Behaviour Research and Therapy 54 (2014) 1–6

Contents lists available at ScienceDirect

Behaviour Research and Therapy

journal homepage: www.elsevier.com/locate/brat

Shorter communication

Fractionating the role of executive control in control over worry: A preliminary investigation

Lauren S. Hallion [a,*], Ayelet Meron Ruscio [a], Amishi P. Jha [b]

[a] University of Pennsylvania, USA
[b] University of Miami, USA

A R T I C L E I N F O

Article history:
Received 10 July 2013
Received in revised form
21 November 2013
Accepted 3 December 2013

Keywords:
Worry
Anxiety
Working memory
Inhibition
Cognitive control

A B S T R A C T

Uncontrollable anxious thought characterizes a number of emotional disorders. Little is known, however, about the cognitive mechanisms that underlie the ability to control these thoughts. The present study investigated the extent to which two well-characterized executive control processes—working memory and inhibition—are engaged when an individual attempts to control worry. Participants completed a concurrent assessment of these processes while attempting to control personally-relevant worried and neutral thoughts. To examine the specificity of these effects to attempts to control worry, versus a residual "depletion" effect of having previously engaged in worry, a subset of participants completed the assessment without instructions to control their worried or neutral thoughts. Attempts to control worry engaged working memory and inhibition to a greater extent than did attempts to control neutral thought. This increased engagement was not explained solely by anxious affect, nor was it significantly associated with trait worry. Engagement did not differ by group, suggesting that executive control depletion by worry cannot be dismissed as an alternative explanation of these findings. These results highlight working memory and inhibition as potentially valuable constructs for deepening our understanding of the nature and treatment of worry and its control.

Uncontrollable worry is the core feature of generalized anxiety disorder (GAD), a disorder associated with diminished quality of life, decreased productivity, and substantial economic burden (Hoffman, Dukes, & Wittchen, 2008). Among individuals with GAD, higher perceived uncontrollability (i.e., difficulty of sustained dismissal) of worry is associated with greater clinical severity, even after other features of GAD are controlled (Hallion & Ruscio, 2013). Uncontrollable worry also affects many adults who do not qualify for a diagnosis of GAD (Ruscio et al., 2005) yet still suffer negative physical and emotional consequences (Watkins, 2008). Although treatments for worry have improved over time, many individuals continue to experience uncontrollable worry after treatment (Mitte, 2005).

One reason for the limited success of current treatments may be our limited understanding of the "cold" cognitive mechanisms that underlie the experience and control of worry and other unwanted thoughts. Intentionally attending to certain stimuli while ignoring others engages a number of executive control processes, the limited cognitive resources responsible for controlled cognition (Cowan, 2005). Two of the most widely recognized executive control processes are working memory (WM), the mental workspace responsible for storing and manipulating information over short periods of time, and inhibition, the ability to override a prepotent response in order to make a task-appropriate but less dominant response (Miyake et al., 2000).

A small but growing literature suggests a link between executive control and the experience of worry and other unwanted thoughts (Hirsch & Mathews, 2012). For example, higher trait worry and GAD are associated with poorer performance on some WM tasks (Christopher & MacDonald, 2005). In experimental research, depressed individuals demonstrated more impaired WM and inhibition after rumination (a repetitive thought process similar to worry) compared to neutral thought ($d = 0.77$, Philippot & Brutoux, 2008; $d = 0.85$, Watkins & Brown, 2002). Similarly, high worriers demonstrated more impaired WM during worry compared to positive thought ($d = 1.00$; Hayes, Hirsch, & Mathews, 2008). Consistent with theoretical accounts of worry as a verbal-linguistic process (Borkovec, Robinson, Pruzinsky, & DePree, 1983), WM is particularly impaired when participants worry in verbal, rather than imagery, form (Leigh & Hirsch, 2011), and ability to worry is impaired during verbal, but not visuospatial, WM tasks (Rapee, 1993).

* Corresponding author. University of Pennsylvania, 3720 Walnut St., Philadelphia, PA 19104, USA. Tel. +1 845 406 2644.
E-mail address: hallion@psych.upenn.edu (L.S. Hallion).

