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BRIEF REPORT

Are Attentional Control Resources Reduced by Worry in Generalized Anxiety Disorder?

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This is the first study to examine attentional control capacities in generalized anxiety disorder (GAD). GAD is characterized by uncontrollable worry. Individuals diagnosed with GAD and healthy participants (HPs) performed a random key-pressing task while thinking about a worrisome or a positive future event, to assess the extent to which attentional control resources are used by worry. Attentional control was also assessed when participants were not instructed to think about a specific topic using the N-back task, which varies in task difficulty, and therefore is sensitive to subtle differences in ability to handle increasing demands on attentional control within the same paradigm. GAD participants (but not HPs) were less random while worrying than thinking about a positive event during the key-pressing task, suggesting that worry consumed more attentional control resources in this population. During the N-Back task, GAD participants performed worse than HPs during the high load conditions only, indicating greater difficulty in sustaining focus on conditions requiring a higher degree of attentional control, even without concurrent task activity. Poor attentional control might underpin the difficulty of GAD individuals to stop worrying and switch to thinking more benign information. Further research could investigate whether worry consumes attentional control resources in other psychological disorders with high rates of worry (e.g., panic disorder, psychosis), as well as the extent to which attentional control is used by other forms of repetitive thinking, such as depressive rumination.

Keywords: attentional control, generalized anxiety disorder, working memory, worry

Generalized anxiety disorder (GAD) is a chronic and debilitating disorder often resulting in poor quality of life (Kessler, Ruscio, Shear, & Wittchen, 2009). Uncontrollable worry, as if talking to oneself about multiple negative outcomes, is the key characteristic of GAD. Although there is growing evidence for the role of cognitive processes in maintaining uncontrollable worry (Hirsch & Mathews, 2012), evidence is also emerging that worry impacts adversely on cognitive processes themselves (Hayes, Hirsch, & Mathews, 2008; Williams, Mathews, & Hirsch, 2014). It is important to determine whether uncontrollable worry in GAD has similar adverse effects that may help maintain the disorder.

There is growing evidence that the process of worrying is associated with deficits of the central executive (CE) function of working memory (WM; Baddeley, 1996). WM is a limited-capacity resource, comprised of an attentional control system, referred to as the CE (i.e., supervisory control system responsible for the inhibition of automatic responses and task switching) as well as two subsidiary systems for verbal and visuospatial information (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). For purposes of clarity, attentional control in this article refers to the ability to sustain focus on tasks in the face of competing activities or shift attention from one task to another.

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The theoretical assumption that worry impairs attentional control is related to the view that there are two attentional control systems: a voluntary or goal-driven system (i.e., influenced by individual goals) and an involuntary or stimulus-driven system (i.e., influenced by salient stimuli). The voluntary system is centered in the prefrontal cortex and is involved in the "top-down" regulation of attention, whereas the involuntary system is responsible for the "bottom-up" control of attention, involving the temporo-parietal and ventral frontal cortices (Corbetta & Shulman, 2002; Miller & Cohen, 2001).

Although the two systems are interacting (Pashler, Johnston, & Ruthruff, 2001), Eysenck, Derakshan, Santos, and Calvo's (2007) attentional control theory suggests that worry is particularly attention-demanding and, consequently, consumes more voluntary attentional resources required to control it. As such, worry impairs attentional control by enhancing the influence of bottom-up processes over the more efficient top-down, goal-driven processes; task efficiency in anxious individuals can thus be reduced although this can be compensated by increased effort (i.e., effectiveness remains intact). Hirsch and Mathews's (2012) cognitive model of pathological worry proposed that negative thoughts and worry arise from an interaction between involuntary processes, such as habitual biases in attention and interpretation favoring threat content, and insufficient or misdirected voluntary resources, such as attentional control, that are recruited by (verbal) worry content and increase the difficulty of redirecting attention to alternative topics. Perseverative worry may also be further compounded by individuals' maladaptive beliefs about worry (e.g., that worry helps them to solve problems; Wells, 2006).

