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The interplay of trait worry and trait anxiety in determining episodic retrieval: The role of cognitive control

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ABSTRACT

Worrying is a key concept in describing the complex relationship between anxiety and cognitive control. On the one hand, cognitive control processes might underlie the specific tendency to engage in worrying (i.e., trait worry), conceptualized as a future-oriented mental problem-solving activity. On the other hand, the general tendency to experience the signs and symptoms of anxiety (i.e., trait anxiety) is suggested to impair cognitive control because worrisome thoughts interfere with task-relevant processing. Based on these opposing tendencies, we predicted that the effect of the two related constructs, trait anxiety and trait worry, might cancel out one another. In statistics, such instances have been termed suppressor situations. In four experiments, we found evidence for such a suppressor situation: When their shared variance was controlled, trait worry was positively whereas trait anxiety was negatively related to performance in a memory task requiring strategic, effortful retrieval. We also showed that these opposing effects are related to temporal context reinstatement. Our results suggest that trait worry and trait anxiety possess unique sources of variance, which differently relate to performance in memory tasks requiring cognitive control.

Worry is a form of future-oriented thinking about possible threatening events, involving predominantly verbal–linguistic thought (Borkovec, Robinson, Pruzinsky, & DePree, 1983; Sibrava & Borkovec, 2006). It is present in many mood and anxiety disorders (Purdon & Harrington, 2006) and is a core feature of generalized anxiety disorder (GAD, American Psychiatric Association, 2013). Besides, it is also a key concept in understanding the complex relationship between anxiety and a diverse set of cognitive processes, which control and organize subordinate-level processing. These processes, called executive functions or cognitive control processes, are associated with mental effort, conscious attention, and prefrontal cortex activity (e.g., Baddeley, 1996; Engle, 2002; Smith & Jonides, 1999).

On the one hand, several theoretical accounts and empirical results suggest that cognitive control processes might underlie the tendency to worry (i.e., trait worry). Some investigators, for example, termed anxiety the "shadow of intelligence", because cognitive processes linked to cognitive control, such as prospection, planning, and problem solving, might underlie anxious experience in general, and worrying in particular (Barlow, 2002; Liddell, 1949). In a similar way, Borkovec et al. (1983, p. 10) defined worry as a "mental problem-solving activity designed to prevent the occurrence of traumatic future events". Moreover, Price and Mohlman (2007) suggested that cognitive control processes might enable participants to selectively focus on abstract verbal–linguistic worries and inhibit threat-related mental imagery, contributing to cognitive avoidance, an important feature of worrying (see e.g., Sibrava & Borkovec, 2006). Furthermore, Dash, Meeten, and Davey (2013)

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proposed that worrying can be related to intensive, effortful elaboration of information, called systematic information processing, involving analytic and verbally based thought processes. Finally, empirical evidence also links worrying and GAD to enhanced cognitive performance (Coplan et al., 2011; Mueller, Nguyen, Ray, & Borkovec, 2010; Perkins & Corr, 2005), to mental effort (Verkuil, Brosschot, Borkovec, & Thayer, 2009), and to overactive regions or increased volume of the prefrontal cortex (Hoehn-Saric, Lee, McLeod, & Wong, 2005; Mathew et al., 2004; Mohlman et al., 2009).

On the other hand, the general tendency to experience the various signs and symptoms of anxiety (i.e., trait anxiety, see Spielberger, 1975) is suggested to impair cognitive control because it is associated with the preferential processing of worrisome thoughts or threatening stimuli (e.g., Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007; Zeidner, 1998) and because worrying during a cognitive task consumes the very same processing resources as those that are used to maintain task-relevant processing (e.g., Eysenck & Calvo, 1992; Hayes, Hirsch, & Mathews, 2008; Rapee, 1993). The most recent and comprehensive formulation of this claim is the attentional control theory (Eysenck et al., 2007), which states that anxiety impairs cognitive control processes by reducing attentional focus, because "anxious individuals preferentially allocate attentional resources to threat-related stimuli whether internal (e.g., worrisome thoughts) or external (e.g., threatening task-irrelevant distractors)" (Eysenck et al., 2007, p. 338).

The interplay of trait worry and trait anxiety— A suppressor situation

Based on the above, trait worry should be positively, whereas trait anxiety should be negatively, related to performance in tasks requiring cognitive control. The two constructs, however, are strongly correlated (see e.g., Startup & Erickson, 2006), and thus they might cancel out or weaken each other's effect on cognitive control. This paradoxical phenomenon is called suppression (Cohen, Cohen, West, & Aiken, 2003; Conger, 1974; Horst, 1941), or a suppression/suppressor situation (Paulhus, Robins, Trzesniewski, & Tracy, 2004; Tzelgov & Henik, 1991) and can be demonstrated in regression models with more than one predictor in all cases where "the relationship between the independent or causal variables is hiding or suppressing their real relationship with Y [the criterion variable], which would be larger or possibly of opposite sign were they not correlated" (Cohen et al., 2003, p. 78).

Evidence for such a suppressor situation comes from studies showing that the statistical control of trait anxiety is required to demonstrate that worry is associated with enhanced cognitive performance (Pajkossy, Dezső, & Paprika, 2009; Siddique, LaSalle-Ricci, Glass, Arnkoff, & Díaz, 2006) and with problem-focused coping (Davey, Hampton, Farrell, & Davidson, 1992). To the best of our knowledge, however, no study has yet investigated systematically how the two opposing tendencies relating cognitive control to trait anxiety and trait worry, respectively, interact to yield a suppressor situation. Thus, the aim of our research was to find further evidence for the link between trait worry and cognitive control and to test for the presence of a suppressor situation.

Due to high levels of multicollinearity (i.e., highly correlated predictors), suppressor situations are prone to provide unreliable effects with only small changes in the data yielding large changes in the results (Lynam, Hoyle, & Newman, 2006; Tzelgov & Henik, 1991). To avoid this, two precautionary measures were taken in designing our research: First, we followed the advice of Tzelgov and Henik (1991) to carefully replicate suppressor situations. Second, besides showing a suppressor situation with a task requiring cognitive control, we also aimed to show the lack of a suppressor situation using a control task, which resembled the first task to the closest possible degree, but did not require cognitive control.

To this end, we tested the hypothesized suppressor situation using tasks of an information processing domain in which cognitive control is involved in some but not all aspects of performance: episodic memory retrieval.

The role of cognitive control in episodic retrieval

Episodic retrieval refers to our ability to recollect and reconstruct details of personally experienced past events (Conway, 2009; Tulving, 1983). It is directed by retrieval cues that interact with the previously stored memory representation to trigger recall (Conway & Pleydell-Pearce, 2000; Moscovitch, 1994).

Cognitive control processes might support the retrieval process to different degrees depending on the accessibility of cues during retrieval. On the one hand, in cases of environmentally cued retrieval,

when the retrieval cue is present in the environment, available to the individual, and there is a strong association between cue and the target memory, cognitive control might not be essential for successful retrieval. Such a situation is modelled in cued recall or in recognition tests. On the other hand, in cases of self-cued retrieval, details of past experience have to be retrieved without any external cue, as modelled in free recall tasks. This requires cognitive control to start an effortful search process, whereby individuals generate potential retrieval cues and monitor the effectiveness of these cues in accessing the memory representation (Brand & Markowitsch, 2008; Conway & Pleydell-Pearce, 2000; Moscovitch, 1994; Petrides, 1996).