0005-7967/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.brat.2013.12.002

A recent theoretical account suggests that the impairments in executive control that are evoked by worry may contribute to the maintenance of uncontrollable worry (Hirsch & Mathews, 2012). Broadly, this model proposes that redirecting one's thoughts away from worry relies on the very executive control processes that worry impairs. That is, worry impairs executive control, which prevents the worrier from terminating his or her worry. The findings reviewed above support the first stage of this model (i.e., worry impairs executive control). However, the proposal that controlling worry relies on the same resources that are impaired by worry remains untested.

Indirect support for this possibility comes from the thought suppression and emotion regulation literatures. Greater WM has been linked to better ability to suppress anxiety-provoking thoughts (Brewin & Smart, 2005; although see Wessel, Overwijk, Verwoerd, & de Vrieze, 2008). The addition of a WM load impaired participants' abilities to suppress thoughts about an upsetting film (Nixon, Cain, Nehmy, & Seymour, 2009), while WM training improved thought suppression ability (Bomyea & Amir, 2011). Finally, exaggerating one's emotional response was found to have a lasting "depleting" effect on WM (Schmeichel, 2007). Although these findings are suggestive, no studies have tested directly whether, and to what extent, attempts to control worry rely on executive control.

The present study examined the extent to which controlling worry draws on WM and inhibition, two executive control processes linked to worry and rumination. Participants engaged in experimentally induced worry and neutral thought. After each thought induction, a subset of participants ("Control Thoughts" group) attempted to control those worried and neutral thoughts while completing a computerized measure of WM and inhibition. This dual task approach capitalizes on the limited nature of executive control: To the extent that controlling worry relies on a specific executive control process (e.g., WM), performance on a concurrently performed task that relies on the same process should suffer (Engle, Conway, Tuholski, & Shisler, 1995). As little is known about the extent to which thought control strategies differentially rely on executive control, participants in the Control Thoughts group were randomly assigned to use one of three common thought control strategies to control both their worry and neutral thoughts.

As the present study assessed WM and inhibition after participants engaged in worry, it was possible that executive control impairments observed during attempts to control worry could be a consequence of having engaged in worry, rather than of attempting to control worry. To our knowledge, no studies have shown a lasting "depleting" effect of worry on executive control, although such an effect would be consistent with recent theoretical accounts (Hirsch & Mathews, 2012). To test the specificity of the effects, a second subset of participants ("No Instruction" group) completed the executive control task without instructions to control their thoughts.

We hypothesized that attempts to control worry would result in poorer WM and inhibition performance compared to attempts to control neutral thought. We further hypothesized that participants who attempted to control worry would experience greater executive control impairment than participants who worried but did *not* attempt to control their thoughts.

Method

Participants

Participants were 100 undergraduate students (56% female). All were age 18 or older, with no history of traumatic brain injury, no current stimulant medication, and no current or past antipsychotic medication. As undergraduate samples include the full range of trait worry scores (Ruscio, Borkovec, & Ruscio, 2001), no requirements based on trait worry or GAD status were imposed.

Materials

Experimental apparatus

The experiment was administered on Dell Pentium IV desktop computers using E-Prime Professional. Stimuli were presented in black ink on a light gray background and were centered on the screen.

Executive control

Participants completed the WM and Inhibition Task (WMIT; Hallion, Coutanche, & Jha, under review; manuscript available upon request), a novel computerized task that provides a simultaneous assessment of WM—particularly the maintenance component of WM—and inhibition. Assessing WM and inhibition simultaneously, rather than sequentially, facilitates within-subjects comparisons and reduces the likelihood that fatigue or mind wandering could confound the results.

The stimuli and general instructions were adapted from the AX-Continuous Performance Task (Barch et al., 1997). In the WMIT, participants view a series of letter stimuli (see Fig. 1). Each stimulus is presented individually for 150 ms, followed by a 300 ms fixation cross. After every third stimulus, the fixation cross is presented for 1300 ms and participants respond as follows: Press "k" if the last letter was X, but only if it was preceded by A. Press "f" in all other cases (i.e., when the last letter is not X, or when the last letter is X preceded by a letter other than A).