Hayes, Hirsch, and Mathews (2008) were the first to investigate the extent to which worry depletes attentional control. High and low worriers worried or thought about a positive topic while performing a random key-pressing task requiring CE resources (Baddeley, 1998). High worriers were less random (indicating less attentional control available for key-pressing) during worry than while thinking about a positive topic. Low worriers were unaffected by topic content and performed better than high worriers in both conditions. Hence, worry depleted resources in high worriers, leaving them less able to shift their attention away from worry and onto the task. Worry is verbal in nature, with little imagery (Hirsch, Mathews, Lequertier, Perman, & Hayes, 2013). Leigh and Hirsch (2011) demonstrated that although verbal worry depleted attentional control resources in high (but not low) worriers, when high worriers engaged in worry using prolonged imagery, group differences disappeared. Taken together, it can be argued that it is not negative thoughts per se, but the verbal form of typical worry that depletes attentional control. Studies have shown that anxious individuals perform worse on tasks that demand high levels of attentional control even without externally imposed worry conditions (e.g., Bishop, 2008; MacLeod & Donnellan, 1993). However, it remains unclear whether individuals with GAD show general limitations in attentional control when cognitive demands are high, that is, regardless of worry.

To our knowledge, no study has examined attentional control capacities in GAD. To examine whether individuals diagnosed with GAD show more permanent deficits in attentional control (i.e., irrespective of concurrent task activity) or only when demands (and thus, the potential for errors) are high, participants performed the N-Back task (Owen, McMillan, Laird, & Bullmore, 2005). This task was selected as it allows manipulation of attentional control using increasing levels of difficulty within the same paradigm. We hypothesized that GAD participants would show reduced attentional control compared to healthy participants, particularly during conditions that require high levels of attentional control. Moreover, we wished to determine whether worry consumes more attentional control than positive topics in GAD individuals by administering the same task (Hayes et al., 2008). We hypothesized that GAD individuals would be less random than healthy participants, particularly during the worry condition.

Method

Participants

Seventeen clients after their first session of cognitive–behavioral treatment (out of possible 12–16 sessions) or on a wait list for GAD (13 female, four male) were recruited from National Health Service clinical psychology clinics within East Anglia, UK. Seventeen healthy participants (HPs) matched to GAD clients for age, gender, and IQ (assessed by the Wechsler Test of Adult Reading; WTAR, Wechsler, 2001) were recruited from local communities through advertisements. The Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (Patient ed.) (First, Spitzer, Williams, & Gibbon, 1997) was used to confirm primary diagnosis for GAD and assess caseness for HPs (Nonpatient ed.). All participants were right-handed. GAD participants were taking escitalopram ($n = 2$), imipramine ($n = 3$), venlafaxine ($n = 3$), alprazolam ($n = 2$), lorazepam ($n = 4$), diazepam ($n = 1$), or buspirone ($n = 2$).

Exclusion criteria were significant depression symptoms (≥29 on the Beck Depression Inventory scale; BDI-II, Beck, Steer, & Brown, 1996) and current or previous substance abuse or dependence (American Psychiatric Association, 1994) to reduce possible effects on task performance. Participants' age ranged from 32 to 55 years; there were no group differences in age, $t(32) = .64$, *ns*, WTAR, $t(32) = .57$, *ns*, or gender, χ^2 $(1) = .18$, *ns*. Groups differed in BDI-II, $t(32) = 18.80$, $p < .001$, and the Penn State Worry Questionnaire (Meyer, Miller, Metzger, & Borkovec, 1990), $t(32) = 33.17$, $p < .001$.

Measures

Penn State Worry Questionnaire. The Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990) assesses trait-like tendencies to engage in worry. Participants rate 16 items on a scale from 1 (*not at all typical of me*) to 5 (*very typical of me*). It demonstrates good internal consistency, retest reliability, and validity and greater correlations with worry than anxiety (Molina & Borkovec, 1994).

BDI-II. The BDI-II assesses depressive symptomatology. Participants rate 21 items about their feelings in their past 2 weeks. Scores range from 0 (*I do not feel sad*) to 3 (*I am so sad or unhappy that I can't stand it*). It shows good internal consistency, retest reliability, and validity.