A crucial component of this controlled search might be the reinstatement of temporal context: Items are associated with the gradually changing internal context during encoding, and this internal context is reinstated during retrieval to produce retrieval cues (see e.g., Sederberg, Howard, & Kahana, 2008). The role of temporal context reinstatement in free recall is evidenced by the contiguity effect: Items studied in temporal proximity tend to be recalled successively (Kahana, 1996).

The current research

Based on the above, our research had two main hypotheses: First, motivated by theoretical considerations (e.g., Barlow, 2002; Dash et al., 2013) and empirical findings (e.g., Coplan et al., 2011; Mueller et al., 2010), we predicted that trait worry will be associated with good cognitive control abilities and thus with good performance in episodic memory tasks requiring self-cued retrieval (Hypothesis 1). Second, we expected to observe a suppressor situation and predicted that controlling for the shared variance of trait anxiety and trait worry will increase or even reveal the positive link between trait worry and self-cued retrieval and the negative link between trait anxiety and self-cued retrieval (Hypothesis 2). In tasks requiring environmentally cued retrieval, which are not exclusively reliant on cognitive control processes, these effects were not expected.

To test these hypotheses, we conducted a set of four studies. Self-cued retrieval was assessed by a free recall task in all four studies, whereas environmentally cued retrieval was assessed by a recognition task in Experiments 1, 2, and 4 and by a cued recall task in Experiment 3. This latter was a paired-associate learning task: Participants learnt word-pairs and then were presented with one word (cue-word) and were required to name its pair (target word). To increase the validity and reliability of our memory measures, in Experiment 4, both the free recall and the recognition task were assessed three times. Finally, we also conducted additional post hoc analyses, in which data from the four studies were combined.

To minimize potential confounding effects, we included several control variables. First, because women are associated with higher levels of anxiety and worry (Holaway, Rodebaugh, & Heimberg, 2006), and with better episodic memory performance (Herlitz, Nilsson, & Bäckman, 1997), the possible mediator role of gender was controlled for in all four studies. Second, because worrying is related to perfectionism (Stöber & Joormann, 2001), which is associated with striving and enhanced motivation to perform well in laboratory tasks (Stöber & Otto, 2006), we included a relevant facet of perfectionism (high personal standards) as a control variable, using a questionnaire in Experiment 2. Besides, we also measured the time participants spent on the self-paced memory tasks in Experiments 2–3, and we assessed their subjective estimate of retrieval effort and interference in Experiment 4. Third, because of its assumed central and causative role in the link between anxiety and cognition (Eysenck et al., 2007; Zeidner, 1998), in Experiment 2, we measured the level of current, experienced anxiety (i.e., state anxiety, Spielberger, 1975). Finally, to ensure that the link between trait worry and self-cued retrieval does not depend solely on the verbal nature of the to-be-learned material, in Experiment 2, we used pictorial stimuli (faces of famous actors).

Experiment 1

In Experiment 1, self-cued retrieval was assessed by a free recall task, whereas environmentally cued retrieval was assessed by a recognition task.

Method

Participants

Data were collected from 94 participants recruited from the Budapest University of Technology and Economics. They participated for partial credit in introductory psychology courses. Two of them were excluded due to random responding in the recognition task, and thus data from 92 participants (44 female, $M_{age} = 21.79$ years, $SD = 2.07$, range = 19–32) were analysed.

Material

Trait anxiety was assessed by the Trait subscale of the State–Trait Anxiety Inventory, Form X (STAI–T; Spielberger, Gorsuch, & Lushene, 1970; Hungarian version: Sipos & Sipos, 1983), assessing the tendency to experience the physiological and psychological signs of anxiety. The inventory consists of 20 items, and response to each item is given on a 4-point scale ranging from 1 (*not at all typical*) to 4 (*very typical*).

To assess trait worry, we used the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990; Hungarian version: Pajkossy, Simor, Szendi, & Racsmány, 2015), which measures the general tendency toward frequent and excessive worry characteristic of GAD. The PSWQ consists of 16 items, and each item is scored on a 5-point scale ranging from 1 (*not at all typical*) to 5 (*very typical*).

The stimuli for the recognition tasks were presented using Presentation® software (Version 14.3, www.neurobs.com). For the memory tasks, we selected 48 moderately frequent nouns based on a Hungarian word frequency norm (Kónya & Pintér, 1985) and created four separate lists.

Design

We presented each participant with one list selected at random from the four different lists. To avoid carry-over effects, we varied task type between subjects (i.e., a between-subjects design): A total of 48 participants (25 female, $M_{age} = 21.73$ years, $SD = 2.20$, range = 19–32) completed the free recall task (recall group), whereas 44 participants (18 female, $M_{age} = 21.69$, $SD = 1.96$, range = 19–27) completed the recognition task (recognition group).

Procedure

Participants were tested individually in a laboratory setting. Each word was displayed on a computer screen for 2 s with a 1-s inter-item interval. Participants were instructed to memorize the words. Words of a given list were presented in the same order in each instance. Following this, simple mathematical problems were solved for 8 min. Thereafter, we asked participants in the recall group to write down the previously presented words on a sheet of paper, whereas participants in the recognition group saw all 48 words sequentially on a computer screen and had to indicate with a key-press whether a given item had been presented during learning or not. The order of presentation during the recognition task was the same for all participants. No time constraints were imposed for the memory tasks, either in this or in the subsequent studies. After completing the memory task, participants filled out the questionnaires and were debriefed.

Data analysis

Free recall performance was measured by recall percentage, whereas for the recognition task, recognition sensitivity index (d') was calculated from hit and false-alarm rates.

To test our hypothesis, a series of hierarchical linear regression analyses were run, with recall percentage and recognition sensitivity as criterion variables. In Steps 1a and 1b, the criterion variables were regressed separately on STAI–T and PSWQ, respectively. In Step 2, STAI–T and PSWQ were entered together into the regression model. Because multiple regression analysis reveals the partial effects of the predictor variables, entering STAI–T and PSWQ together enabled us to investigate their independent effect with the shared variance partialled out.

MacKinnon, Krull, and Lockwood (2000) showed that testing a suppressor effect is mathematically equivalent to the testing of a mediator effect, and thus its statistical analysis is also similar. The change in the predictor's effect on the criterion caused by accounting for the mediator/suppressor variable is estimated, and the indirect effect of the predictor on the criterion *through* the mediator is calculated. We report the indirect effects associated with the anxiety measures, for both recognition and free recall performance, as criterion. We used the method suggested by Preacher and Hayes (2008), which applies bootstrapping to estimate the indirect effect and its 95% confidence interval. To compare indirect effects, we also report a scale-independent effect size measure, the completely standardized indirect effect index (Preacher & Kelley, 2011).

