Emotion

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BRIEF REPORT

The Effect of Negative Affect on Cognition: Anxiety, Not Anger, Impairs Executive Function

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It is often assumed that negative affect impairs the executive functions that underlie our ability to control and focus our thoughts. However, support for this claim has been mixed. Recent work has suggested that different negative affective states like anxiety and anger may reflect physiologically separable states with distinct effects on cognition. However, the effects of these 2 affective states on executive function have never been assessed. As such, we induced anxiety or anger in participants and examined the effects on executive function. We found that anger did not impair executive function relative to a neutral mood, whereas anxiety did. In addition, self-reports of induced anxiety, but not anger, predicted impairments in executive function. These results support functional models of affect and cognition, and highlight the need to consider differences between anxiety and anger when investigating the influence of negative affect on fundamental cognitive processes such as memory and executive function.

Keywords: executive function, negative affect, anxiety, anger, set-shifting

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Negative affective states such as anxiety and anger often appear to lead us to make poor decisions. In line with these observations, a number of laboratory studies have shown that inducing negative mood states leads to a reduction in executive functions (e.g., Allen, Schaefer, & Falcon, 2014; Kalanthroff, Cohen, & Henik, 2013; Padmala, Bauer, & Pessoa, 2011). However, other studies have failed to find these effects (Dreisbach, 2006), and some have even found that negative affect can improve executive function (Pessoa, Padmala, Kenzer, & Bauer, 2012).

One critical factor that may help make sense of the above disagreements is to consider the type of negative affect induced. For example, anxiety and anger are two different kinds of negative affective states that are associated with unique autonomic nervous system responses (Kreibig, 2010), inflammatory cytokine profiles (Moons & Shields, 2015), and patterns of neural activity (Phan, Wager, Taylor, & Liberzon, 2002). These differences likely stem from the fact that anxiety is an avoidance-motivated emotion, whereas anger is an approach-motivated emotion (Carver & Harmon-Jones, 2009). Most previous studies of affect and executive function have used nonspecific inductions of negative affect (e.g., presenting a violent film), so it is not clear how incidental anxiety or anger impact executive function.

Several lines of evidence led us to hypothesize that anxiety, but not anger, should impair executive function. First, avoidance motivation is more cognitively draining than approach motivation (Roskes, Elliot, Nijstad, & De Dreu, 2013). As such, because anxiety is an avoidance-motivated emotion but anger is approach-motivated, anxiety may impair executive function by diminishing cognitive resources, whereas anger should not. Second, acute stress impairs executive function in part by increasing noradrenaline (Alexander, Hillier, Smith, Tivarus, & Beversdorf, 2007), and only state anxiety—not state anger—is correlated with noradrenergic receptor occupation (Yu, Kang, Ziegler, Mills, & Dimsdale, 2008). Thus, anxiety may impair executive function by both draining cognitive resources and concurrently enhancing noradrenergic activity, whereas anger is unlikely to impair executive function.

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In the current study we randomly assigned participants to an anxiety induction, anger induction, or neutral mood induction and assessed executive function. We predicted that there would be no difference in postinduction executive function performance between the anger induction and neutral mood induction conditions, but that the anxiety induction would significantly impair executive function relative to both the neutral mood induction and the anger induction.

Method

Participants

There were 153 undergraduates (120 females) who participated in exchange for course credit. This sample size was determined based upon prior research that found an effect size of $\eta_p^2 = 0.10$ when determining an effect of negative affect on executive function (Padmala, Bauer, & Pessoa, 2011). Because we hypothesized that there would be no effect of anger on executive function, we wanted our study to have the power to find an effect if it exists; to achieve 0.95 power for an effect size of $\eta_p^2 = 0.10$ we needed approximately 150 participants. The mean age of the sample was 20.18 ($SD = 1.85$). No participants were excluded from analysis.

Materials

Mood induction. To induce anger, anxiety, or a neutral mood, we had participants write autobiographical essays used in previous research (e.g., Bodenhausen, Sheppard, & Kramer, 1994; Moons & Shields, 2015; Tiedens & Linton, 2001). Participants wrote for six minutes about an unresolved anxiety-inducing situation (anxiety induction condition), an unresolved angering situation (anger induction condition), or the events of the previous day (neutral mood induction condition).