N-Back Task (Owen et al., 2005). This task is used as a general attentional control capacity measure. Participants watch a sequence of letters, one at a time, on a computer screen and press a key on their keyboard whenever an item is identical to the one presented "n" positions before, where "n" is proportional to the cognitive load. In the 0-back condition the target letter was "X." In the one, two, and three back conditions, the target letter (e.g., A) was defined as any letter that was identical to the one presented in the preceding one, two, or three trials (e.g., AA, ABA, AGHA), respectively. One hundred and 50 letters in yellow font were presented on a blue screen for 1 s each (separated by blue screen intervals lasting for 1 s each). The task lasted for 6 min and the order of trials was nonrandomized. Accuracy and reaction times (RTs) were recorded.

Random Generation Key-Pressing Task (Hayes et al., 2008). Participants identified personally relevant (worrisome or positive) future events for each thought condition in a random generation key-pressing task (Hayes et al., 2008). Personal relevance ratings on a scale from 1 (*not relevant*) to 10 (*extremely relevant*) were used to ensure that possible effects on randomization could not be accounted for by differences in topics relevance across conditions. Prior to each condition, the researcher asked questions for 2 min following the form "What would be bad about that?" for the worrisome condition (Davey & Levy, 1998) or "What would be good about that?" for the positive condition (Startup & Davey, 2001) to prime salient aspects of the identified topics.

Participants were instructed that every time they heard a beep, they should press a random key on their keyboard and return to thinking about their topic. The computer generated tones every 3 s and participants generated sequences of key-presses using a 15-item key box for 5 min. Generating random responses requires high levels of attentional control to monitor and "break away" from tendencies to produce well-rehearsed sequences (e.g., ascending key series). To the extent that resources are consumed by other tasks (e.g., worry), the generated output is less random (Baddeley, 1998).

Randomness was scored using the Random Number Generation (RNG) index. Scores range from 0 to 1 based on consecutive response pairs; scores closer to 1 indicate that pairs of keys were pressed repeatedly, rather than equally distributed. Higher values indicate less random performance and therefore, less attentional control resources available for the task. To compute the RNG, the RGCalc software was used (Towse & Neil, 1998).

Mood ratings. Participants' levels of anxiety, depression, and happiness were assessed using three visual analogue scales. Each scale was labeled *not at all* at one end and *extremely* on the other with scores ranging from 0 to 100 mm (extremely).

Thought valence ratings. Following each condition, participants rated the valence of their thoughts by reporting the percentage of these being negative, positive, and neutral.

Filler task. To reduce possible carry-over effects between thought conditions, the Speed of Comprehension Test was used (Baddeley, Emslie, & Nimmo-Smith, 1992). Participants indicated whether statements were true (e.g., "Ants are living creatures") or false for 2 min. To decrease the likelihood of the task precipitating anxiety, instructions emphasized that speed was not important.

WTAR. This task was administered to ensure that group differences were not attributed to general intellectual abilities. Participants read words aloud that are irregular in pronunciation: the number of errors made was used as an estimate of general intellectual functioning. WRAT correlates highly with Wechsler Adult Intelligence Scale (3rd ed.; WAIS-III) full scale IQ scores and shows good test–retest reliability and internal consistency.

Procedure

Participants were administered the SCID-IV and completed the PSWQ and BDI-II measures. To minimize possible carry-over effects from the two thought conditions, participants performed the N-Back task first. In counterbalanced order within groups, participants then completed the two conditions of the key-pressing task. Prior to each condition, participants completed a mood rating form and in between the two conditions, they completed the filler task. After each condition, participants completed another mood rating and the thought valence rating form. Participants completed the WTAR last and were reimbursed $6 for their participation.

Results

N-Back Task

Accuracy. Analysis of variance (ANOVA) was carried out with Group (GAD, HPs) as the between-subjects factor and the Load Condition (0, 1, 2, 3 levels) as repeated-measures. No significant main effect of Group, $F(1, 32) = 0.95$, *ns*, $\hat{\eta}_P^2 = .56$, or Group x Condition interaction, $F(3, 96) = 0.62$, *ns*, $\hat{\eta}_P^2 = .92$, were found. A significant main effect of Condition, $F(3, 96) = 641.44$, $p < .001$, $\hat{\eta}_P^2 = .95$, was found suggesting decreases in accuracy with increased difficulty, all $t(33) > 2.76$, $p < .001$, $d > 0.80$.