Given the fact that participants learned different word lists, their memory performance might have been determined to some extent by differences between the relative difficulties of the four lists. The variables representing memory performance might therefore be clustered, which would violate the non-independence of observations assumption of ordinary least squares regression. To correct for this, following the advice of Cohen et al. (2003), we incorporated the clustered structure into the model in Step 3, by entering PSWQ and STAI–T together with three dummy variables representing the list learned by the individual

Table 1. Descriptive statistics of Experiments 1–4.

Variable	Experiment 1		Experiment 2		Experiment 3		Experiment 4
	M (*SD*)	α	*M* (*SD*)	α	*M* (*SD*)	α	*M* (*SD*)
STAI–T	39.91 (9.27)	.89	37.48 (12.39)	.88	43.77 (10.16)	.89	40.39 (8.50)
PSWQ	43.13 (13.57)	.93	40.39 (13.87)	.93	45.06 (13.07)	.93	46.29 (13.45)
Free recall: recall percentage	0.39 (0.21)		0.63 (0.20)		0.44 (0.23)		0.39 (0.13)
Cued recall: recall percentage					0.57 (0.25)		
Recognition: hit rate	.79 (.18)		.89 (.10)				.84 (.13)
Recognition: false-alarm rate	.12 (.12)		.13 (.15)				.12 (.10)
Recognition: sensitivity	2.26 (0.86)		2.48 (0.78)				2.38 (0.70)

Note: PSWQ = Penn State Worry Questionnaire; STAI–T = Spielberger State–Trait Anxiety Inventory, Trait version; α = Cronbach's alpha value indexing internal reliability. For Experiments 1–2, values related to the questionnaires are computed using the whole sample.

participant. Another dummy variable was entered to control for the possible mediator role of gender.

The distribution of recall percentage was skewed, resulting in non-normal distribution and heteroscedasticity of the regression residuals. We thus felt it appropriate to use log-transformed values of recall percentage in all analyses.

We also looked at the variance inflation factors indexing the levels of multicollinearity: In none of the multiple regression models of Experiments 1–4 did its level exceed four. Because only values above 10 are regarded problematic (Cohen et al., 2003), we suggest that high collinearity was not a problem in our analyses.

Results and discussion

Descriptive statistics related to memory performance, PSWQ, and STAI–T are presented in Table 1. Trait worry and trait anxiety were correlated in both groups (recall group: $r = .75$, $p < .001$; recognition group: $r = .83$, $p < .001$).

The first two steps of the hierarchical regression analysis are shown in Table 2. In the recall group, supporting Hypothesis 1, higher levels of trait worry predicted better free recall performance (Step 1b: $β = 0.29$, $p < .048$). The predictions of Hypothesis 2, however, were only partially confirmed: Controlling the shared variance of trait worry and trait anxiety in Step 2 significantly altered the effect of trait anxiety (Step 1a: $β = 0.12$; Step 2: $β = −0.21$; standardized indirect effect through trait worry: 0.33, 95% confidence interval, CI [0.02, 0.65]), but not the effect of trait worry (Step 1b: $β = 0.29$; Step 2: $β = 0.45$; standardized indirect effect through trait anxiety: −0.16, 95% CI [−0.55, 0.16]) on recall percentage. Moreover, these results must be interpreted with some caution due to insufficient model fit, $F(2, 45) = 2.57$, $p = .09$. The regression coefficients, however, remained unchanged in Step 3 (trait anxiety: $B = −0.006$, $SE_B = 0.005$, $β = −0.24$, $p = .23$; trait worry: $B = 0.007$, $SE_B = 0.003$, $β = 0.43$, $p = .03$), where accounting for the recall effects of list difficulty improved model fit, $F(6,$

Table 2. Hierarchical linear regression analyses of the effect of trait worry and trait anxiety on recall percentage and recognition sensitivity in Experiment 1.

Model	Model parameters		Predictor parameters				Indirect effect of the predictor on the criterion [with 95% CI]	
	R^2	F	Predictor	β	B	SE_B	Unstand.	Stand.
(A) *Criterion: recall percentage*[a]								
Step 1a	.01	0.7	STAI–T	0.12	0.003	0.003		
Step 1b	.08	4.1*	PSWQ	0.29*	0.005	0.002		
Step 2	.10	2.6+	STAI–T	−0.21	−0.005	0.005	0.008 [0.001, 0.015]	0.33 [0.02, 0.65]
			PSWQ	0.45*	0.007	0.003	−0.002 [−0.008, 0.002]	−0.16 [−0.55, 0.16]
(B) *Criterion: recognition sensitivity*								
Step 1a	.01	0.1	STAI–T	0.01	0.001	0.016		
Step 1b	.01	0.4	PSWQ	0.09	0.006	0.010		
Step 2	.02	0.5	STAI–T	−0.22	−0.022	0.028	0.023 [−0.025, 0.006]	0.22 [−0.24, 0.61]
			PSWQ	0.28	0.018	0.018	−0.012 [−0.040, 0.021]	−0.18 [−0.64, 0.28]

Note: Data for Step 3 are not presented. PSWQ = Penn State Worry Questionnaire; STAI–T = Spielberger State–Trait Anxiety Inventory, Trait version; *B* = regression coefficient; SE_B = standard error of the regression coefficient; β = standardized regression coefficient; CI = confidence interval; unstand. = unstandardized; stand. = standardized.
[a]Log transformed values of recall performance were used.
+$p < .1$. *$p < .05$.

41) = 3.08, p = .01. Because gender was also entered as a predictor in Step 3, its confounding role can be excluded.

As can be seen in Panel B of Table 2, no significant effects emerged in the recognition group in Steps 1–2, and this was the case also in Step 3, after entering gender and the dummy variables representing list difficulty [trait anxiety: B = −0.011, SE_B = 0.030, β = −0.11, p = .71; trait worry: B = 0.009, SE_B = 0.020, β = 0.13, p = .68; model fit: $F(6, 43)$ = 0.98, p = .45]. Thus, the link between trait worry and good memory performance was specific to the free recall task and was not present in the case of the recognition task.

Experiment 2

In Experiment 2, we aimed to replicate the results of Experiment 1 and to control for potential confounders. We again contrasted free recall and recognition, as analogues of self-cued and environmentally cued retrieval. This time, however, pictorial stimuli, faces of well-known actors and actresses, were presented to the participants. Besides, we controlled the level of perfectionism and state anxiety.

Method

Participants

One-hundred and fourteen participants (54 female, M_{age} = 21.40 years, SD = 2.26, range = 18–34) were recruited from the Budapest University of Technology and Economics. They participated in exchange for partial credit in introductory psychology courses.

Material

In addition to the measures used in Experiment 1, we used the State subscale of the State Trait Anxiety Questionnaire, Form X (STAI–S, Spielberger et al., 1970, Hungarian version: Sipos & Sipos, 1983). It consists of 20 items describing physiological and psychological signs of anxiety. The participants have to rate on a 4-point scale ranging from 1 (*not at all*) to 4 (*extremely*) to which extent they experience these signs at the moment.

