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Stress-Related Cognitive Interference Predicts Cognitive Function in Old Age

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Abstract

Both subjective distress and cognitive interference have been proposed as mechanisms underlying the negative effects of stress on cognition. Studies of aging have shown that distress is associated with lower cognitive performance, but none have examined the effects of cognitive interference. One hundred eleven older adults ($M_{\text{age}} = 80$) completed measures of working memory, processing speed, and episodic memory as well as self-report measures of subjective distress and cognitive interference. Cognitive interference was strongly associated with poorer performance on all 3 cognitive constructs, whereas distress was only modestly associated with lower working memory. The results suggest that cognitive process related to stress is an important predictor of cognitive function in advanced age.

Keywords

aging; stress; cognitive interference; cognition; cognitive performance

Extensive research has documented that the experience of stress can result in significant negative health consequences (Baum & Posluszny, 1999; Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002). In addition, there is evidence that the experience of stress can impair performance on cognitive tasks such as episodic memory (e.g., Jelicic, Geraerts, Merckelbach, & Guerrieri, 2004) and working memory (Klein & Boals, 2001a, 2001b) in both young adults and older adults (Caswell et al., 2003; Lee, Kawachi, & Grodstein, 2004; Lupien et al., 1997; Sliwinski, Smyth, Hofer, & Stawski, in press; Wolf, Kudielka, Hellhammer, Hellhammer, & Kirschbaum, 1998). There has been considerable theoretical development of both physiological (e.g., Sapolsky, Krey, & McEwen, 1986) and psychological (e.g., Eysenck & Calvo, 1992) accounts of the stress–cognition link. Although a wealth of data exists documenting the negative effects of prolonged elevations in physiological markers of stress, such as cortisol, on cognition (for reviews, see Belanoff, Gross, Yager, & Schatzberg, 2001; Lupien & McEwen, 1997), less is known about how psychological or cognitive responses to stress relate to cognitive performance, especially in advanced age. The purpose of the current study is to examine the associations among subjective distress and cognitive interference and cognition in old age.

Most psychological accounts propose that stress impairs cognitive function by reducing the amount of attention one can devote to information processing (e.g., Kahneman, 1973). More specifically, the negative effects of stress on cognition will be manifested when task

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performance requires attentional control, or effortful cognitive processing (Hasher & Zacks, 1979). Thus, the psychological effects of stress on cognition are largely a result of a resource competition, such that stress acts as a cognitive load, creating a dual-task situation whereby attention is divided between task demands and coping with environmental demands. Prominent accounts of cognitive aging have asserted that older adults have diminished attentional capacity (Craig, 1984, 1986) and a compromised ability to inhibit irrelevant information (Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999). These accounts predict that older adults should be especially impaired in dual-task performance, and a meta-analysis of dual-task studies in aging was consistent with this prediction (Verhaeghen, Steitz, Sliwinski, & Cerella, 2003). If stress thus competes for attentional resources, then its effects may be amplified in advanced age when attentional resources are already diminished.

Two approaches to measuring stress have been taken in research relating the effects of stress to cognitive functioning. One approach involves measuring individuals' subjective appraisals of how stressful individuals perceive their lives to be. Theorists such as Lazarus (1999) have argued that when individuals appraise life to be stressful, cognitive resources must be allocated to coping with environmental demands, reducing the resources available to perform cognitive functions. Furthermore, J. Smith (2003) argued that the negative effects of stress on cognitive function should be especially apparent in old age because of age-related decreases in physical and mental resources needed for coping. Following this reasoning, individuals who perceive life as more stressful should exhibit poorer cognitive performance. Subjective perceptions of how stressful previous life events are have been associated with poorer decision making (Baradell & Klein, 1993), problem solving (Klein & Barnes, 1994), working memory (Klein & Boals, 2001b, Studies 1 and 2), and analogical reasoning (Yee, Edmonson, Santoro, Begg, & Hunter, 1996) performance in young adults. Studies of aging have provided similar findings, indicating that individuals who report higher levels of subjective distress exhibit poorer episodic memory, fluid intelligence, and processing speed performance (Jorm et al., 1993), as well as an increased risk of cognitive decline (Wilson et al., 2003, 2005).

An alternative method of assessing the effects of stress used by Klein and Boals (2001a, 2001b) is to assess an individual's level of cognitive reactivity (i.e., intrusive thoughts and avoidant thinking) in response to stress. Cognitive interference (Sarason, Pierce, & Sarason, 1996), intrusive off-task thoughts and images, and the intentional suppression of such intrusions have been thought to compete for the same limited attentional resources as working memory (Teasdale et al., 1995; Teasdale, Proctor, Lloyd, & Baddeley, 1993). Klein and her colleagues (Klein & Boals, 2001a, 2001b) presented evidence consistent with the cognitive interference account, suggesting that cognitive representations of stress (i.e., intrusive thoughts and the intentional suppression-removal of these thoughts from mind) compete for the same limited resources needed to execute working memory tasks (see also Eysenck & Calvo, 1992). Klein and Boals (2001b, Study 3) showed that, in young adults, stress-related intrusive and avoidant thinking was negatively related to working memory performance. Klein and Boals (2001a) also demonstrated that a stress-reduction intervention (see Smyth, 1998, for review) could improve working memory function by reducing one's amount of reported cognitive interference. Although evidence links cognitive interference to poor performance, we are not aware of any studies that have demonstrated an association between stress-related cognitive interference and cognitive performance in older adults.