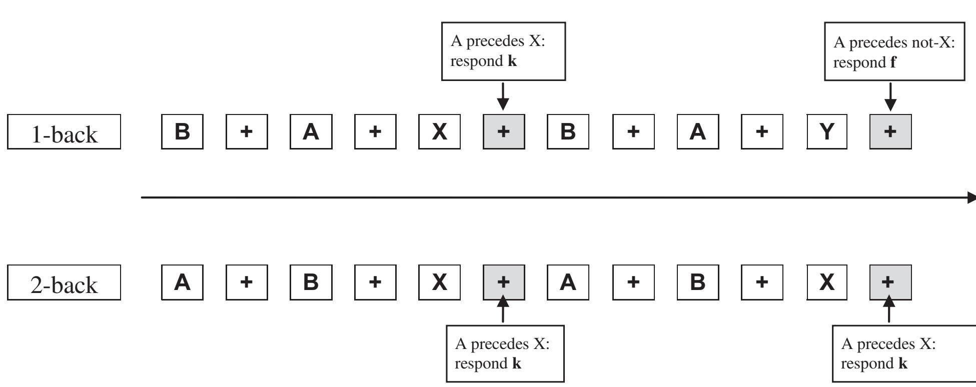

Fig. 1. A schematic of the working memory and inhibition task. Working memory is assessed by comparing performance in the 2-back (high demand) vs. 1-back (low demand) conditions. Inhibition is assessed by comparing performance when the correct response is "f" (high demand) vs. "k" (low demand).

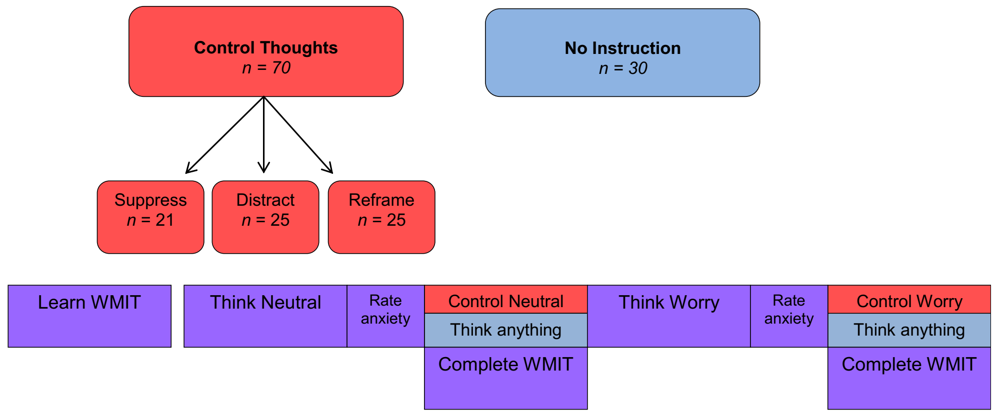

Fig. 2. Study design. Red represents tasks completed by the Control Thoughts group. Blue represents tasks completed by the No Instruction group. Purple represents tasks completed by both groups. The order of worry and neutral thought was counterbalanced across subjects. WMIT = Working Memory and Inhibition Task. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The WMIT comprises high- and low-demand trials for WM and inhibition, as follows:

WM: The WM component of the WMIT was adapted from the N-back task (Jonides et al., 1997). On low demand trials (60 trials), participants report whether an A was presented immediately prior to the X (one-back). On high demand trials (60 trials), participants report whether an A was presented two stimuli prior to the X (two-back). High and low demand trials were counterbalanced throughout the task.

Inhibition: The inhibition component of the WMIT was adapted from a widely used Response Inhibition task (Braver, Barch, Gray, Molfese, & Snyder, 2001). The WMIT is designed such that the correct response is "k" (i.e., A before X) on 70% of trials (84 trials) and "f" (i.e., not A before X) on 30% of trials (36 trials). Trials requiring an "f" response are high demand trials because the participant needs to inhibit a prepotent response, whereas trials requiring a "k" response are low demand trials because "k" is the prepotent response. The order of high and low demand trials was pseudorandomized and counterbalanced across high and low WM demand trials.

WMIT responses are analyzed in terms of accuracy and reaction time (RT). The availability of each executive control process is determined by subtracting performance on low demand trials (which do not rely on executive control and instead reflect nonspecific effects such as slowing or fatigue) from performance on high demand trials (which reflect nonspecific effects plus executive control demands). This subtraction yields a single "cost score" that reflects the extent to which that process is impaired or engaged by a competing task (e.g., controlling worry).