To account for motivational factors, we measured time on task for both memory tasks. Besides, participants also filled out seven items of the Frost Multidimensional Perfectionism Scale (FMPS; Frost, Marten, Lahart, & Rosenblate, 1990), constituting the Personal Standards subscale (FMPS–PS). The items are scored on a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) and were translated to Hungarian for the purposes of the present study.

The memory tasks were conducted using Presentation® software (Neurobehavioral Systems, CA, USA). Stimuli were selected from 74 pictures taken from free internet databases, all depicting faces of well-known, famous actors, actresses, or musicians.

Design

Recall type was varied between subjects: A total of 56 participants (24 female, M_{age} = 21.55 years, SD = 2.27, range = 19–34) completed the free recall task (recall group), whereas 58 participants (27 female, M_{age} = 21.22 years, SD = 2.23, range = 18–30) completed the recognition task (recognition group). In the recall group, FMPS–PS and STAI–S data were missing for nine participants.

Procedure

During a stimulus selection procedure preceding the learning phase, participants were presented with the 74 faces sequentially and were asked to provide the name belonging to the given face. The procedure was stopped after the participant identified 28 faces. If fewer than 28 famous faces were successfully named, a second selection round was initiated in which, if the participant requested, the experimenter helped by providing the first name of the famous person. If unable to identify 28 pictures in the two selection rounds, participants (22 altogether) were excluded from the experiment.

In the subsequent learning phase, 14 of the selected 28 faces were selected at random and were presented in a random order. Otherwise, the learning and delay phase was identical to that in Experiment 1. In the free recall task, participants had to recall the names belonging to the faces presented and type the recalled name via a keyboard. In the recognition task, all 28 faces were presented in a random order, and participants were asked to indicate with a key-press whether they recognized the faces presented during the learning phase. The questionnaires were filled out between the selection and the learning phases.

Data analysis

All analyses were identical to those conducted in Experiment 1, with two exceptions. First, the distribution of recall percentage was not skewed, and thus no log transformation was necessary. Second, a different set of confounders was entered in Step 3: Besides gender, we also entered FMPS–PS, STAI–S, and time

Table 3. Hierarchical linear regression analyses of the effect of trait worry and trait anxiety on recall percentage and recognition sensitivity in Experiment 2.

Model	Model parameters		Predictor parameters				Indirect effect of the predictor on the criterion [with 95% CI]	
	R^2	F-test	Predictor	β	B	SE B	Unstand.	Stand.
(A) *Criterion: recall percentage*								
Step 1a	.03	1.7	STAI–T	−0.17	−0.004	0.003		
Step 1b	.01	0.4	PSWQ	0.08	0.001	0.002		
Step 2	.12	3.7*	STAI–T	−0.50*	−0.011	0.004	0.007 [−0.001, 0.014]	0.32 [−0.03, 0.65]
			PSWQ	0.44*	0.007	0.003	−0.005 [−0.011,−0.001]	−0.36 [−0.76,−0.01]
(B) Criterion: recognition sensitivity								
Step 1a	.01	0.2	STAI–T	−0.05	−0.003	0.007		
Step 1b	.01	0.1	PSWQ	0.04	0.002	0.007		
Step 2	.02	0.6	STAI–T	−0.24	0.013	0.012	0.01 [−0.012, 0.035]	0.18 [−0.21, 0.64]
			PSWQ	0.23	0.013	0.012	−0.010 [−0.037, 0.010]	−0.19 [−0.70, 0.18]

Note: Data for Step 3 are not presented. PSWQ = Penn State Worry Questionnaire; STAI–T = Spielberger State–Trait Anxiety Inventory, Trait version; B = regression coefficient; SE B = standard error of the regression coefficient; β = standardized regression coefficient; CI = confidence interval; unstand. = unstandardized; stand. = standardized.
*p < .05.

spent on the final memory task. Due to their superior prior knowledge, we expected superior memory performance for participants succeeding in the first round of the selection phase. Thus, to avoid clustering of observations, similar to Experiment 1, we also entered a dummy variable representing in which selection round the participant identified the 28 faces.

Results and discussion

Descriptive statistics related to PSWQ, STAI–T, and memory performance are presented in Table 1. The mean total score computed for the whole sample was 33.83 (*SD* = 13.30) for STAI–S and 16.94 (*SD* = 4.78) for FMPS–PS. Trait worry and trait anxiety were correlated in both groups (recall group: *r* = .73, *p* < .001; recognition group: *r* = .80, *p* < .001).

The results of the first two steps of the regression analyses are shown in Table 3. Contrary to Hypothesis 1, trait worry was not associated with higher recall percentage (Step 1b: β = 0.08, *p* = .55). In line with Hypothesis 2, however, we observed a suppressor situation: Controlling their shared variance significantly altered the effect of both trait worry and trait anxiety, and, as a consequence, they became oppositely linked to recall percentage (trait anxiety—Step 1a: β = −0.17, Step 2: β = −0.50, standardized indirect effect through trait worry: 0.32, 95% CI [−0.03, 0.65]); trait worry—Step 1b: β = 0.08, Step 2: β = 0.44, standardized indirect effect through trait anxiety −0.36, 95% CI [−0.76, −0.01]). Although in the case of trait anxiety, the indirect effect was only marginally significant, the opposite partial

effects of trait anxiety and trait worry remained significant in Step 3, after entering several potential confounders [trait anxiety: *B* = −0.010, *SE_B* = 0.005, β = −0.47, *p* = .04; trait worry: *B* = 0.009, *SE_B* = 0.003, β = 0.58, *p* = .01; model fit: *F*(7, 39) = 3.55, *p* = .005], indicating that the demonstrated pattern is independent of these factors. Thus, in contrast to Experiment 1, we could demonstrate the link between trait worry and free recall performance only after controlling for trait anxiety. In the recognition group, neither trait worry nor trait anxiety predicted memory performance in Steps 1–2 (see Panel B of Table 3), and the same was true for Step 3 [trait anxiety: *B* = −0.004, *SE_B* = 0.016, β = −0.08, *p* = .78; trait worry: *B* = 0.05, *SE_B* = 0.011, β = 0.08, *p* = .39; model fit: *F*(7, 50) = 4.3, *p* < .001].

Experiment 3

The first two studies used a between-study design, and thus differences between the groups could have caused the different effects of the anxiety measures on self-cued and on environmentally cued retrieval. Moreover, we used in both studies a recognition task to assess environmentally cued retrieval. Recognition, however, is a less demanding task than free recall, and thus ceiling effects might have also contributed to the lack of effect seen in environmentally cued retrieval. Thus, in Experiment 3, we used a within-subject design and a different, more demanding task for environmentally cued retrieval: a paired-associates learning paradigm.

Table 4. Hierarchical linear regression analyses investigating the effect of trait worry and trait anxiety on recall percentage in the free and the cued recall tasks in Experiment 3.