This brief review of the literature suggests that both subjective appraisals of distress and cognitive interference are plausible pathways by which stress could affect cognition in advanced age. However, studies examining the effects of distress and cognitive interference on cognition have typically focused on only one of these potential pathways and not both simultaneously. This is potentially problematic because distress and cognitive interference are related (Clark, 2004), and if their effects are not examined simultaneously, unique associations

between each pathway and cognitive performance cannot be identified. In addition, a number of previous studies have not controlled for depressed mood or reported depressive symptoms. Depressed mood and depressive symptomatology are related to general life distress and cognitive interference (Hankin, Fraley, & Abela, 2005; Nolen-Hoeksema, Parker, & Larson, 1994; Robinson & Alloy, 2003), as well as cognitive function (McBride & Abeles, 2000; O'Connell & Abeles, 2001; Wilson et al., 2002; Wilson, Mendes de Leon, Bennett, Bienias, & Evans, 2004). These findings suggest that it is important to consider, and control for, the effects of depressive symptomatology when examining how subjective distress and stress-related cognitive interference relate to cognition.

Identifying pathways through which stress may affect cognition is maximally informative when theory and research can be integrated. To this end, identifying links between distress, cognitive interference, and cognitive function will be of the greatest utility when the cognitive functions examined are known to be affected by stress. There is growing evidence demonstrating that the experience of stress impairs cognition and that these effects may be exacerbated in advanced age. Previous research has demonstrated that both acute and chronic stressors affect cognition. Acute laboratory stressors such as public speaking impair paired associates memory performance (Lupien et al., 1997) and selective attention (Wolf et al., 1998) in older adults. Similarly, naturally occurring daily stressors (Almeida, Wethington, & Kessler, 2002) are particularly detrimental to attention-demanding cognitive function in old age (Sliwinski et al., in press). Chronic stress, specifically caregiving for a spouse with dementia, is also associated with deficits on the digit symbol substitution test (Caswell et al., 2003), episodic memory, and general cognitive function (Lee et al., 2004). Furthermore, only Caswell et al. and Sliwinski et al. have examined potential psychological mediators of the stress effects on cognition. Caswell et al. demonstrated that the effect of caregiver status (i.e., chronic stress) was mediated by self-reported distress, even after controlling for depression, whereas Sliwinski et al. showed that stress-related changes in negative mood could not account for the effects of stress on cognitive performance. Therefore, examining multiple potential pathways through which stress may be related to cognitive function would provide an important contribution toward understanding the stress–cognition link, especially as it applies to advanced age.

The current study was conducted to extend previous research by examining the associations among measures of subjective distress and cognitive reactivity to stress, and multiple cognitive functions. First, we examined the extent to which individual differences in subjective distress and stress-related cognitive interference were associated with individual differences in cognitive function in older adults, while controlling for depressive symptoms. Second, we examined the effects of stress on three cognitive functions that are related to both stress and aging: working memory, processing speed, and episodic memory. Whereas previous studies have used single-item indicators of cognitive function exclusively, we included multiple measures of each cognitive construct and used latent variable models to improve our construct validity. This is especially important as previous research (Caswell et al., 2003) made claims that stress can impair processing speed based on a single indicator (i.e., the digit symbol substitution test) that has been demonstrated to have a substantial memory component (Piccinin & Rabbitt, 1999), or prior studies have used general cognitive constructs composed of tasks tapping a variety of abilities (e.g., Lee et al., 2004; Wilson et al., 2005).

We predicted that cognitive interference would be the strongest predictor of individual differences in working memory but would be unrelated to processing speed and episodic memory deficits. This is consistent with theories of aging, which argue that age is associated with an increased susceptibility to cognitive interference (Hasher & Zacks, 1988; Hasher et al., 1999) and increased dual-task costs (Verhaeghen et al., 2003). It is also consistent with the cognitive interference account of the stress–cognition link that suggests working memory may be particularly vulnerable to off-task thoughts (Eysenck & Calvo, 1992; Klein & Boals,

2001a, 2001b). Consistent with previous research (Caswell et al., 2003), we also predicted that subjective feelings of distress would be associated with slower processing speed ability, suggesting that distress is associated with compromised information processing efficiency.

Method

Participants

One hundred eleven older adults from the Syracuse metropolitan area were recruited from the community, as well as from a senior residence center. The average age of the sample was 80.01 years ($SD=6.20$, range =66–95), and 28% of the sample was male. Participants had, on average, 15.12 years of education ($SD=2.40$, range =8–22) and were compensated in the amount of \$60 for their participation.