RT. RT for correct responses was analyzed using an ANOVA with Group as the between-subjects factor and Load Condition as repeated-measures. A significant main effect of Group was found, $F(1, 32) = 11.80$, $p = .002$, $\hat{\eta}_P^2 = .27$, with GAD participants requiring longer RT than HPs (.16 and −.16, respectively). A main effect of Condition was also found, $F(3, 96) = 23.68$, $p < .001$, $\hat{\eta}_P^2 = .42$, suggesting longer RT with increased difficulty (all comparisons-except between N-Back-2 and N-Back-3, $t(33) = -1.38$, *ns*- were significant, all $t(33) > -2.24$, $p < .03$, $d > -0.50$). Finally, there was a significant Group × Condition interaction, $F(3, 96) = 4.83$, $p = .01$, $\hat{\eta}_P^2 = .13$. Groups did not differ during N-Back-0, $t(32) = 1.41$, *ns*, and N-Back-1, $t(32) = 1.19$, *ns*. GAD participants required significantly longer RT than HPs during N-Back–2, $t(18) = 3.04$, $p = .007$, $d = 1.04$, and N-Back-3, $t(32) = 3.90$, $p < .001$, $d = 1.39$.

Random Key-Pressing Task

An ANOVA was carried out on RNG scores with Group as the between-subjects factor and Thought Condition (Positive, Worry) as repeated-measures. There was a significant effect of Group, $F(1, 32) = 21.06$, $p < .001$, $\hat{\eta}_P^2 = .39$, with GAD participants being less random than HPs ($M = .23$, $SD = .05$ and $M = .16$, $SD = .03$, respectively) and for Condition, $F(1, 32) = 9.05$, $p = .005$, $\hat{\eta}_P^2 = .22$, with less random responses while worrying than thinking about a positive topic ($M = .21$, $SD = .07$ and $M = .18$, $SD = .05$, respectively). There was also a significant Group × Condition interaction, $F(1, 32) = 5.71$, $p = .02$, $\hat{\eta}_P^2 = .15$. GAD participants were less random during worry than in the positive condition, $t(16) = -3.78$, $p = .002$, $d = -0.90$, with no such differences in HP, $t(16) = -0.44$, *ns*. GAD participants were significantly less random than HPs during worry, $t(32) = 5.13$, $p < .001$, $d = 2.10$, and positive conditions, $t(32) = 2.81$, $p = .008$, $d = 1.20$.

Covariance analyses were conducted for each condition separately, with mood and thought valence ratings as covariates. Controlling for mood[1] or valence[2] did not alter the results, suggesting no significant effects on randomization (Fs > 4; Tables 1 and 2).

Further exploratory analyses showed no significant correlations between PSWQ and RNG scores during worry, $r(15) = .17$, *ns*, or positive, $r(15) = .09$, *ns*, condition, N-Back RT, all $r(15) < .09$, *ns*, and N-Back accuracy, all $r(15) < -.10$, *ns*, scores for GAD participants. Also, no significant correlations were found between BDI and RNG worry, $r(15) = .07$, *ns*, or positive, $r(15) = .12$, *ns*, condition scores, N-Back RT, all $r(15) < .12$, *ns*, and accuracy, all $r(15) < -.11$, *ns*, scores. Similarly, HPs showed no significant correlations between PSWQ and RNG worry, $r(15) = .16$, *ns*, or positive, $r(15) = .01$, *ns*, condition scores, N-Back RT, all $r(15) < .06$, *ns*, and accuracy, all $r(15) < -.08$, *ns*, scores. No significant correlations were found between BDI and RNG worry, $r(15) = .12$, *ns*, or positive, $r(15) = .11$, *ns*, condition scores, N-Back RT, all $r(15) < .10$, *ns*, and accuracy, all $r(15) < -.12$, *ns*, scores. Hence, effects did not appear to be accounted for by general trait worry or depressed mood.