Model	Model parameters		Predictor parameters				Indirect effect of the predictor on the criterion [with 95% CI]	
	R^2	F	Predictor	β	B	SE_B	Unstand.	Stand.
(A) *Criterion: recall percentage (free recall)*								
Step 1a	.03	1.5	STAI–T	−0.18	−0.004	0.003		
Step 1b	.06	3.1[+]	PSWQ	0.25[+]	0.005	0.003		
Step 2	.25	7.2*	STAI–T	−0.54**	−0.012	0.004	0.008 [0.003, 0.016]	0.36 [0.15, 0.68]
			PSWQ	0.59**	0.010	0.003	−0.006 [−0.011, −0.003]	−0.33 [−0.58, −0.17]
(B) *Criterion: recall percentage (cued recall)*								
Step 1a	.01	0.3	STAI–T	−0.07	−0.002	0.004		
Step 1b	.01	0.1	PSWQ	0.03	0.001	0.003		
Step 2	.02	0.3	STAI–T	−0.15	−0.004	0.005	0.002 [−0.003, 0.009]	0.08 [−0.13, 0.32]
			PSWQ	0.13	0.002	0.004	−0.002 [−0.007, 0.002]	−0.09 [−0.37, 0.10]

Note: Data for Step 3 are not presented. PSWQ = Penn State Worry Questionnaire; STAI–T = Spielberger State–Trait Anxiety Inventory, Trait version; B = regression coefficient; SE_B = standard error of the regression coefficient; β = standardized regression coefficient; CI = confidence interval; unstand. = unstandardized; stand. = standardized.
[+]$p < .1$. *$p < .05$. **$p < .01$.

Method

Participants

Forty-seven undergraduate students of the Pázmány Péter Catholic University, Hungary, volunteered (30 female, $M_{age} = 22.09$ years, $SD = 2.00$, range = 19–28).

Material

To measure trait worry and trait anxiety, the instruments used in Experiment 1 were applied. Based on a Hungarian word frequency norm (Kónya & Pintér, 1985), two sets of 16 weakly associated word pairs were constructed, all words being moderately frequent nouns and all pairs containing two words from different categories.

Design

In Experiments 1–2 we used a between-subjects design, and thus group differences could have contributed to the differences observed between self-cued and environmentally cued retrieval. Thus, in Experiment 3, task type (free vs. cued recall) was varied within subject, with all participants taking part in both tasks. One of the word-pair lists was used in the cued recall task, whereas the target words from the other word-pair list were used in the free recall task. Pairing of the word-pair lists with the memory task was counterbalanced, as was the order of the two memory tasks.

Procedure

The memory tasks were conducted successively in one session. To reduce proactive interference, participants filled out the PSWQ and the STAI–T between the two memory tasks. In the learning phase, each word-pair in the cued recall task and each word in the free recall task was shown for 4 s on a computer screen with no inter-item interval. The delay period lasted 5 min. Then, in the free recall task, participants had to write down the previously presented words on a sheet of paper, whereas in the cued recall task, the cue words were presented successively, and participants had to write down the target word. The to-be-learned material in the learning phase and the cue words in the test-phase were presented in the same order for each participant.

Data analysis

All analyses were identical to the ones performed in Experiment 2, except for the set of confounders entered in Step 3 of the hierarchical linear regression analyses: Beside gender and time on task, we also entered a dummy variable representing task order, because this might have affected recall levels—causing the clustering of observations.

Results and discussion

Descriptive statistics are presented in Table 1. Trait worry and trait anxiety were significantly correlated ($r = .62$, $p < .001$). Recall percentage was higher in the cued than in the free recall task, $t(46) = 3.72$, $p < .001$.

The results of the first two steps of the hierarchical regression analyses are shown in Table 4.

Contrary to Hypothesis 1, there was only a non-significant tendency relating trait worry to better free recall performance (Step 1b: β = 0.25, p = .09), and in line with Hypothesis 2, controlling their shared variance significantly altered the effect of both trait anxiety and trait worry on recall percentage in the free recall task (trait anxiety—Step 1a: β = −0.18, Step 2: β = −0.54, standardized indirect effect through trait worry 0.36, 95% CI [0.15, 0.68]; trait worry—Step 1b: β = 0.25, Step 2: β = 0.59, standardized indirect effect through trait anxiety −0.33, 95% CI [−0.58, −0.17]). The pattern of results remained the same also in Step 3, after controlling the effect of gender, time on task, and task order [trait anxiety: $B = -0.012$, $SE_B = 0.004$, β = −0.50, p = .004; trait worry: $B = 0.009$, $SE_B = 0.003$, β = 0.52, p = .003; model fit: $F(5, 41) = 5.02$, p = .001]. No similar effects were found for the cued recall performance, either in Steps 1–2 (see Panel B of Table 4) or in Step 3 [trait anxiety: $B = -0.005$, $SE_B = 0.005$, β = −0.19, p = .37; trait worry: $B = 0.003$, $SE_B = 0.004$, β = 0.15, p = .49; model fit: $F(5, 41) = 0.21$, p = .95].

Experiment 4

In the first three studies, we assessed memory performance by only one test, which might have led to low reliability of our memory measures. Thus, to increase the reliability of measurement and the validity of our findings, in Experiment 4, we assessed memory performance multiple times.

Method

Participants

Fifty-two undergraduate students were paid for their participation (38 female, $M_{age} = 22.08$ years, $SD = 1.88$, range = 19–28).

Material

We created six word lists of 14 words by using the words from Experiments 1 and 3 (we made only minor changes to the earlier lists). We created three list of 18 words, which were used as new words in the recognition tasks. The new words were matched in length and frequency to the to-be-remembered words. The new words were selected based on the Hungarian word frequency norm (Kónya & Pintér, 1985). Trait worry and trait anxiety were measured similarly to earlier studies.

Design

Task type (free recall vs. recognition) was varied within subject, with two experimental sessions: In one of the sessions, participants completed three free recall tasks, whereas in the other session, they completed three recognition tasks successively. The pairing of task type (free recall or recognition) with session (1st or 2nd) was counterbalanced. The assignment of the word lists to the specific task followed a pseudorandom order using four different sequences. In these sequences, the lists were assigned to different task (free recall or recognition), to different session (1st or 2nd) and to different positions in the specific session (1st, 2nd, or 3rd).

Procedure

The stimulus presentation software Presentation® was used (Neurobehavioral Systems, CA, USA). For both task types, the words were presented in random order. Then a delay of 5 min followed, filled in with mathematical problem solving. Finally, participants conducted either a free recall or a recognition task, which were similar to that used in Experiment 2. Anxiety measures were administered at both sessions. To reduce proactive interference, participants filled out the anxiety measures in between the memory tasks. At the end of each session, we used a Likert scale, to assess participants' subjective assessment of retrieval effort during retrieval and the interference they experienced during the session. After the second session, participants were debriefed.

Data analysis

Similarly to previous studies, hierarchical linear regression analyses were conducted. Recall rates and sensitivity values were averaged across the three tasks and were used as dependent variables. PSWQ/STAI–T scores from the two sessions were also averaged, as were the subjective estimates of effort/interference. The regression analyses were identical to the ones performed in Experiment 2, except for the set of confounders entered in Step 3 of the hierarchical linear regression analyses: Beside gender and time on task, we entered three dummy variables representing which pseudorandom sequence was used for the participant and also the subjective estimate of the participants regarding retrieval effort and interference, respectively. If assumptions were met, Pearson's, otherwise

Table 5. Hierarchical linear regression analyses investigating the effect of trait worry and trait anxiety on recall percentage in the free and the cued recall tasks in Experiment 4.