Materials

Stress-related distress was measured using Cohen and colleagues' (Cohen, Kamarck, & Marmelstein, 1983) Perceived Stress Scale (PSS). The PSS is a 14-item measure assessing an individual's subjective appraisal of how stressful or burdensome his or her life has been over the past month. Responses to questions (e.g., "In the past month, how often have you felt nervous or 'stressed'?" and "In the past month, how often have you felt difficulties were piling up so high that you could not overcome them?") are made on a 5-point scale (1 = *never*, 5 = *very often*). Negatively worded questions are reverse coded, and a total score is obtained by summing the values of all the items, with higher scores reflecting greater levels of perceived stress. Cronbach's alpha for the PSS in this sample was .75.

Stress-related cognitive interference was measured using the Impact of Event Scale (IES; Horowitz, Wilner, & Alvarez, 1979). The IES is a 15-item scale assessing the frequency of experiencing intrusive thoughts (e.g., "I thought about it when I didn't mean to") and avoiding thinking about a past stressful event (e.g., "I tried to remove it from my memory"). Participants first indicated the most stressful event of their lives (e.g., death of a loved one, divorce–separation) and then completed the 15-item IES. Responses were made on a 4-point scale (1 = *not at all*, 4 = *often*), with negatively worded items being reverse scored. Scores can be obtained for each subscale by adding the 7 intrusive subscale items and 8 avoidant subscale items together. In addition, these two subscales can be summed to create a composite (i.e., total) index of responses to the stressful event. In the current sample reliability (alphas) for the intrusive and avoidant subscales were .92 and .82, respectively, and the correlation between the scales was $r(109) = .61$, $p < .01$. The reliability for the total score was .91.

Participants also indicated how stressful their reported experience was on a 5-point scale (1 = *not at all*, 5 = *a great deal*) with higher scores indicating greater stress. They also indicated the month and year the event occurred and ended, or whether it was ongoing, and from this we determined the number of months since the end of the event (0 representing an ongoing event, 24 months indicating an event that ended 2 years prior). Because the experience of cognitive interference with respect to a past stressful event may be related to the severity of the event or the recentness of its occurrence, these last two items, representing IES event severity and IES event recentness, respectively, were included in all analyses to test, and control, for these possible effects.

The IES is often conceptualized as reflecting responses to a single life experience that produce cognitive interference (intrusions and avoidance–thought suppression). Participants self-select the stressor on which to report (as described earlier) and the degree to which it has produced intrusions and avoidance in the reporting period (i.e., the past week). Although tapping into one's current state, this certainly raises the possibility that responses to the IES may be

reflective of a person's traitlike disposition to experience off-task thoughts or ruminate and thus be a more general marker of a tendency to experience cognitive interference related to stressors (independent of the specific stressor reported on). Finally, it is also possible that IES scores may reflect a combination of both trait and state cognitive interference (and certainly may not capture all of the state variation in cognitive interference). Notwithstanding this issue, and acknowledging that additional measures of cognitive interference would be useful, we used the total IES score to represent cognitive interference (i.e., the sum of intrusive thoughts and efforts of thought suppression–avoidance).

Depressive symptoms were measured using the Center for Epidemiological Studies—Depression scale (CES–D; Radloff, 1977). The CES–D is an established measure consisting of 20 items assessing negative mood and depression (e.g., “I feel depressed,” and “I am happy”). Responses were indicated on a 4-point scale (1 = *not at all*, 4 = *very much*) with positively worded items being reverse coded. A negative mood–depression score was calculated by summing the responses on the 20 items, with higher scores indicating greater levels of depression–negative mood. Cronbach's alpha for the CES–D in the current sample was .86.

Episodic memory—Immediate and delayed recall was measured using a controlled learning procedure developed by Buschke (1984). Individuals were presented with a list of 16 words and had to associate each word with a category cue. After a study phase and a 20-s distractor period during which individuals counted backward, free recall was assessed. Individuals were prompted with the category cue for any word not freely recalled. This procedure was repeated six times, and the score on this test was the total number of words recalled across the six trials. Delayed recall was the total items remembered (out of 16) 30 min after the final free-recall trial.

Episodic memory was also measured using the Woodcock–Johnson Memory for Names test (Woodcock, McGrew, & Mather, 2001). Individuals were shown displays of simple figures depicting “space aliens” and were required to associate a name (e.g., “Jawf”) with each figure. We tested learning of the figure–name associations by displaying a set of figures and requiring participants to point to the figure corresponding to a given name (e.g., “Point to Jawf”). After participants learned each name and figure, memory for the current and previously learned pairs was tested. A total of 12 pairs were learned and tested across 12 trials. The total number of correct responses served as the dependent variable.