Correlations Between General Attentional Control and Randomization Performance

Bivariate correlations were computed between RNG scores and accuracy and RT for N-Back trials for each group separately. GAD participants showed significant correlations between the N-Back-2, $r(15) = .55$, $p = .02$, and N-Back-3 RT, $r(15) = .59$, $p = .01$, and RNG scores during worry. N-Back-2 RT also correlated with RNG scores during the positive condition, $r(15) = .59$, $p = .01$. No other correlations were significant ($p > .05$).

Discussion

In keeping with predictions, GAD individuals were less random on the key-pressing task while worrying than while thinking about a positive topic, indicating fewer residual attentional control resources available during the worrying process. Healthy participants' performance did not differ between conditions and they performed consistently better than GAD participants, irrespective of thought condition. This indicates that fewer resources were available to perform concurrent thought tasks when GAD individuals were thinking about personally relevant topics, irrespective of valence.

Unsurprisingly, GAD participants reported more negative thoughts and anxiety than HPs during the key-pressing task, regardless of condition. Group differences in task performance remained even after controlling for negative thoughts or anxiety. Leigh and Hirsch (2011) demonstrated it is not negative content (or mood) per se that influences attentional control, but rather the verbal nature of pathological worry that is problematic. Cognitive processing biases toward threat are well-established in GAD (e.g., Hayes, Hirsch, Krebs, & Mathews, 2010; Hayes, Hirsch, & Mathews, 2010; Mathews, May, Mogg, & Eysenck, 1990). Such biases occur during verbal worry and utilize resources (Hirsch & Mathews, 2012). Indeed, when high worriers develop a more benign interpretation bias, less attentional control is taken up by verbal worry, suggesting that negative biases utilize resources (Hirsch, Hayes, & Mathews, 2009).

During the N-back task, GAD participants required longer RTs than HPs to perform the higher load conditions. Longer RTs in these conditions were also associated with poorer randomization performance during the key-pressing task. Reduced general attentional control capacity may have influenced the extent to which the process of worrying restricted GAD participants' residual resources capacity during the key-pressing task. Groups did not differ in accuracy during the N-Back task. Such findings are in agreement with studies arguing that attentional control does not affect RT and accuracy similarly, but they reveal different mechanisms whereby stimuli capture attention. For instance, Prinzmetal, McCool, and Park (2005) argue that top-down voluntary attention processes enhance the perceptual representation of stimuli (and consequently, the allocation of processing resources for identification), affecting thus both accuracy and RT. Instead, involuntary attentional capture does not change the perceptual representation (accuracy) but reflects a process they call "channel selection," involving making decisions about which stimuli require a response (which stimuli is the relevant "channel"). As such,

Table 1
Key-Pressing and N-Back Tasks' scores, Split by Group

	Healthy participants *M* (*SD*)	GAD *M* (*SD*)
RNG[a]		
Positive condition	0.15 (0.05)	0.21 (0.05)
Worry condition	0.16 (0.03)	0.26 (0.06)
N-Back-0		
Correct responses (out of 6)	6.00 (0.00)	6.00 (0.00)
RT (ms)	0.42 (0.08)	0.48 (0.12)
N-Back-1		
Correct responses (out of 3)	3.00 (0.00)	3.00 (0.00)
RT (ms)	0.54 (0.18)	0.62 (0.18)
N-Back-2		
Correct responses (out of 3)	2.88 (0.33)	2.64 (0.60)
RT (ms)	0.55 (0.08)	0.85 (0.40)
N-Back-3		
Correct responses (out of 3)	1.94 (0.42)	1.88 (0.85)
RT (ms)	0.64 (0.14)	0.88 (0.20)

Note. RNG = random generation index; GAD = generalized anxiety disorder; RT = reaction time.
[a] Higher scores indicate less random performance or attentional control capacity.