Model	Model parameters		Predictor parameters				Indirect effect of the predictor on the criterion [with 95% CI]	
	R^2	F	Predictor	β	B	SE_B	Unstand.	Stand.
(A) *Criterion: recall percentage*								
Step 1a	.02	1.2	STAI–T	−0.15	−0.002	0.002		
Step 1b	.01	0.1	PSWQ	0.03	0.001	0.001		
Step 2	.09	2.5[+]	STAI–T	−0.54*	−0.009	0.004	0.006 [0.001, 0.011]	0.39 [0.04, 0.70]
			PSWQ	0.47[+]	0.005	0.002	−0.005 [−0.008, −0.002]	−0.45 [−0.75, −0.16]
(B) *Criterion: recognition sensitivity*								
Step 1a	.01	0.3	STAI–T	0.01	0.001	0.012		
Step 1b	.01	0.1	PSWQ	−0.01	−0.001	0.007		
Step 2	.01	0.1	STAI–T	−0.02	−0.002	0.021	0.001 [−0.033, 0.039]	0.02 [−0.39, 0.46]
			PSWQ	0.02	0.001	0.013	−0.001 [−0.022, 0.021]	−0.02 [−0.41, 0.39]

Note: Data for Step 3 are not presented. PSWQ = Penn State Worry Questionnaire; STAI–T = Spielberger State–Trait Anxiety Inventory, Trait version; B = regression coefficient; SE_B = standard error of the regression coefficient; β = standardized regression coefficient; CI = confidence interval; unstand. = unstandardized; stand. = standardized.
[+]$p < .1$. *$p < .05$.

Spearman's, correlation coefficient was used to compute test–retest correlations of memory and anxiety measures.

Results and discussion

Descriptive statistics are presented in Table 1. Test–retest reliability of the anxiety measures were high (PSWQ: $r = .93$, $p < .05$; STAI: $r_s = .76$, $p < .05$), whereas the correlations between memory performance between the three memory tasks was modest (recognition sensitivity: $r_{s\ 1st–2nd} = 0.48$, $p < .001$, $r_{s\ 1st–3rd} = 0.51$, $p < .001$, $r_{s\ 2nd–3rd} = 0.38$, $p < .001$; recall percentage: $r_{s\ 1st–2nd} = 0.47$, $p < .001$, $r_{1st–3rd} = 0.22$, $p = .10$, $r_{s\ 2nd–3rd} = 0.29$, $p < .05$).

As can be seen in Table 5, contrary to Hypothesis 1, trait worry was not related to free recall performance in Step 1 (Step 1b: $\beta = 0.03$, $p = .86$). In line with Hypothesis 2, however, after controlling their shared variance, both the effect of trait anxiety and that of trait worry increase significantly (trait anxiety—Step 1a: $\beta = −0.15$, Step 2: $\beta = −0.54$, standardized indirect effect through trait worry: 0.39, 95% CI [0.04, 0.70]; trait worry—Step 1b: $\beta = 0.03$, Step 2: $\beta = 0.47$, standardized indirect effect through trait anxiety: −0.45, 95% CI [−0.75, −0.16]). Similar to Experiment 1, the fit of Step 2 model was insufficient, $F(2, 49) = 2.52$, $p = .09$, but the pattern of results remained unchanged in Step 3, after entering several confounding variables increased model fit [trait anxiety: $B = −0.009$, $SE_B = 0.003$, $\beta = −0.55$, $p = .014$; trait worry: $B = 0.005$, $SE_B = 0.002$, $\beta = 0.50$, $p = .03$; model fit: $F(8, 43) = 3.26$, $p = .001$].

Finally, no similar effects were found for recognition sensitivity, either in Steps 1–2 (see Panel B of Table 5) or in Step 3 [trait anxiety: $B = −0.005$, $SE_B = 0.005$, $\beta = −0.19$, $p = .37$; trait worry: $B = 0.003$, $SE_B = 0.004$, $\beta = 0.15$, $p = .49$; model fit: $F(5, 41) = 0.21$, $p = .95$].

Additional analyses

Comparing partial and indirect effects in self- versus environmentally cued recall

In all four studies, we observed significant effects for self-cued, but not for environmentally cued, retrieval. As each study used a relatively small sample, however, the demonstrated effects might be present in the environmentally cued condition too, but undetected due to low statistical power.

To increase statistical power, we used meta-analytical methods for combining the results of our studies. We applied the Hedges–Vevea random-effect model (Hedges & Vevea, 1998) and used the observed effect size estimates from each study (standardized indirect effect estimates for the suppression effect, and regression coefficients for the partial effects) to estimate the population effect determining these observed effects. Table 6 contains the population estimates, significance tests, and 95% CIs.

This analysis revealed significant partial effects of the anxiety measures for both the self-cued and the environmentally cued retrieval, respectively. Crucially, the partial effects related to both trait worry and trait anxiety were higher in the former case, as the 95% CIs were non-overlapping. Furthermore, the indirect

Table 6. Results of the meta-analysis: Population estimates of partial and indirect effects related to trait worry and trait anxiety.

	Partial effect				Indirect effect			
	Self-cued		Env-cued		Self-cued		Env-cued	
Predictor	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
PSWQ	0.49***	[0.37, 0.59]	0.16*	[0.02, 0.30]	−0.33***	[−0.45, −0.20]	−0.12$^+$	[−0.26, 0.02]
STAI	−0.45***	[−0.59, −0.31]	−0.16*	[−0.29, −0.02]	0.35***	[0.22, 0.47]	0.13$^+$	[−0.02, 0.26]

Note: CI: Confidence Interval; Env-cued: Environmentally cued.
$^+p < .1$; *$p < .05$; ***$p < .001$.

effects of the anxiety measures were significant in the case of self-cued retrieval, whereas there was only a non-significant tendency for the suppressor effects in environmentally cued retrieval. Despite the large nominal difference between indirect effects related to self and environmentally cued retrieval, CIs of the estimates overlap, so no significant differences in the magnitude of suppression could be demonstrated.

Analysis of temporal contiguity

Free recall requires cognitive control for the generation of retrieval cues, and one of the crucial processes involved might be the reinstatement of temporal context (Sederberg et al., 2008). Thus, if the demonstrated link between trait worry and free recall is due to the involvement of cognitive control in cue generation, as hypothesized, then trait worry should be related not only to overall recall level, but also to individual differences in temporal context reinstatement.

Thus, in a post hoc analysis, we examined whether trait worry is related to individual differences in the tendency to recall items from neighbouring study positions successively. To represent these individual differences in a single variable, Sederberg, Miller, Howard, and Kahana (2010) computed a non-parametric, rank-based summary measure, called temporal factor, whereas Healey, Crutchley, and Kahana (2014) relied on factor analytic procedures. Both methods rely on data from experiments with several free recall trials per participant using a short or even no delay. Our design characteristics differed from the above studies, which might be suboptimal for these analyses, resulting in biased estimates.