Postinduction executive function. Postinduction executive function was measured using the Berg Card Sorting Test (BCST), an open-source version of the Wisconsin Card Sorting Test (WCST; Mueller & Piper, 2014). This task was chosen because it is well-validated global executive function task, requiring working memory, inhibition, and cognitive flexibility (Nyhus & Barceló, 2009), although it primarily utilizes cognitive flexibility in healthy undergraduates (Miyake et al., 2000). Additional information on this task is available in Supplementary Material. The primary outcome in this task is the number of perseverative errors a person makes, which indicates a continued application of a rule that is no longer appropriate; higher scores thus indicate worse performance.

Baseline executive function. Baseline executive function was measured using the PEBL Trail Making Test (pTMT), which is an open source version of the Trail Making Test. The pTMT was chosen as the measure of baseline executive function because in a multiple regression of neuropsychological tests, it was the strongest predictor of performance of perseverative errors (Sánchez-Cubillo et al., 2009).

Self-reported emotions. At baseline and immediately after the emotion induction, participants reported the extent to which they currently felt a variety of emotions using unmarked seven point scales anchored at 1 (*not at all*) and 7 (*very much*). Embedded among other emotions, participants reported the extent to which they currently felt anxious, angry, and stressed.

Self-reported motivation. To assess whether our manipulation altered motivation to perform on the postinduction executive function task, we asked participants, "How motivated were you to perform well on the card-sorting task?" Participants answered this question using an unmarked nine-point scale anchored at 1 (*not at all*) and 9 (*very much*).

Procedure

Upon arriving at the lab, participants were randomly assigned to one of three conditions: a neutral mood induction, anxiety induction, or anger induction, resulting in the assignment of $n_{\text{neutral}} = 52$, $n_{\text{anxiety}} = 53$, and $n_{\text{anger}} = 48$. Participants first completed the baseline executive function measure. For the next 40 min, participants completed filler personality questionnaires. Participants then completed the preinduction mood questionnaire. Next, participants completed the emotion induction. Following the induction, participants completed the postinduction mood questionnaire. Finally, participants completed the postinduction executive function task before completing the demographics and debriefing forms (that included the question assessing motivation). No participant inferred the hypothesis we tested.

Analytic Strategy

All analyses were planned analyses of interest, with directional tests used where directional effects were hypothesized. Effect size estimates for *g* were derived using the bootES package in **R**. In analyses incorporating covariates, participant race, sex, and preinduction emotions were considered as covariates for postinduction self-reported emotions, because both race (Matsumoto, 1993; Vrana & Rollock, 2002) and sex (Simon & Nath, 2004) influence self-reports of emotions, whereas age and baseline executive function were considered as covariates for postinduction executive function. There were no missing data. Postinduction executive function and baseline executive function were log transformed to correct for skew.

Results

Table 1 presents descriptive statistics and zero-order correlations.

Manipulation Check

As hypothesized, postinduction anxiety was significantly greater in the anxiety induction condition ($M = 3.68$, 95% confidence interval [CI] [3.28, 4.09]) than in the neutral mood induction condition ($M = 2.60$, 95% CI [2.19, 3.01]), $t(149) = 3.69$, $p < .001$, and than in the anger induction condition ($M = 2.96$, 95% CI [2.54, 3.39]), $t(149) = 2.41$, $p = .017$. Similarly, postinduction anger was significantly greater in the anger induction condition ($M = 3.39$, 95% CI [2.94, 3.84]) than in the neutral mood induction condition ($M = 1.53$, 95% CI [1.09, 1.96]), $t(149) = 5.85$, $p < .001$, and than in the anxiety induction condition ($M = 2.64$, 95% CI [2.21, 3.07]), $t(149) = 2.37$, $p = .019$. Finally, postinduction stress did not differ between the anger induction ($M = 4.09$, 95% CI [3.73, 4.44]) and anxiety induction ($M = 4.09$, 95% CI [3.76, 4.43]) conditions, $t(149) = 0.03$, $p > .250$, although postinduction

Table 1
Descriptive Statistics and Bivariate Correlations Between Variables of Interest