The WMIT has good concurrent and discriminant validity vis-à-vis established measures of executive control. In a validation study (Hallion et al., under review), performance on the WM and inhibition components of the WMIT correlated $r = 0.40$ and $r = 0.50$ with performance on the Operation Span (OSPAN) test of WM (Unsworth, Heitz, Schrock, & Engle, 2005) and Response Inhibition test (Braver et al., 2001), respectively.[1]

[1] In the present study, the WMIT also included an exploratory component assessing switching, another executive control process. On a small subset of trials (16 trials), stimuli were presented in blue ink. On "blue" trials, participants followed different instructions (press "k" if X is preceded by a letter other than A). Blue trials were excluded from analyses. The subsequent trial (i.e., the trial on which the participant switched back to the dominant task) was designated a high switching demand trial. However, as switching performance was not reliably associated with performance on a well-established switching task (Rogers & Monsell, 1995; $r = -0.27$) in the validation study, switching data are not presented here.

Worry and anxiety assessment

Participants rated state anxiety using a 0–100 scale (e.g., Hayes et al., 2008). Participants also completed the Penn State Worry Questionnaire (PSWQ), a measure of trait worry with good psychometric properties (Meyer, Miller, Metzger, & Borkovec, 1990) and a wide range of scores in the present sample ($M = 51.68$, $SD = 11.71$).

Manipulation check

After the experiment, a subset of participants ($n = 17$) rated their effort and success in thinking their worried and neutral thoughts as well as time spent controlling those thoughts. Control Thoughts participants also rated their effort to use their assigned thought control strategy. All ratings were made on a 1 (low) to 4 (high) scale.

Design

A 2 (worry versus neutral thought; within-subjects) × 2 (Control Thoughts versus No Instruction; between-subjects) × 3 (thought control strategy; between-subjects, Control Thoughts group only) mixed factorial design was used (see Fig. 2). All participants engaged in a worry period and a neutral thought period, counterbalanced across participants. Following each thought period, the Control Thoughts group was instructed to control (i.e., stop thinking about) their thoughts using one of three randomly assigned strategies (suppress, distract, reframe) while completing the WMIT. This dual-task design permitted an assessment of the extent to which WM and inhibition were differentially engaged by attempts to control worry versus neutral thought. The No Instruction group completed the same thought inductions but were not instructed to control their thoughts during the subsequent WMIT.

Procedure

Participants read a definition and example of worried and neutral topics and identified one future-oriented, personally relevant topic ("a topic that has been on your mind recently") of each type.

Participants in the Control Thoughts group next read a description of one thought control strategy: "suppress the thought" (suppression; $n = 21$), "distract yourself from the thought" (distraction; $n = 24$), or "look on the bright side of the thought" (reframing; $n = 25$). Participants were told that they would be asked to control their worried and neutral thoughts using their assigned strategy later in the experiment. The No Instruction group ($n = 30$) was instructed to "think about anything" after completing each thought period (Purdon, 1999).

All participants learned the WMIT, completed a practice WMIT with and without feedback, and were given opportunities to ask questions.

Participants next completed the first three-minute thought period. Participants were instructed to think about their worry or neutral topic in the way they normally think about it, as intensely as possible. Immediately after the first thought period, participants rated their state anxiety, then completed 120 trials of the WMIT while controlling their thoughts using their assigned strategy (Control Thoughts) or while thinking about anything (No Instruction). Participants repeated the procedure for their other thought topic (worry or neutral), then completed the PSWQ. A subset of participants also completed the manipulation check.

Results

Participants who did not understand the task or follow directions (accuracy ≤ 3 *SD* below the mean) were excluded from analyses ($n = 6$; 3 each from the Control Thoughts and No Instruction groups). Overall accuracy of the remaining participants was high ($M = 92\%$, $SD = 7\%$) and did not differ by group, $t(93) = -0.36$, $p = .722$. Error trials, anticipatory responses (RTs less than 150 ms), and outliers (RTs ≥ 3 *SD* above or below each participant's mean RT) were also excluded from analyses.

