (see Inclusion/exclusion criteria). However, it is possible that participants were more likely to attribute any subjective cognitive complaints as unpleasant side effects of their comorbid medical conditions, which could have also been influenced by the self-knowledge of the potential cognitive decline that accompanies having multiple medical conditions. It is also possible that an association between greater number of medical comorbidities and objective cognition would be observed in larger samples, as only a subset ($n = 62$) completed the online cognitive tasks in our study, or in samples with marked cognitive deficits (e.g., in a mild cognitive impaired sample).

Another related and noteworthy finding is that older age was generally associated with worse objective cognition, but not subjective cognition. These results are consistent with some previous findings in the literature. For instance, in older adults, subjective cognition decline has been shown to be associated with mental and health status, but not age or highest level of education, as demonstrated in objective cognition (J. Lee et al., 2020). Similarly, another study showed that age is not related to metacognitive ratings of objective cognitive performance, but is associated with objective cognitive performance (in this case episodic memory; [Hertzog & Dunlosky, 2011]). In addition, studies have noted that other factors, such as attitudes, and metacognitive beliefs related to perceived control over age-related cognitive decline, are also

associated with subjective cognitive ratings (Hertzog et al., 1998; Lachman, 2006). Thus, future work should examine whether these factors impact subjective cognition in older adults to a greater degree than biological age.

Given previous findings showing worse declines in processing speed and executive function in older women (not men [Levine et al., 2021]), the present results provide insight into the potential longer-term impact of COVID-19-related state anxiety on the trajectory of possible cognitive decline. Further, because of the greater risk of mild cognitive impairment and Alzheimer's disease with increasing age (Riedel et al., 2016), as well as sex differences in the prevalence of these disorders (Mielke et al., 2014), findings suggest anxiety specifically related to COVID-19 and other pandemics should be considered in the understanding and/or treatment of risk factors related to cognitive decline. Similarly, given that subjective cognitive disruption has been linked to Alzheimer's disease pathology (Lin et al., 2019) and increased risk of developing mild cognitive impairment and Alzheimer's disease (Lin et al., 2019; Rabin et al., 2017), our findings shed light on potential targets for intervention during a pandemic, which may be particularly important for women. For instance, monitoring stress and/or anxiety symptoms related to a pandemic in mid-to-late life and implementing sex-specific anti-anxiety/coping treatments may help mitigate cognitive decline. However, given that the present findings are based on cross-sectional associations, more work is needed to evaluate temporal characteristics and underlying mechanisms of the associations between COVID-19-related anxiety and subjective/objective cognitive function.

The present study has several limitations. First, the nature of online self-reporting of demographics and survey items through Qualtrics panels inherently leads to potential data quality concerns (in terms of reliability) as well as generalization of data reported by volunteers (who opt in for survey completion on various topics). However, a meta-analysis (Walter et al., 2019) recently showed that compared to conventional data collection methods, online panel data collection has similar psychometric properties. Additionally, recommended procedures by Walter et al. (2019) for online recruitment and data collection were followed (pre-screening questions, tracking of IP address to ensure only one response per participant), thus mitigating data quality concerns. Second, traditional gender roles were not assessed (e.g., time spent providing childcare or parental care for women, time spent doing household chores or remote work). Given our sex-specific findings regarding the impact of COVID-19 anxiety on cognition, these will be important to measure and consider in future larger scale studies. Third, as previously mentioned, given that only a subset of participants completed the online cognitive tasks, findings for association between COVID-19-related anxiety and objective cognition should be investigated in larger samples. Fourth, although a specific aim of this study was to examine how sex moderates associations between COVID-19-related anxiety and cognition in a sample of aging adults, it will be important to compare findings in younger populations to see if the results reported here are specific to middle-aged and older adults. Fifth, as stated previously, findings are based on cross-sectional associations; thus, prospective studies are needed to determine temporal information regarding the relationship between examined variables. Sixth, the present

study provides novel and important information regarding the potential sex-specific impact of COVID-19 state anxiety on a range of cognitive function. However, future studies should consider obtaining larger sample sizes in order to provide appropriate power for analyses that adopt a multivariate approach such as structural equation modeling to assess independent, multiple regression equations simultaneously (Nusair & Hua, 2010). Finally, the sample largely consisted of White/European American individuals (88%) and was restricted to individuals living in the United States, therefore future research should attempt to examine findings in a more racially, ethnically, and internationally diverse study sample.

Conclusions

Findings suggest that middle-aged and older adult women (but not men) in the United States may be more vulnerable to the effects of greater COVID-19-related state anxiety, in terms of its impact on everyday cognitive failures and objective processing speed. Prospective studies are needed to examine the temporal nature and duration of these associations. Different sex-specific patterns of associations between COVID-19-related anxiety, subjective everyday cognition, and objective cognition promote the need for sex-specific efforts to prevent and potentially treat the negative behavioral and psychological impacts of COVID-19 in aging populations.

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