Working memory—The operation span (Turner & Engle, 1989) required participants to maintain letters in memory while simultaneously solving math equations. Math equations and letter pairs were presented on a computer screen one at a time. Participants were instructed to read a series of math equation and letter pairs (i.e., “Is $2 \times 2 + 1 = 4$? B”) out loud, indicate whether the answer given was correct by saying “yes” or “no,” and then read the letter out loud. They were instructed to remember each letter for a subsequent serial recall test. Sets of two to five equation–letter pairs were presented serially until three question marks (???) appeared on the screen, which served as a cue for participants to recall the letters they had seen in the order they were presented. All set sizes were sampled two times in random order. A score was obtained by summing all letters of completely recalled sets. For example, if a person were to correctly recall all letters in Set Size 2 (score of 4, i.e., 2×2) and one set of letters in Set Size 3 (score of 3, i.e., 3×1), his or her operation span score would be 7. A maximum score of 28 was possible for the operation span, and this score served as the dependent variable.

A 2-back version of the *n*-back task (Awh et al., 1996; E. Smith & Jonides, 1997) was used whereby individuals decided whether the currently presented stimulus was the same or different than a stimulus presented two screens back. Stimuli (the digits 1–9) were presented one at a

time in random order in the center of a computer screen. The stimulus digits appeared in white on a black screen. Individuals were instructed to press one of two keys as accurately and quickly as possible indicating whether the current stimuli was the same (“/” key) or different (“z” key) than the stimulus observed two screens back. Stimuli appeared immediately upon a participant’s response; no interstimulus interval (ISI) was included. Half of the trials required a response of same, half required a response of different. Three blocks of 20 items were presented for a total of 60 trials. Accuracy rates were average across the 60 trials to create an average accuracy rate. This average accuracy was arcsine transformed to normalize the distribution.

A variation of Garavan’s (1998) serial-attention task, the Keep-Track 2, was used to assess the accuracy with which individuals could keep separate running counts of two distinct items, simultaneously. Participants were presented with one of two geometric shapes (a rectangle or a triangle) presented in the center of a computer screen, and the task was to press the space bar each time they counted the displayed object. The following item appeared immediately after the space bar was pressed (i.e., no ISI). Counts totals for each shape were reported after trial ranging between 8 and 16 items in length. Accuracy rates were pooled across trials and were arcsine transformed to normalize the distribution.

Processing speed—Two variations of Salthouse’s (1996) number match–processing speed task were used as indices of processing speed efficiency. In the easy variation, participants had to make a decision as to whether two 3-digit strings were composed of the same numbers or not. Responses were indicated by pressing the “/” key if the digit strings were the same and the z key if the digit strings were different. In the difficult variation, participants had to decide whether two 5-digit strings were composed of the same numbers. Responses were indicated in the same manner as stated earlier, and trials were separated by a 500-ms intertrial interval. Thirty-two trials were completed for both the three- and five-item versions of the task. Response times (RTs) for each variation were calculated by averaging across trials on which a correct response was made; RTs served as the dependent variable.

A serial counting task (Keep-Track 1) was used to assess simple processing speed efficiency. Participants were presented with one of two geometric shapes (a circle and a diamond) on a computer screen, one at a time, in random order. The task was to count only one of the two objects (the circle) while ignoring the other (the diamond). After a shape was displayed, participants were instructed to press the space bar as quickly as possible after they had counted the shape. A new stimulus would appear immediately after the space bar had been pressed (i.e., no ISI). At the end of each trial participants reported the number of targets they counted. Five trials with between 8 and 14 items per trial were administered (for a total of 60 RTs). The average time to count an object served as the dependent measure, and only RTs from trials on which counting was accurate were included.

Procedure

Participants were given a brief overview of the study and provided informed consent approved by the Syracuse University Institutional Review Board. Participants were informed that they were participating in a longitudinal study examining changes in health and cognition in adulthood. Although participants performed the cognitive tests repeatedly as part of the longitudinal component, only data from their first assessment were included in the present analysis to avoid any influence of retest effects. A trained research assistant tested participants individually. Individuals completed the CES–D, the PSS, and the IES outside of the lab after their cognitive testing.

Results

The results are presented in three sections. First, we present descriptive statistics and correlations between the cognitive and psychosocial measures. Second, we tested our hypothesized measurement model consisting of the processing speed, working memory, and episodic memory constructs using confirmatory factor analysis (CFA). Finally, a structural equation model is presented examining the associations between subjective distress, cognitive interference, and the three cognitive constructs.

Descriptive Statistics and Correlations

Descriptive statistics for each of the cognitive and stress measures are presented in Table 1. As shown in Table 1, the skew and kurtosis values are well within appropriate ranges for satisfying assumptions of normality for the current analyses. There was a small amount of missing data (<1%) for the cognitive tasks due to tester errors, equipment malfunctions, and participants' inability to complete a task. Because of the missing data, all CFAs and structural equation models were estimated using maximum-likelihood estimation.

The correlation matrix in Table 2 shows that age shared a reliable amount of variance with each of the cognitive measures (R^2 s ranging from 4%–16%), except the operation span. The IES total score was significantly correlated with operation span, and two processing speed measures, Number Match 3 and Keep Track. Although the associations between IES total score and the other two working memory tasks were not significant, the correlations were in the hypothesized direction. The observed relationships indicate that individuals reporting higher levels of stress-related cognitive interference exhibit poorer working memory and slower processing speed performance. Subjective distress and depressive symptoms, measured using the PSS and CES–D, respectively, were unrelated to performance on any of the cognitive measures.