For each executive control process, accuracy and RT cost scores (e.g., Engle et al., 1995) were computed by subtracting performance in the high demand condition from performance in the low demand condition. For ease of interpretation, absolute cost values are presented, with higher numbers reflecting a greater cost. Separate cost scores were computed for WM and inhibition during attempts to control worry and neutral thought, resulting in eight cost scores.

Preliminary analyses

As accuracy and RT cost scores did not differ by thought control strategy (all $F(2, 65) \leq 2.00$, $p \geq .143$, $\eta^2_p \leq 0.05$) or counterbalancing order (all $t(98) \leq 1.86$, $p \geq .066$, $d \leq 0.27$), data were collapsed into one Control Thoughts group and one No Instruction group for analysis.

On the manipulation check, participants reported comparable effort and success focusing on worry versus neutral thoughts (both $t(16) \leq 0.01$, $p \geq .999$) and spent comparable time controlling worry versus neutral thoughts ($t(16) = -1.73$, $p = .104$, $d = -0.42$). The Control Thoughts group reported spending substantially longer ($d = 0.84$) controlling worry ($M = 2.57$, $SD = 1.13$) than did the No Instruction group ($M = 1.80$, $SD = 0.62$), although the difference was marginally significant in the subsample assessed ($t(15) = -1.80$, $p = .092$). On average, the Control Thoughts group tried "fairly hard" to employ their assigned strategy ($M = 3.00$, $SD = 0.89$). However, participants reported more difficulty controlling their worried than neutral thoughts, as evidenced by a longer latency to "turn off" worry ($t(16) = 3.23$, $p = .005$).

Use of executive control while controlling worry

To test the hypothesis that controlling worry relies on executive control to a greater extent than controlling neutral thought, we used paired-samples *t*-tests to compare WM and inhibition cost during attempts to control worry versus neutral thought. Because the No Instruction group was not instructed to control thoughts, only the Control Thoughts group was included in these analyses. Participants experienced greater costs for WM accuracy and inhibition RT during attempts to control worry compared to neutral thought (see Table 1), suggesting that controlling worry relied more heavily on WM and inhibition than did controlling neutral thought. By contrast, WM RT and inhibition accuracy costs did not differ by thought type. All effect sizes remained similar when trait worry was controlled, although the effect for inhibition RT was reduced to marginal significance ($p = .056$, $\eta^2_p = 0.04$).

We examined whether the observed differences could be explained by elevated state anxiety after worry. Although anxiety was significantly higher following worry ($M = 67.71$, $SD = 17.35$) than neutral thought ($M = 8.13$, $SD = 15.68$; $t(62) = 22.46$, $p < .001$, $d = 2.83$), anxiety was not significantly associated with WM accuracy cost ($r(68) = 0.07$, $p = .549$), nor inhibition RT cost ($r(68) = 0.10$, $p = 0.407$) during attempts to control worry.

To determine whether WM and inhibition engagement during attempted thought control varied as a function of trait worry, trait worry was correlated with WM accuracy and inhibition RT costs during attempts to control worry and neutral thought. Trait worry was marginally positively associated with inhibition RT cost ($r(64) = 0.21$, $p = 0.092$) and negatively associated with WM accuracy cost ($r(64) = -0.23$, $p = 0.064$) during attempts to control worry. Thus, as trait worry increased, controlling worry drew marginally more heavily on inhibition but less heavily on WM. Trait worry was not associated with WM or inhibition cost during attempts to control neutral thought (both $r(63-64) \leq 0.18$, both $p \geq 0.145$).

Attempts to control versus residual effects of worry

Independent-samples *t*-tests were used to test whether greater WM and inhibition costs while controlling worry were attributable specifically to control attempts rather than to residual depletion effects of worry. Contrary to our hypothesis, WM accuracy cost was not reliably greater in the Control Thoughts ($M = 0.04$, $SD = 0.07$) than the No Instruction ($M = 0.01$, $SD = 0.10$) group after worry, $t(93) = 1.34$, $p = 0.185$, $d = 0.35$. Inhibition RT costs were also comparable in the Control Thoughts ($M = 105.76$, $SD = 66.91$) and

Table 1
Working memory and inhibition performance during attempts to control worry versus neutral thought.