Because of this, we used an alternative approach: First, we calculated the absolute lag for each recall transition, which is the absolute value of the difference between study positions of the previously and the currently recalled word. Then, we computed the proportion of the retrieved items that were retrieved from a neighbouring study position of the previously recalled item (temporally similar item recall

percentage, TSI%): We counted the number of recalled items for which the absolute lag was not higher than a maximum lag value (denoted with k) and then divided this count by the number of retrieved items. Because we did not want to decide arbitrarily what counts as a recall from a neighbouring position, we gradually changed the value of maximum lag k from one to nine, resulting in nine TSI% values, with a more and more relaxed definition of temporal similarity (TSI%$_{k=1}$, TSI%$_{k=2}$, ... TSI%$_{k=9}$).

In a similar way, we computed the proportion of the original memory set that were recalled *not* from neighbouring study positions of the previously recalled item (temporally non-similar item recall percentage, TNI%): We first counted the number of temporally similar items, for which the lag was not smaller than a minimum lag value (denoted with l). Then this count was divided by the number of studied items. Again, by increasing the value of the minimum lag l from 2 to 10,[1] we calculated nine TNI% values, with more and more constrained definition of temporal non-similarity (TNI%$_{l=2}$, TNI%$_{l=3}$, ... TNI%$_{l=10}$). For the calculation of both TSI% and TNI% values, respectively, we excluded the first recalled item and items recalled after intrusion errors, because for these items, temporal lag could not be defined. The values of the different TSI% and TNI% indices are presented in Figure 1a.

Because the opposite partial effects of trait worry and trait anxiety were demonstrated in all four studies, and study-specific differences were of no importance here, we pooled together the samples from Experiments 1–4. Data from seven participants, with no consecutive correct recalls, were excluded, and thus the sample for this analysis was $N = 196$ (overall recall level: $M = .48$, $SD = .22$).

Then, we performed 18 linear regression analyses with the different TSI% and TNI% values, respectively, as criterion variables. The predictors were trait anxiety, trait worry, and three dummy variables controlling for study-specific effects in recall level. Because of the high sample size and significant
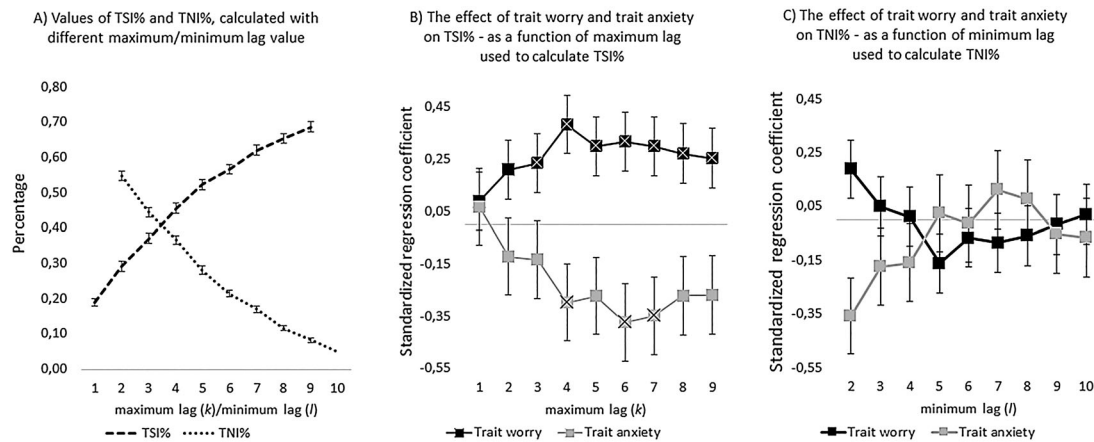
Figure 1. The effect of trait worry and trait anxiety on recall of temporally similar and non-similar items.

Note: TSI%: the number of temporally similar items (the absolute lag between the study position of the currently and previously recalled item is not higher than a maximum lag value k), divided by the number of retrieved items. TNI%: the number of temporally non-similar items (the absolute lag between the study position of the currently and previously recalled item is not smaller than a minimum lag value l), divided by the number of retrieved items. (a) Values of TSI% and TNI%; error bars represent the standard error of the mean. (b) Effect of trait worry and trait anxiety on TSI%; error bars represent the standard error of the regression coefficients; crossed squares indicate significant regression coefficient. (c) Effect of trait worry and trait anxiety on TNI%; error bars represent the standard error of the regression coefficients. None of the regression coefficients is significant.

study-specific differences, model fit was appropriate in all cases (all Fs > 2.l2, ps < .05), except for TSI%$_{k=7}$, TSI%$_{k=8}$, and TSI%$_{k=9}$, where the F test failed to reach significance. Figure 1b shows the standardized regression coefficients of trait worry and trait anxiety, respectively, predicting TSI%, as a function of maximum lag k. The effect of trait worry was significant, when the maximum lag used for TSI% was higher than 2, whereas the opposite effect of trait anxiety was significant for TSI%$_{k=4}$,TSI%$_{k=6}$, and TSI%$_{k=7}$. In contrast, we found no effect for either trait worry or trait anxiety in predicting TNI% values, regardless of the minimum lag used (see Figure 1c). Thus, the effects related to the anxiety measures are only present if the criterion variable represent the retrieval of temporally similar items. This pattern of results suggests that the opposite partial effects of trait worry and trait anxiety demonstrated in Experiments 1–4 are mediated through the recall of temporally similar items.

General discussion

In four studies, we demonstrated a positive association between trait worry and performance in episodic memory tasks requiring self-cued retrieval. In three of these studies, this link was only revealed after controlling the level of trait anxiety. Consequently, we identified a strong interplay between trait anxiety and trait worry: Controlling their shared variance, trait worry

exerted a consistent positive effect whereas trait anxiety exerted a consistent negative effect on self-cued memory performance (although in Experiment 1 the partial effect of trait anxiety was not significant). We also ruled out the potential confounding role of gender, state anxiety, high motivation, and perfectionism.

In line with our hypotheses, these effects were not present in any of our four studies for tasks requiring environmentally cued retrieval. Interestingly, and in contrast with our predictions, a follow-up meta-analysis combining the results of our studies showed that there is a small, but significant aggregate partial effect of the anxiety measures even in the case of environmentally cued retrieval. This might be explained by the fact that there are no process pure memory tasks (Jacoby, 1991), and different cognitive processes can contribute to performance in any memory task. Indeed, although control processes are essential to self-cued retrieval, they might also operate in parallel with the more automatic, cue-driven processes of environmentally cued retrieval. For instance, during a recognition task, participants may rely on control processes to retrieve contextual details to inform their decision on whether they have seen the presented target or not. Because cognitive control requirement is more pronounced for self-cued retrieval (where these control processes play a decisive role), than for environmentally cued retrieval (where these control processes are not essential), the

significantly stronger partial effect trait worry in self-cued than in environmentally cued retrieval, revealed by our meta-analysis, also supports the claim that trait worry is associated with cognitive control processes underlying episodic retrieval. This interpretation is further bolstered by our post hoc analyses showing that our findings were related to the contiguity effect, a marker of the cue-generation process during free recall (Sederberg et al., 2008).