CFA

Our measurement–CFA model with three latent constructs representing working memory, processing speed, and episodic memory can be seen in Figure 1. We allowed the residuals between the following pairs of tasks to be correlated: 2-back and Keep-Track 2, Number Match 3 and 5, and free- and delayed-recall tasks to control for shared method variance. We used the chi-square test for goodness of fit, comparative fit index (CFI), Tucker–Lewis index (TLI), and root-mean-square error of approximation (RMSEA) to assess model fit (Bentler, 1990; Bentler & Bonnet, 1980). Relative fit indices such as the CFI and TLI are considered acceptable if their values are above .90. An RMSEA value of .08 is considered to indicate adequate model fit, whereas an RMSEA of .05 or less indicates excellent fit (Browne & Cudeck, 1992). This model provided an excellent fit to the data, $\chi^2(21, N=111)=18.99, p=.59$, CFI =1.00, TLI =1.02, RMSEA <.01. The intercorrelations between the latent constructs were all significant ($p <.0001$).

We next estimated a structural model (see Figure 2) in which subjective distress (PSS) and stress-related cognitive interference (IES) were entered into the model as predictors of latent processing speed, working memory, and episodic memory ability, controlling for age, IES event severity and recentness, and depressive symptoms. This model provided an excellent fit to the data, $\chi^2(57, N=111)=58.11, p=.43$, CFI =.997, TLI =0.993, RMSEA =.013. The parameter estimates for the effects of the predictor variables on the cognitive constructs can be seen in Table 3. Partial effect estimates were obtained in a model in which all cognitive constructs were regressed on each covariate simultaneously. Total effect estimates were obtained by estimating intercorrelations between the covariates and cognitive constructs instead of regressing the latter on the former. This method allows for the examination of unique

(partial) associations between our covariates and cognitive constructs, as well as unpartialled (total) associations.

Analysis of the total effects indicated that both age and cognitive interference were negatively related to working memory, processing speed, and episodic memory. In addition, subjective distress and depressive symptoms exhibited moderate negative associations with working memory ($r_s = -.21$ and $-.20$, $p < .10$, respectively). When the effects of age, subjective distress, depressive symptoms, and cognitive interference were considered simultaneously (i.e., partial estimates in Table 3), only age and IES total score, our measure of cognitive interference, were uniquely associated with cognitive performance. In both instances, the associations indicated that higher levels of each were associated with lower performance. Furthermore, any evidence of an association between either subjective distress or depressive symptoms and working memory was abolished when the effect of cognitive interference was estimated simultaneously. Thus, there is evidence of both age-related deficits in working memory, processing speed, and episodic memory, and cognitive interference deficits in each of those constructs.

The effect of cognitive interference on working memory was consistent with our hypotheses, but the effect on processing speed and episodic memory was unexpected. None of the other estimates of the predictor variables were statistically significant. It is worth noting that the standardized effect of cognitive interference on working memory and processing speed is comparable to that of age.¹ The results of this model suggest that it is not the degree to which individuals perceive their lives to be stressful but the extent to which they report experiencing intrusive thoughts or ruminate about a stressful life experience that is associated with cognitive performance deficits.

Previous research has demonstrated gender differences in reactivity to stress (e.g., Otte et al., 2005), and gender differences in the effect of stress-response variables, such as cortisol, on cognition (e.g., Seeman, McEwen, Singer, Albert, & Rowe, 1997; Wolf, Schommer, Hellhammer, McEwen, & Kirschbaum, 2001). To determine whether our results were magnified because of the large proportion of women in the sample (only 28% of the current sample was male), we tested two additional models. First, we reestimated our model with gender included as a covariate. The model fit was satisfactory, $\chi^2(63, N=111) = 64.32$, $p = .43$, CFI = .997, TLI = 0.992, RMSEA = .014, and did not result in a significant change in model fit when compared with our model without gender, $\Delta\chi^2(6) = 6.21$, ns . Next, we estimated a model including three interaction terms: Gender $\times$ Depressive Symptoms, Gender $\times$ Subjective Distress, and Gender $\times$ Cognitive Interference. This model provided a satisfactory fit to the data, $\chi^2(81, N=111) = 79.77$, $p = .52$, CFI = 1.000, TLI = 1.002, RMSEA = .000, and did not result in a reduction in fit over the model including a main effect for gender, $\Delta\chi^2(18) = 15.44$, ns , or our initial model, $\Delta\chi^2(24) = 21.65$, ns . Therefore, these analyses provide preliminary evidence that no reliable gender differences were observed.