	Attempts to control worry			Attempts to control neutral			|*t*|	*p*	|*d*|
	Low demand *M* (*SD*)	High demand *M* (*SD*)	Cost |*M*| (*SD*)	Low demand *M* (*SD*)	High demand *M* (*SD*)	Cost |*M*| (*SD*)			
Working memory									
Accuracy	0.94 (0.06)	0.91 (0.11)	0.04 (0.07)	0.92 (0.12)	0.92 (0.09)	0.003 (0.11)	2.14*	0.036	0.40
RT	322 (91)	337 (91)	15 (60)	308 (94)	320 (99)	12 (58)	0.30	0.760	0.05
Inhibition									
Accuracy	0.95 (0.08)	0.86 (0.11)	0.08 (0.08)	0.95 (0.93)	0.86 (0.14)	0.09 (0.14)	0.50	0.620	0.09
RT	301 (83)	407 (109)	107 (67)	290 (94)	377 (103)	90 (65)	2.24*	0.028	0.23

Note. RT = reaction time. RT data are presented in milliseconds. Due to rounding error, reported costs may differ slightly from costs as calculated using data presented in the table. All df = 66–67.
* = $p < .05$.

No Instruction (M = 93.04, SD = 68.67) groups after worry, $t(93) = -0.83$, $p = .409$, $d = 0.19$.

Discussion

Which executive control processes are engaged when a person tries to stop worrying? The present study examined two promising candidates: WM and inhibition. These processes were assessed while participants attempted to control their worried and neutral thoughts. Participants performed more poorly on measures of WM (accuracy) and inhibition (RT) when trying to control worry compared to neutral thought, suggesting that these processes were especially engaged by attempts to control worry. The extent of engagement was not significantly associated with trait worry, nor with state anxiety after worrying.

Importantly, participants who controlled their worry (Control Thoughts) did not differ significantly from participants who were not instructed to control their worry (No Instruction) in the extent to which they engaged WM ($d = 0.35$) or inhibition ($d = 0.19$) after worrying. This raises the possibility that the observed impairments in WM and inhibition resulted from worry itself, rather than from attempts to control worry. This interpretation arguably is also exciting; to our knowledge, no research has demonstrated a lasting detrimental effect of worry on executive control, despite theoretical models consistent with a depletion account of worry (Hirsch & Mathews, 2012). If worrying has sustained effects on executive control, it could help to explain the concentration difficulties that characterize GAD and perhaps depression. Nevertheless, because executive control was not assessed during worry, the present findings cannot distinguish between these competing accounts. It is also possible that some participants in the No Instruction group elected to control their worry in order to better focus on the cognitive task, thereby reducing the difference between groups. Arguing against this possibility, we found a large, though marginally significant, difference between the groups in time spent controlling worry. Future research assessing WM and inhibition during worry and attempts to control worry will be necessary to address these possibilities.

One question raised by the present findings is why accuracy (but not RT) was impaired for WM, while RT (but not accuracy) was impaired for inhibition. Although not predicted a priori, this pattern is perhaps unsurprising. Impaired accuracy is a likely consequence of WM failures, which can result in "forgetting; " RT is based only on accurate trials. This assertion is consistent with research suggesting that accuracy is a more valid measure of WM than RT on the N-back task (Miller, Price, Okun, Montijo, & Bowers, 2009), on which the WM component of the WMIT is based. In contrast to WM, successful inhibition requires participants to slow down to make the appropriate non-dominant response. This could lead to slower RT but intact accuracy, especially if participants favored accuracy over speed. The high overall accuracy in the present study (92%) lends support to this interpretation.

Notably, the present study did not find the expected interaction between trait and state worry (Hayes et al., 2008). Instead, higher trait worry marginally predicted less engagement of WM and more engagement of inhibition during attempts to control state worry. The small size and marginal significance of these effects suggest caution against strong conclusions about the relationship between trait worry and executive control. Nevertheless, our findings suggest that this relationship may be more complex than previously believed.