In the following, we turn to two crucial questions regarding the interpretation of our results: (a) theoretical meaning of the demonstrated partial effects, and (b) processes differentiating self-cued versus environmentally cued retrieval.

The partial effects of trait anxiety and trait worry

In all four studies, we found consistent opposite partial effects of trait worry and trait anxiety on free recall performance. Importantly, however, these partial effects do not represent the impact of the original constructs, as the common part of the predictors' variance is removed in multiple regression analysis (see e.g., Lynam et al., 2006). In our case, the observed correlations of trait worry and trait anxiety were about .7, and this implies that about half of the constructs' variance is shared, and thus only the remaining 50% of the variance is responsible for the demonstrated partial effects. Although one could argue that this independent variance simply reflects measurement error, we suggest that the independent parts of trait worry and trait anxiety are theoretically meaningful for three reasons: (a) The scales have high internal consistency indicating low measurement error, (b) the partial effects are related to self-cued and environmentally cued retrieval in a meaningful manner, and (c) previous findings have already indicated partial independence of the constructs (Davey et al., 1992; Pajkossy et al., 2009; Siddique et al., 2006). Nevertheless, these partial effects do not represent the original constructs anymore, thus, following the advice of Lynam et al. (2006), we propose an explanation about what they theoretically stand for.

The independent part of trait worry, after controlling trait anxiety, highlights the fact that individuals with similar levels of trait anxiety might differ somewhat in their tendency to worry. We suggest that the degree to which anxiety manifests itself in a tendency to engage in worrying is determined by the same cognitive control processes as those that contribute to free recall performance, explaining the positive partial link between trait worry and free recall. In a similar vein, the partial effect of trait anxiety, after controlling trait worry, represents to which degree worry, a threat-related mental problem-solving activity, is associated with other signs and symptoms of anxiety. One of these signs is reduced attentional control disrupting the retrieval process, thus explaining the partial negative effect between trait anxiety and free recall performance.

Alternatively, taking into account the comorbidity of anxiety and depression (e.g., Pollack et al., 2005) and the suggested contamination of the STAI scale with depressive symptomatology (Bados, Gómez-Benito, & Balaguer, 2010; Bieling, Antony, & Swinson, 1998), partialling out the shared variance of PSWQ and STAI might remove adverse effects of depression. There are data suggesting that depression decreases memory performance especially if strategic processing is required (Hertel, 2000), and thus the negative partial effect of trait anxiety on memory performance requiring strategic retrieval might also reflect this effect, or the combination of negative effects related to both anxiety and depression.

The self-cued versus environmentally cued distinction—What does it represent?

Originally, we contrasted self-cued and environmentally cued retrieval because self-cued, but not environmentally cued, retrieval requires mental effort and attentional resources to initiate a cue-generation process (Conway & Pleydell-Pearce, 2000; Moscovitch, 1994; Petrides, 1996). Just as self-cued retrieval, worrying might also require effortful processing to engage in mental-problem-solving attempts (Borkovec et al., 1983), to focus on abstract verbal worries (Price & Mohlman, 2007), or to engage in analytic, verbal processing associated with systematic processing (Dash et al., 2013). Thus the partial effect of trait worry on self-cued retrieval observed in our study might be linked to the control of processing resources, capturing the ability to effectively recruit effortful, strategic retrieval processes during cue generation.

Alternatively, self-cued, but not environmentally cued, retrieval relies heavily on the formation of semantic associations between items at encoding (e.g., words from the same category are retrieved subsequently) and on the strategic search of semantic memory at retrieval (e.g., search for items of a semantic category and assess its familiarity; see, e.g., Long,

Öztekin, & Badre, 2010). The tendency of worrying has been associated with both verbal predominance (Sibrava & Borkovec, 2006) and the analytic, verbal mode of systematic information processing (Dash et al., 2013), and thus the link between trait worry and free recall performance might be mediated by the ease of verbal–conceptual processing enhancing organizational strategies at encoding and strategic semantic search at retrieval. Common neural pathway might be the language-related brain network of the left prefrontal cortex, associated with worry and anxious apprehension (Engels et al., 2007; Heller, Nitschke, Etienne, & Miller, 1997), with encoding operations and strategic retrieval in episodic memory tasks (e.g., Leynes, 2002; Long et al., 2010; Nolde, Johnson, & Raye, 1998) and also with systematic information processing (Dash et al., 2013). A recent study directly supports this interpretation: After controlling the level of negative affectivity and test anxiety, trait worry was found to be positively associated with verbal, but not with non-verbal, intelligence (Penney, Miedema, & Mazmanian, 2015).

Finally, self-cued, but not environmentally cued, retrieval depends crucially on contextual cues (Kahana, 1996; Sederberg et al., 2008), and thus the link between trait worry and free recall performance might be mediated by the effective binding of items to context at encoding and by the effective reinstatement of temporal context at retrieval. Binding and recollection of contextual details underlie not only the re-experiencing of past events (e.g., Howard & Eichenbaum, 2013), but also imagining future events (Schacter, Addis, & Buckner, 2007) and projecting the self into the past and the future (Buckner & Carroll, 2007). These processes are evidently related to the suggestions relating worry to planning (Barlow, 2002) and future-oriented mental problem solving activity (Borkovec et al., 1983), offering the possibility that the common processes underlying the ability to re-experience the past and imagine the future might underlie the link between trait worry and free recall performance. Because medial-temporal lobe structures and particularly the hippocampus are suggested to be involved in these processes (Howard & Eichenbaum, 2013; Schacter et al., 2007), this interpretation might also be relevant with respect to claims about the involvement of the hippocampus in both anxiety and memory (Bannerman et al., 2014; Davidson & Jarrard, 2004; Gray & McNaughton, 2000).

The current study cannot provide decisive evidence in favour of any of the theoretical alternatives delineated above. Thus, further research is warranted to specify the cognitive control processes responsible for the demonstrated positive association between trait worry and self-cued retrieval.

Finally, some limitations of our research must be addressed. First, our participants were undergraduate students, and thus our results cannot be generalized to samples with high levels of pathological worry or anxiety. Second, we assessed the level of pathological worrying as measured by the PSWQ, and thus further research should clarify whether the same pattern of results could be observed using measures of non-pathological worrying (e.g., the Worry Domains Questionnaire; Tallis, Eysenck, & Mathews, 1992). Third, our studies were correlational in nature and therefore provide only indirect support for our hypothesis about common underlying cognitive processes contributing to both trait worry and strategic retrieval.

Notwithstanding these limitations, we demonstrated that the unique variance of trait worry, independent of trait anxiety, predicts better self-cued and, to a lesser degree, also better environmentally cued retrieval. This association seems to arise due to common cognitive processes underlying trait worry and memory retrieval. Future studies, bridging gaps between memory and anxiety research, are required to identify these common processes and to describe the underlying causal relations.

Note

1. Because a minimum lag value of 1 would imply that all words are counted, the value of *l* was varied between 2 and 10.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

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