Discussion

The present results confirmed our primary hypothesis that stress-related cognitive interference depletes attentional resources (e.g., Kahneman, 1973) and is associated with lower working memory performance (Klein & Boals, 2001b) in older adults. In addition, we also observed unique associations between cognitive interference and processing speed and episodic memory. Subjective distress was modestly associated with lower working memory ($r = -.21$,

¹We tested the equivalence of these effects directly in a series of models in which the effects of IES total score and age on each cognitive construct were constrained to be equal. Constraining the effects of age and IES on working memory to be equivalent did not significantly decrease model fit, $\Delta\chi^2(1) = 0.003$, $p = .96$. Model fit did not decrease when this constraint was imposed for the age and IES effects on processing speed, $\Delta\chi^2(1) = 1.17$, $p = .28$, or to a lesser extent, episodic memory, $\Delta\chi^2(1) = 3.38$, $p = .07$.

$p < .10$); however, this association was reduced when the effects of cognitive interference were considered simultaneously. These results indicate that, in old age, stress-related cognitive interference is associated with poorer working memory, processing speed, and episodic memory ability, independent of subjective distress and depressive symptomatology. In this sample of older adults, cognitive reactivity to stress (i.e., cognitive interference) is a stronger correlate of cognitive performance than subjective appraisals of distress.

Our observed results are consistent with the cognitive interference (e.g., Eysenck & Calvo, 1992; Klein & Boals, 2001a, 2001b; Sarason, Sarason, Keefe, Hayes, & Shearin, 1986) account of the stress–cognition link. In addition, given the current results, if stress affects cognition by acting as a dual-task load, then the effects of this load may dampen cognitive performance in general, not just in highly demanding processes. This latter finding suggests that interference effects on cognition may be more diffuse than previously assumed, at least in old age. Cognitive interference was associated with processing speed and episodic memory performance, not just working memory as would be predicted based on existing theoretical models (Eysenck & Calvo, 1992). Another explanation of the observed effects is that cognitive interference is associated with performance deficits in a broader range of functions in advanced age. This latter hypothesis, however, cannot be tested using the current data, as the current sample does not include young adults to test for age differences in the effects of cognitive interference. Nonetheless, the association between cognitive interference and cognitive performance deficits is consistent with theories that postulate an age-related inability to inhibit off-task interference (e.g., Hasher & Zacks, 1988; Hasher et al., 1999). Alternatively, age-related declines in attentional resources (Craig, 1984, 1986) may simply render all cognitive processing more effortful, and the effects of cognitive interference would hinder all cognitive functions because any cognitive interference would tax the limited-capacity cognitive system.

Although previous studies have found subjective distress and depressive symptoms to predict cognitive function in advanced age (Jorm et al., 1993; Wilson et al., 2002, 2003, 2004, 2005), we found only weak evidence for such associations, specifically with lower working memory. The differences in results could be due to a number of reasons. First, previous studies have focused on distress, not taking into account cognitive interference. Variance shared between distress or depressed mood and cognition could have been variance attributable to cognitive interference that was not controlled statistically. This explanation may seem unlikely in the present data as the total effects of subjective distress and depressive symptoms were only moderately significant ($p < .10$). The sample used in the current study was notably smaller ($N = 111$) than Wilson's sample ($N = 6,158$), and effect sizes in both studies were comparable and small (4.5% and 1.0% of the variance explained, respectively). Our failure to replicate Wilson's results might be due to a lack of statistical power in our sample. Thus, although stress-related cognitive interference may mediate the association between subjective distress, depressive symptoms, and cognitive function, the current study does not provide evidence of this. Future research could be conducted to test this possibility.

The association of cognitive interference with lower levels of cognitive function, independent of subjective distress and depressive symptoms, could also be due to age-related differences in the relative influences of each of these factors on cognitive function. The sample included in the current study is notably older (mean age = 80) than samples used in previous studies (mean age = 70–75; e.g., McBride & Abeles, 2000; O'Connell & Abeles, 2001; Wilson et al., 2005). For example, Carstensen and her colleagues (Carstensen, 1995; Carstensen, Isaacowitz, & Charles, 1999) have argued that older adults emphasize positive, and minimize negative, social and emotional interactions. Thus, self-reports of subjective distress and depressive symptoms may be less related to cognitive function with increasing age because of older adults' ability to regulate emotions (Gross et al., 1997) or because of age-related differences in exposure to stressors (Almeida & Horn, 2004; Sliwinski et al., in press).

Although stress-related cognitive interference was uniquely associated with lower levels of working memory, processing speed, and episodic memory function in this sample of older adults, we must consider the alternate explanations of the cognitive interference–cognition association. In the current study we assessed cognitive interference that individuals reported to be specific to a particular stressor. We cannot, however, be sure that these self-reports are stressor specific, specific to stress (i.e., content related to any salient stresses, not just a single event), or an index of a relatively stable inclination to experience cognitive interference in general (Pierce et al., 1998; Yee et al., 1996). The IES is thought to reflect responses to a single life experience that produce cognitive interference. The event is one that is salient at the time of responding, that is, participants self-select the stressor on which to report and the degree to which it has produced intrusions and efforts toward avoidance in the reporting period. This reporting period, even when the event is long past, encompasses the current time frame (e.g., over the past week). Thus, the IES intends to measure current intrusion–avoidant responses to a stressor, regardless of when the event occurred. However, this measurement approach raises the possibility of two additional interpretations of these results. The first alternative interpretation would hold that the IES may not reflect cognitive interference specific to the reported stressor but rather could indicate cognitive interference attributable to an individual's overall level of stress. The significant, albeit modest, correlation ($r = .33$) between the IES total score and the PSS is somewhat consistent with this possibility.