Why might worry and its control rely more heavily on executive control compared to other types of thought? Our findings suggest that this effect is not due solely to state anxiety. One possibility is that worry is more vivid, elaborated, or engaging than neutral thought, causing disengagement from worry to be more cognitively demanding. Previous research (e.g., Hayes et al., 2008) has sometimes used positive thought as a comparison condition to control for these features of worry. However, as positive affect influences executive control (e.g., reduces perseveration and increases distractibility; Dreisbach & Goschke, 2004), positive thought is also a problematic comparison condition. Future studies employing multiple comparison conditions may help identify the features of worry that make it so difficult to control.

The present findings—and the questions they raise—highlight several promising directions for future research. Having linked uncontrollable worry to disruptions in WM and inhibition, an important next step is to identify the mechanisms through which controlling worry disproportionately engages these processes. The identification of such mechanisms could inform the development of targeted interventions designed to improve executive control through training. Another valuable future direction is to investigate the role of executive control in other types of unwanted thoughts (e.g., obsessions, intrusive memories, rumination). By identifying fundamental similarities and differences between these types of thoughts, as well as common processes that may maintain them, this work may set the stage for more potent, efficient interventions for disorders characterized by uncontrollable thought.

Although preliminary, these findings suggest that individuals with uncontrollable worry may benefit from cognitive training to improve WM and inhibition. An emerging literature suggests that meditation may improve WM and other aspects of executive control (e.g., Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010). During meditation, individuals practice sustaining attention and disengaging from internal stimuli, including worry. Long-term meditation practice is associated with reduced activation in brain regions associated with executive control (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007), suggesting that disengaging from internal stimuli may become easier with practice. Computerized "brain training" programs have also generated considerable interest; however, the clinical utility of current programs is an open question (e.g., Hallion & Ruscio, 2011; Shipstead, Redick, & Engle, 2012). Although we are not aware of any studies investigating this possibility, executive control improvements may also be a mechanism of change in stimulus control interventions for worry (Borkovec, Wilkinson, Folensbee, & Lerman, 1983), wherein patients are instructed to worry only at a designated time and place. By practicing inhibiting worry during non-designated times, patients may effectively train the cognitive mechanisms responsible for disengagement from worry. If further research implicates specific executive control impairments in difficulty controlling worry, interventions that strengthen those processes could prove a valuable and resource-effective adjunct to traditional cognitive-behavioral therapy for GAD and other disorders characterized by perseverative thought.

References

Barch, D. M., Braver, T. S., Nystrom, L. E., Forman, S. D., Noll, D. C., & Cohen, J. D. (1997). Dissociating working memory from task difficulty in human prefrontal cortex. *Neuropsychologia, 35*(10), 1373–1380.

Bomyea, J., & Amir, N. (2011). The effect of an executive functioning training program on working memory capacity and intrusive thoughts. *Cognitive Therapy and Research, 35*(6), 529–535.

Borkovec, T. D., Robinson, E., Pruzinsky, T., & DePree, J. (1983). Preliminary exploration of worry: some characteristics and processes. *Behaviour Research and Therapy, 21*, 9–16.

Borkovec, T. D., Wilkinson, L., Folensbee, R., & Lerman, C. (1983). Stimulus control applications to the treatment of worry. *Behaviour Research and Therapy, 21*(3), 247–251.

Braver, T. S., Barch, D. M., Gray, J. R., Molfese, D. L., & Snyder, A. (2001). Anterior cingulate cortex and response conflict: effects of frequency, inhibition, and errors. *Cerebral Cortex, 11*(9), 825–836.

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *Proceedings of the National Academy of Sciences, USA, 104*, 11483–11488.

Brewin, C. R., & Smart, L. (2005). Working memory capacity and suppression of intrusive thoughts. *Behaviour Research and Therapy, 36*(1), 61–68.

Christopher, G., & MacDonald, J. (2005). The impact of clinical depression on working memory. *Cognitive Neuropsychiatry, 10*(5), 379–399.

Cowan, N. (2005). Capacity limits for unstructured material. In N. Cowan (Ed.), *Working memory capacity* (pp. 1–37). New York, NY: Psychology Press, Taylor & Francis Group.

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(2), 343–353.

Engle, R. W., Conway, A. R. A., Tuholski, S. W., & Shisler, R. J. (1995). A resource account of inhibition. *Psychological Science, 6*, 122–125.

Hallion, L. S., Coutanche, M. N., & Jha, A. P. (2013). *Development and validation of the working memory and inhibition task*. under review.