Variable mean, 95% CI	1	2	3	4	5	6
Across all conditions						
1. Preinduction anxiety 3.05 [2.75, 3.34]	1					
2. Preinduction anger 1.70 [1.49, 1.91]	.252**	1				
3. Postinduction anxiety 3.09 [2.78, 3.40]	.607***	.239**	1			
4. Postinduction anger 2.50 [2.21, 2.79]	.164*	.305***	.366***	1		
5. Baseline executive function 9.96 [9.93, 9.98]	.039	.019	−.029	.047	1	
6. Postinduction executive function 2.21 [2.10, 2.32]	−.007	.133	.109	.029	.157*	1
Neutral mood induction	1	2	3	4	5	6
1. Preinduction anxiety 2.94 [2.40, 3.49]	1					
2. Preinduction anger 1.85 [1.47, 2.22]	.374**	1				
3. Postinduction anxiety 2.54 [2.01, 3.07]	.806***	.526***	1			
4. Postinduction anger 1.60 [1.27, 1.92]	.363**	.677***	.578***	1		
5. Baseline executive function 9.98 [9.94, 10.0]	.106	−.052	.107	−.020	1	
6. Postinduction executive function 2.11 [1.90, 2.31]	.012	.164	.016	.086	.080	1
Anxiety induction	1	2	3	4	5	6
1. Preinduction anxiety 3.04 [2.53, 3.54]	1					
2. Preinduction anger 1.62 [1.24, 2.00]	.235†	1				
3. Postinduction anxiety 3.68 [3.17, 4.19]	.467***	.088	1			
4. Postinduction anger 2.60 [2.11, 3.09]	−.072	.338*	.266†	1		
5. Baseline executive function 9.94 [9.90, 9.97]	−.064	.035	−.121	−.123	1	
6. Postinduction executive function 2.38 [2.20, 2.57]	−.003	.172	.041	−.090	.264†	1
Anger induction	1	2	3	4	5	6
1. Preinduction anxiety 3.17 [2.65, 3.68]	1					
2. Preinduction anger 1.63 [1.28, 1.97]	.123	1				
3. Postinduction anxiety 3.04 [2.47, 3.61]	.573***	.163	1			
4. Postinduction anger 3.35 [2.76, 3.95]	.260†	.206	.319*	1		
5. Baseline executive function 9.95 [9.90, 9.99]	−.005	.052	−.054	.189	1	
6. Postinduction executive function 2.14 [1.97, 2.31]	−.042	.076	.175	.076	.265†	1

Note. $N = 153$, $n_{\text{neutral}} = 52$, $n_{\text{anxiety}} = 53$, and $n_{\text{anger}} = 48$. Baseline and postinduction executive function were log transformed to correct for significant skew; higher values on these measures indicate worse executive function. Baseline executive function means and correlations are partial and represent Part B of the pTMT, controlling for Part A. Postinduction executive function represents perseverative errors on the Berg Card Sorting Task. CI = confidence interval.
† $p \leq .10$. * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

stress was greater in both the anger and anxiety induction conditions than in the neutral mood induction condition ($M = 3.04$, 95% CI [2.69, 3.38]), $t(149) = 4.92$, $p < .001$ (see Supplementary Material for analyses of arousal).

Primary Analyses

Effect of the anxiety and anger manipulations on executive function. Planned contrasts tested whether anxiety, but not anger, impaired executive function. As hypothesized, participants committed significantly more perseverative errors in the anxiety induction condition ($M = 2.38$, 95% CI [2.20,2.56]) than in the neutral mood induction condition ($M = 2.11$, 95% CI [1.92,2.29]), $t(150) = 2.10$, $p = .019$, $g = 0.41$ (Figure 1a). Moreover, as hypothesized, participants did not differ in the number of perseverative errors they committed in the anger induction condition ($M = 2.14$, 95% CI [1.95,2.33]) and the neutral mood induction condition, $t(150) = 0.25$, $p > .250$, $g = 0.05$. Finally, as hypothesized, participants committed significantly more perseverative errors in the anxiety induction condition than did participants in the anger induction condition, $t(150) = 1.80$, $p = .037$, $g = 0.38$.

Controlling for covariates (i.e., age and baseline executive function) only strengthened the above results. As hypothesized, participants committed significantly more perseverative errors in the anxiety induction condition ($M = 2.42$, 95% CI [1.23,2.59]) than in the neutral mood induction condition, $t(147) = 2.32$, $p = .011$, $\omega^2_G = .03$. Additionally, participants did not differ in the number of perseverative errors committed between the anger induction condition ($M = 2.14$, 95% CI [1.95,2.33]) and the neutral mood induction condition ($M = 2.12$, 95% CI [1.94,2.30]), $t(147) = 0.19$, $p > .250$, $\omega^2_G < .01$. Moreover, participants committed significantly more perseverative errors in the anxiety induction condition than in the anger induction condition, $t(147) = 2.10$, $p = .019$, $\omega^2_G = .02$.

There were no outliers in the above analyses greater than 3 *SD*s above the mean in absolute value. Excluding outliers greater than 2 *SD*s above the mean in absolute value only strengthened the results.