[1] Higher levels of anxiety and depression, all $t(126) > 4.23$, $p < .03$, but lower levels of happiness, $t(126) = -4.51$, $p = .03$, were reported by the GAD group than HP. During worry, anxiety and depression, all $t(33) > -8.76$, $p < .001$, increased, and happiness, $t(33) = 14.95$, $p < .001$, decreased. During the positive condition, happiness, $t(33) = -16.58$, $p < .001$, increased, while depression and anxiety, all $t(33) > 9.97$, $p < .001$, decreased. Significant findings were at least of a medium effect size ($d > 0.50$).

[2] During both conditions, GAD participants reported more negative and less positive thoughts than HP; they also reported less neutral thoughts during worry, all $t(32) > -2.28$, $p < .01$, but not positive, $t(32) = -.21$, *ns*, condition than HP. During worry, groups reported more negative and positive than neutral, and more negative than positive, thoughts, all $t(32) > -2.43$, $p < .01$. In the positive condition, groups reported more positive than negative or neutral thoughts, all $t(32) > -34.01$, $p < .001$. HPs also reported less negative than neutral thoughts, $t(16) = -4.95$, $p = .001$, but GAD participants didn't, $t(16) = -1.64$, *ns*. Significant findings were at least of a medium effect size ($d > 0.50$).

Table 2
Thought Valence Ratings Percentages for Each Condition, Split by Group

Condition	Positive condition *M* (*SD*)			Worry condition *M* (*SD*)		
	Negative	Positive	Neutral	Negative	Positive	Neutral
GAD	16.47 (3.43)	64.71 (3.29)	18.82 (3.32)	81.47 (9.64)	7.06 (5.60)	11.47 (6.55)
HP	6.47 (2.93)	74.41 (11.97)	19.41 (10.73)	63.82 (13.97)	12.35 (7.72)	23.82 (14.20)

Note. GAD = generalized anxiety disorder; HP = healthy participants.

involuntary attention affects RTs, but not accuracy outcomes. According to the attentional control theory (Eysenck et al., 2007; Eysenck & Derakshan, 2011), worry impacts more on task efficiency than effectiveness, whereas efficiency refers to the relationship between the effectiveness of performance and the processing resources (effort) invested. It is also possible that GAD participants invested a greater effort, which in turn, could explain similar accuracy between groups. Nonetheless, as perceived effort was not assessed, it is not possible to draw any firm conclusions. Further research should address these issues.

Clinical Implications

Cognitive bias modification may be useful because it improves attentional control during worry (Hirsch et al., 2009) and reduces worry and anxiety (Hirsch et al., 2011; Krebs, Hirsch, & Mathews, 2010; Schmidt, Richey, Buckner, & Timpano, 2009). Furthermore, when high worriers imagine a worry topic, compared to thinking about it in the normal verbal manner, attentional resources are equivalent to that of low worriers (Leigh & Hirsch, 2011), suggesting that imagining a worry instead of verbally thinking about it may be helpful in freeing up resources to switch away from worry. Future research could examine whether there are similar beneficial effects of engaging in imagery of worry topics in individuals with GAD. Clinical outcomes may benefit from incorporating imagery-based techniques (Borkovec & Inz, 1990; Stokes & Hirsch, 2010) enabling clients to have the attentional control resources required to terminate worry. Studies examining the role of imagery on the randomization task in GAD are also warranted.

Strengths and Limitations

This study has particular strengths and limitations. This is the first study to examine general attentional control and attentional control during worry in clients diagnosed with GAD. GAD is highly comorbid (Kessler, Chiu, Demler, Merikangas, & Walters, 2005) and many of the clients in this study might have experienced comorbidities. It is, therefore, possible that findings are attributed to symptomatology beyond worry or GAD, for instance anxiety or depressive mood. However, when mood was controlled for, our findings remained significant, supporting that a reduction in attentional control capacity was related to normal verbal worry, rather than to mood states. Nevertheless, studies recruiting larger samples are important in elucidating the role of attentional control in GAD further. Because worry is evident across most psychiatric disorders, future research could determine the extent to which worry consumes attentional control resources in other disorders (e.g., panic disorder, psychosis). Worry and depressive rumination share many common features (Watkins, Moulds, & Macintosh, 2005), so investigating whether rumination uses attentional control in depressed individuals will also be an interesting direction for future research.

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