Hallion, L. S., & Ruscio, A. M. (2011). A meta-analysis of the effects of cognitive bias modification on anxiety and depression. *Psychological Bulletin, 137*(6), 940–958.

Hallion, L. S., & Ruscio, A. M. (2013). Should uncontrollable worry be removed from the definition of GAD? A test of incremental validity. *Journal of Abnormal Psychology, 122*(2), 369–375.

Hayes, S., Hirsch, C., & Mathews, A. (2008). Restriction of working memory capacity during worry. *Journal of Abnormal Psychology, 117*(3), 712–717.

Hirsch, C. R., & Mathews, A. (2012). A cognitive model of pathological worry. *Behaviour Research and Therapy, 50*, 636–646.

Hoffman, D. L., Dukes, E. M., & Wittchen, H. (2008). Human and economic burden of generalized anxiety disorder. *Depression and Anxiety, 25*(1), 72–90.

Jha, A. P., Stanley, E. A., Kiyonaga, A., Wong, L., & Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion, 10*(1), 54–64.

Jonides, J., Schumacher, E. H., Smith, E. E., Lauber, E. J., Awh, E., Minoshima, S., et al. (1997). Verbal working memory load affects regional brain activation as measured by PET. *Journal of Cognitive Neuroscience, 9*, 462–475.

Leigh, E., & Hirsch, C. R. (2011). Worry in imagery and verbal form: effect on residual working memory capacity. *Behaviour Research and Therapy, 49*, 99–105.

Meyer, T. J., Miller, M. L., Metzger, R. L., & Borkovec, T. D. (1990). Development and validation of the Penn State Worry Questionnaire. *Behaviour Research and Therapy, 28*(6), 487–495.

Miller, K. M., Price, C. C., Okun, M. S., Montijo, H., & Bowers, D. (2009). Is the *N*-back task a valid neuropsychological measure for assessing working memory? *Archives of Clinical Neuropsychology, 24*, 711–717.

Mitte, K. (2005). Meta-analysis of cognitive behavioral treatments for generalized anxiety disorder: a comparison with pharmacotherapy. *Psychological Bulletin, 131*(5), 785–795.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: a latent variable analysis. *Cognitive Psychology, 41*, 49–100.

Nixon, R., Cain, N., Nehmy, T., & Seymour, M. (2009). The influence of thought suppression and cognitive load on intrusions and memory processes following an analogue stressor. *Behavior Therapy, 40*, 368–379.

Philippot, P., & Brutoux, F. (2008). Induced rumination dampens executive processes in dysphoric young adults. *Journal of Behavior Therapy and Experimental Psychiatry, 39*, 219–227.

Purdon, C. (1999). Thought suppression and psychopathology. *Behaviour Research and Therapy, 37*, 1029–1054.

Rapee, R. M. (1993). The utilisation of working memory by worry. *Behaviour Research and Therapy, 31*, 617–620.

Rogers, R. D., & Monsell, S. (1995). Cost of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124*(2), 207–231.

Ruscio, A. M., Borkovec, T. D., & Ruscio, J. (2001). A taxometric investigation of the latent structure of worry. *Journal of Abnormal Psychology, 110*(3), 413–422.

Ruscio, A. M., Lane, M., Roy-Byrne, P., Stang, P. E., Stein, D. J., Wittchen, H. U., et al. (2005). Should excessive worry be required for a diagnosis of generalized anxiety disorder? Results from the US National Comorbidity Survey Replication. *Psychological Medicine, 35*(12), 1761–1772.

Schmeichel, B. J. (2007). Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *Journal of Experimental Psychology: General, 136*(2), 241–255.

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods, 37*, 498–505.

Watkins, E. (2008). Constructive and unconstructive repetitive thought. *Psychological Bulletin, 134*(2), 163–206.

Watkins, E., & Brown, R. G. (2002). Rumination and executive function in depression: an experimental study. *Journal of Neurology, Neurosurgery, and Psychiatry, 72*, 400–402.

Wessel, I., Overwijk, S., Verwoerd, J., & de Vrieze, N. (2008). Pre-stressor cognitive control is related to intrusive cognition of a stressful film. *Behaviour Research and Therapy, 46*, 496–513.