Individual differences analyses. To determine if individual differences—rather than mean differences—in anxiety predicted executive function, we regressed perseverative errors (log transformed) on postinduction anxiety and postinduction anger, controlling for covariates. The results indicated that postinduction ratings of anxiety predicted perseverative errors, $\beta = .22$, $t(140) = 2.10$, $p = .038$, $\Delta R^2 = .03$, whereas postinduction ratings of anger did not, $\beta = -.09$, $t(140) = -1.04$, $p > .250$, $\Delta R^2 < .01$ (Figure 1b). There was no interaction with experimental condition, $p > .250$ indicating that the same pattern of individual differences was observed in all induction groups. Moreover, a test of difference

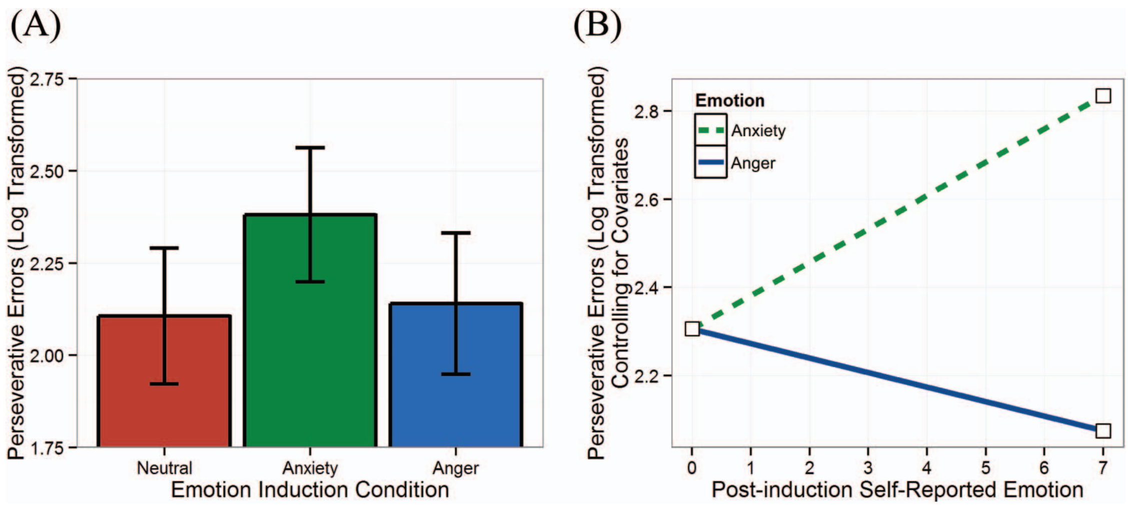

Figure 1. Effects of emotions on executive function. (A) An acute induction of anxiety, $g = 0.41$, but not anger, $g = 0.05$, produced significantly more perseverative errors relative to a neutral mood induction. Error bars represent 95% confidence intervals of the mean. (B) Controlling for preinduction emotions, age, race, sex, and baseline executive function, postinduction self-reports of anxiety, $\beta = .22$, but not self-reports of anger, $\beta = -.09$, predicted perseverative errors. See the online article for the color version of this figure.

between dependent slopes indicated that the slope predicting perseverative errors from postinduction anxiety was significantly greater than the slope predicting perseverative errors from postinduction anger, $t(140) = 2.05$, $p = .042$, indicating that postinduction anxiety was a significantly better predictor of perseverative errors than was postinduction anger. These results did not differ with baseline executive function excluded from the model; postinduction anxiety remained a significant predictor of perseverative errors, $\beta = .21$, $p = .05$, whereas postinduction anger remained nonsignificant, $\beta = -.07$, $p = .40$.

We next attempted to determine the robustness of the regression analyses. Analyses of DFBETAS revealed nine influential outliers (|DFBETAS|>0.162) on the slope regressing perseverative errors on postinduction anxiety. Removing these outliers did not alter the results; postinduction anxiety was significant, $p = .048$, and postinduction anger remained nonsignificant, $p > .250$. Analyses of DFBETAS revealed 14 influential outliers on the slope regressing perseverative errors on postinduction anger. Removing these outliers did not alter the results; postinduction anxiety remained significant, $p = .022$, and postinduction anger remained nonsignificant, $p > .250$. Removing all of these outliers in conjunction (19 participants in total) did not alter the results; postinduction anxiety remained a significant predictor of perseverative errors, $\beta = .26$, $t(121) = 2.21$, $p = .029$, $\Delta R^2 = .03$, and postinduction anger remained nonsignificant, $\beta = -.02$, $t(121) = -0.21$, $p > .250$, $\Delta R^2 < .01$.