A second alternative interpretation is that response to the IES reflects a person's traitlike disposition to experience off-task thoughts or ruminate. In this case, the IES might be a more general marker of a person's tendency to experience cognitive interference. This latter possibility is consistent with arguments that working memory capacity is very closely related to one's ability to suppress interfering information/off-task thoughts (Engle, 2002; Unsworth, Heitz, & Engle, 2005). In order to bolster the claim that cognitive interference actually mediates stress effects on cognition, one would need to demonstrate that stress causes both decreased cognitive performance and increased cognitive interference and that the latter mediates the former.

This study is not without its limitations. The results presented come from cross-sectional data, which do not allow for the examination of causal effects of stress-related cognitive interference on cognition. In contrast to our use of multiple indicators for the assessment of each cognitive construct, our assessment of cognitive interference, subjective distress, and depressive symptoms relied on single indices of each. Using multiple measures to operationalize cognitive interference, distress, and depressive symptoms would help to improve our construct validity and provide better estimates of the associations with cognitive function. In addition, the present study focused only on psychological indicators of stress and how they related to individual differences in cognitive function. Considerable evidence exists demonstrating that physiological indicators of stress (e.g., cortisol) are related to cognitive performance in advanced age (Lupien et al., 1994, 1998). The current data did not contain physiological markers of stress reactivity or distress and cannot address how individual differences in physiological indicators of stress are related to cognitive function.

Future research could be conducted to address a number of unresolved issues. First, cognitive interference, subjective distress, and depressive symptoms, as well as physiological markers of stress, could be assessed repeatedly, within individuals over time. This would allow for examination of how changes in both psychological and physiological markers of stress are related to cognitive function, within individuals and over time. Such an examination would provide evidence of within-person stress–cognition processes, compared with the between-persons associations presented in the current study. Also, demonstrating that the experience of stress impairs cognitive function and that psychological (e.g., cognitive interference or subjective distress) and/or physiological (e.g., cortisol) reactivity, in response to that specific

event, mediates such impairment would provide strong evidence of important mechanisms underlying the stress–cognition link. Preliminary evidence for the effectiveness of such an approach has been demonstrated by Lupien et al. (1997) and Wolf, Kudiela, Hellhammer, Hellhammer, and Kirschbaum (1998). In these studies, older adults' episodic memory performance was found to be poorer after stress compared with before, and increases in cortisol were moderately related to the observed declines. Although these studies included cortisol as a potential mechanism responsible for stress-related cognitive impairments, we are not aware of any studies with older adults that have used such designs and included indicators of physiological and psychological reactivity to stress.

Despite limitations, this study is one of the first to demonstrate that individual differences in self-reports of stress-related cognitive interference are associated with individual differences in cognitive performance in advanced age. The magnitude of this relationship is considerable. Furthermore, the results extend beyond earlier theoretical predictions suggesting that the effects of cognitive interference on cognitive function may not be constrained to working memory but also include processing and episodic memory, at least in old age.

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Figure 1.

Three-factor latent variable model of cognitive function. Standardized parameter estimates are shown, and all were significant ($p < .001$). OSPAN =operation span; KT2 Acc =Keep-Track 2 accuracy (arcsine transformed); NB2 Acc =2-back accuracy (arcsine transformed); KT1 RT =Keep-Track 1 response time; NM3 RT =Number Match 3 response time; NM5 RT =Number Match 5 response time; Recall MN =Memory for Names; Recall Free =selective reminding free recall; Recall Delayed =selective reminding delayed recall. Abbreviation $e\#$ (where # is a unique number) indicates that a unique residual was included for each variable estimated.

Figure 2.

Schematic of structural equation model used to examine predictors of cognitive function. CES–D =Center for Epidemiological Studies—Depression Scale; IES–Sev =Impact of Event Scale—Event severity rating; IES–Time =Impact of Event Scale—Event recentness (in months); IES–Total =Impact of Event Scale—Total score (cognitive interference), PSS =Perceived Stress Scale (general life distress); OSPAN =operation span; NB2 Acc =2-back accuracy (arcsine transformed); KT2 Acc =Keep-Track 2 accuracy (arcsine transformed); KT1 RT =Keep-Track 1 response time; NM3 RT =Number Match 3 response time; NM5 RT =Number Match 5 response time; Recall MN =Memory for Names; Recall Free =selective reminding free recall; Recall Delayed =selective reminding delayed recall.

Table 1

Descriptive Statistics for Cognitive Measures and Predictor Variables

Measure	M	SD	Skew	Kurtosis	N
Operation span	20.20	3.16	-.13	-.23	109
2-back (Acc)	.95	.19	-.52	.19	106
Keep-Track 2 (Acc)	.65	.39	.84	.39	108
Number Match 3 (RT)	2,005.25	557.34	.91	1.29	109
Number Match 5 (RT)	3,736.27	1,201.06	.29	-.60	109
Keep-Track 1 (RT)	772.85	177.22	.55	-.07	108
Free recall	46.80	11.31	.20	-.14	111
Delayed recall	9.18	3.14	-.17	-.80	111
Memory for Names	45.35	10.78	-.62	2.19	110
PSS	17.16	6.64	.03	-.49	111
CES-D	21.51	5.53	1.10	1.90	111
IES-Total	29.72	10.59	.04	-1.23	111
IES-Severity	4.14	.77	-.77	.57	111
IES-Time	268.39	235.91	.83	-.35	111
Age	80.08	6.35	.26	-.43	111

Note. Acc = Arcsine-transformed accuracy; RT = response time in milliseconds; PSS = Perceived Stress Scale (general life distress); CES-D = Center for Epidemiological Studies—Depression Scale; IES-Total = Impact of Event Scale—Total score (cognitive interference); IES-severity = Impact of Event Scale—Event severity rating; IES-Time = Impact of Event Scale—Event recentness (in months).

Table 2
Pearson Product-Moment Correlations for Cognitive Measures and Predictor Variables

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. OSPAN	—														
2. NB2 (AC)	.24	—													
3. KT2 (AC)	.31	.36	—												
4. NM3 (RT)	-.39	-.28	-.30	—											
5. NM5 (RT)	-.27	-.21	-.34	.77	—										
6. KT1 (RT)	-.15	-.13	-.08	.37	.28	—									
7. Recall (F)	.34	.06	.13	-.38	-.19	-.25	—								
8. Recall (D)	.32	.03	.13	-.28	-.16	-.27	.69	—							
9. Recall (MN)	.34	.23	.17	-.31	-.21	-.24	.39	.37	—						
10. PSS	-.16	-.06	-.05	.13	.01	.01	-.09	-.07	.01	—					
11. CES-D	-.14	-.13	-.11	.07	-.06	.06	.02	.14	-.03	.52	—				
12. IES-Total	-.32	-.11	-.15	.34	.19	.30	-.13	-.13	-.15	.33	.29	—			
13. IES-Severity	-.11	.06	-.03	-.10	-.11	.03	.11	.19	.03	.16	.25	.19	—		
14. IES-Time	.04	-.07	-.15	-.12	-.14	-.05	-.10	-.11	-.20	-.08	.01	-.19	-.01	—	
15. Age	-.15	-.25	-.32	.34	.25	.33	-.35	-.31	-.26	.15	.13	.17	-.02	.12	—

Note. Correlations in boldface were significant ($p < .05$). OSPAN = operation span; NB2 = 2-back; AC = arcsine transformed accuracy rate; KT2 = Keep-Track 2; NM3 = Number Match (three item); RT = response time in milliseconds; NM5 = Number Match (five item); KT1 = Keep-Track 1; Recall (F) = selective reminding free recall; Recall (D) = selective reminding delayed recall; Recall (MN) = Memory for Names; PSS = Perceived Stress Scale; CES-D = Center for Epidemiological Study—Depression; IES-Total = Impact of Event Scale (15-item)—Total score; IES-Severity = Impact of Event Scale—Event severity rating; IES-Time = Impact of Event Scale—Event recentness (in months).

Table 3

Standardized Structural Model Parameter Estimates for Predictors of Cognitive Function

Parameter	Total effects	Partial effects
PSS → WM	-.21 [†]	-.05
PSS → PS	.16	-.03
PSS → EM	-.09	-.09
CES-D → WM	-.20 [†]	-.04
CES-D → PS	.12	-.02
CES-D → EM	.06	.19
IES-Total → WM	-.40 ^{**}	-.34 ^{**}
IES-Total → PS	.51 ^{**}	.46 ^{**}
IES-Total → EM	-.25 ^{**}	-.25 [*]
IES-Severity → WM	-.11	-.04
IES-Severity → PS	-.11	-.17
IES-Severity → EM	.19	.18
IES-Time → WM	-.03	-.06
IES-Time → PS	-.11	-.09
IES-Time → EM	-.24 [†]	-.24
Age → WM	-.30 [*]	-.21 [†]
Age → PS	.51 ^{**}	.44 ^{**}
Age → EM	-.50 ^{**}	-.43 ^{**}

Note. PSS =Perceived Stress Scale; WM =working memory; PS =processing speed; EM =episodic memory; CES-D =Center for Epidemiological Study—Depression scale; IES-Total =Impact of Event Scale (15-item)—Total score; IES-Severity =Impact of Event Scale—Event severity rating; IES-Time =Impact of Event Scale—Event recentness (in months).

[†]
 $p < .10$.

^{*}
 $p < .05$.

^{**}
 $p < .01$.