The above results illustrate a robust effect of acute increases in emotions that coincide with the experimental results discussed above. In particular, acute increases in anxiety, but not acute increases anger, predicted executive dysfunction. Taken together, the sum of the results discussed here paint a clear picture: anxiety, but not anger, impairs executive function.

Motivation. To assess whether motivation played a role in the current results, we tested whether the anxiety or anger inductions decreased motivation to perform well on the postinduction executive function task. Self-reported motivation was not significantly greater in the neutral mood induction condition ($M = 7.02$, 95% CI [6.50,7.54]) than it was in the anxiety induction ($M = 6.74$, 95% CI [6.22,7.25]), $t(150) = 0.77$, $p > .250$, or the anger induction ($M = 7.08$, 95% CI [6.54,7.62]), $t(150) = -0.17$, $p > .250$. Thus, the unique effects of anxiety on executive function did not appear to be related to motivational changes.

Additional analyses. For the reader's interest, additional analyses (i.e., of essay content) can be found in the online Supplementary Material.

Discussion

Prior executive function research has often viewed negative affect as a relatively unitary construct. Numerous studies have shown that negative affect impairs executive function, but this research has not taken into account that different negatively valenced affective states may differentially influence cognitive processes. Our results indicate that not all high-arousal, negative affective states influence executive function equally. In particular, we found that an acute induction of anxiety, but not anger, impaired executive function. Moreover, individual differences in postinduction anxiety, but not postinduction anger, predicted executive function impairments. Together, these results offer the first evidence that similar negatively valenced affective states can have different effects on executive function.

Our results are in agreement with research that has found differential effects of anxiety or anger on cognitive processes such as decision-making (Lerner & Keltner, 2001) and information processing (Moons & Mackie, 2007). Our results, however, are the first to show differential effects of anxiety and anger on fundamental cognitive processes, such as executive function, that may underpin higher-order cognitive processes like those mentioned above. These findings thus support a functional model of the association between affect and cognition, illustrating that different affective states can differentially influence cognitive processes (Nabi, 1999).

Most research investigating fundamental cognitive processes such as memory and executive function implicitly holds to a unitary model, treating negative affect and its effects on these cognitive processes as relatively homogenous (e.g., Giron & de Almeida, 2010; McCullough & Yonelinas, 2013). Our results, however, suggest that not all negative affect should be treated equally when investigating its effects on cognition. Indeed, our results suggest that negative affect inductions that do not also increase avoidance motivation may have negligible effects on executive function, whereas negative affect inductions that also increase avoidance motivation may impair executive function.

This study has limitations. First, autobiographical essays are one of many emotion inductions, and a different induction might produce different results. However, autobiographical emotion inductions produce similar neural activity to other emotion inductions (Phan et al., 2002), making the idea of finding different results with a different induction unlikely. Nonetheless, we do not claim that anger will never impair executive function; instead, we only claim that under mild or moderate conditions anger is relatively less important than anxiety for impacting executive function. Second, the executive function task used in this study is but one of many, and it is unknown whether different results would be obtained using another task not primarily utilizing cognitive flexibility. Indeed, the question of whether different executive function subcomponents, such as working memory, may be differentially influenced by anger or anxiety is an interesting one, and one that should be answered by future research. Third, it is possible that the emotion inductions may have differentially induced arousal, and arousal may be responsible for the effects observed. This possibility is unlikely, however, as another study using a nearly identical manipulation and set of instructions with a sample of participants of roughly equivalent age, race, and gender measured a number of cardiovascular indices and found that the anxiety and anger inductions produced equivalent increases in arousal (Moons & Shields, 2015). Finally, the emotion induction we used induced incidental emotions, rather than emotions that were integral to the executive function task. It is unknown whether anxiety or anger that are induced by an executive function task might produce effects similar to what we observed here, although this is an intriguing avenue for future research.

Conclusion

This article presents the first evidence that various negative affective states differentially influence cognitive processes. We found that, despite theoretically equivalent valence and arousal, the avoidance-motivated emotion of anxiety, but not the approach-motivated emotion of anger, impaired executive function. Future research exploring the effects of negative affect on cognition should, therefore, consider not only the valence of an affective state, but also its arousal and motivation.

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