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Cognitive control in romantic love: the roles of infatuation and attachment in interference and adaptive cognitive control

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ABSTRACT
Besides physiological, behavioural, and affective effects, romantic love also has cognitive effects. In this study, we tested (1) whether individual differences in infatuation and/or attachment level predict impaired interference control even in the absence of a love booster procedure, and (2) whether individual differences in attachment level predict reduced adaptive cognitive control as measured by conflict adaptation and post-error slowing. Eighty-three young adults who had recently fallen in love completed a Stroop-like task, which yielded reliable indices of interference control (i.e. the interference effect) and adaptive cognitive control (i.e. conflict adaptation and post-error slowing). We did not observe the predicted negative association between infatuation or attachment level and interference control. It might be that reduced interference control with love only happens when people are actively thinking about their beloved. In addition, we observed only weak evidence for the prediction that attachment level is associated with reduced conflict adaption. The results did show, however, that attachment level is associated with less post-error slowing, which is in line with the notion that attachment to a romantic partner buffers against aversive events. Our findings suggest that attachment is associated with reduced adaptive cognitive control, which could have implications in everyday life.

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Congruency effect; post-error slowing; passionate love; companionate love; Stroop task

Romantic love is accompanied by physiological changes (e.g. pounding heart), behavioural changes (e.g. caregiving), and affective changes (e.g. euphoria and anxiety) (Fisher, 1998). Romantic love is also accompanied by cognitive changes (e.g. enhanced attention and memory for beloved-related information) (Langeslag, Olivier, Köhlen, Nijs, & Van Strien, 2015). Cognitive control allows us to adapt our behaviour when task demands change. It is modulated by affective factors such as reward, humour, arousal, mood, and approach/avoidance motivation (Van Steenbergen, 2015). So, cognitive control may be modulated by romantic love as well, but this has hardly been studied.

Because romantic love is not a unitary construct, its influence on cognitive control could be driven by different aspects, such as infatuation (or passionate love) and attachment (or companionate love) (Fisher, 1998). Infatuation is the overwhelming, amorous feeling for one individual that is typically most intense during the early stage of love, while attachment is the comforting feeling of emotional bonding with another individual that takes some time to develop (Fisher, 1998; Langeslag, Muris, & Franken, 2013). Infatuation is associated with both positive and negative affect, such as feelings of euphoria, anxiety, and nervousness, whereas attachment is associated with positive affect, such as feelings of happiness, security,

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calmness, and comfort (Fisher, 1998; Gonzaga, Turner, Keltner, Campos, & Altemus, 2006).

Cognitive control has been studied using conflict tasks such as Stroop and flanker tasks. In the Stroop task, colour words (e.g. "yellow") are presented in coloured ink and participants are instructed to respond to the ink colour rather than the word meaning. In flanker tasks, three or more stimuli (e.g. arrows, letters, or words) are presented and participants are instructed to respond to the central stimulus rather than the flanking stimuli. On congruent trials, task-irrelevant information (e.g. word meaning or flanking stimuli) matches task-relevant information (e.g. ink colour or central stimulus), which results in fast and accurate responses. On incongruent trials, the task-irrelevant information contradicts the task-relevant information, which results in slower and/or less accurate responses. The difference in response time (RT) and accuracy between incongruent and congruent conditions is the interference effect, which is an inverse measure of interference control (Eriksen & Eriksen, 1974; Stroop, 1992).

One previous study has tested the effect of romantic love on interference control. In that study, a higher score on the Passionate Love Scale (PLS) in young adults who had recently fallen in love was associated with reduced interference control in Stroop and flanker tasks (Van Steenbergen, Langeslag, Band, & Hommel, 2014). These tasks were performed after a procedure that involved the boosting of love feelings using a mood induction procedure that included a writing task and listening to beloved-related music. But people are in love and hence could still have impaired cognitive control even when their feelings are not boosted by this procedure. Therefore, the present study tested whether the effect of love on interference control conceptually replicates without a love booster procedure. In addition, even though its name implies that it measures infatuation (i.e. passionate love), the PLS actually taps into both infatuation and attachment without dissociating them (Langeslag et al., 2013). In the present study, we tested whether the effect of love on interference control is driven by infatuation and/or attachment. We used the Infatuation and Attachment Scales (IAS) that were developed since the previous study to measure infatuation and attachment levels separately (Langeslag et al., 2013).

Cognitive control adaptively increases when events, such as incongruent trials or errors, signal the need for this. Sequential analyses of trials in conflict tasks allow investigation of this adaptive cognitive control in two ways. First, the interference effect is smaller following incongruent than congruent trials (Gratton, Coles, & Donchin, 1992), which is called conflict adaptation. Second, responses are more cautious and hence slower after errors than after correct trials (Rabbitt, 1966), which is called post-error slowing. The present study investigated the relationship between romantic love and adaptive cognitive control.

Although the association between romantic love and adaptive cognitive control has not been studied yet, previous studies have shown that conflict adaptation is reduced by positive affect induction and increased by negative affect induction (Van Steenbergen, 2015; Van Steenbergen, Band, & Hommel, 2010; Van Steenbergen, Band, Hommel, Rombouts, & Nieuwenhuis, 2015). And electroencephalography studies have shown that positive affect attenuates neural error processing (Van Wouwe, Band, & Ridderinkhof, 2011; Wiswede, Münte, Krämer, & Rüsseler, 2009), which in turn might modulate adaptive post-error slowing (Gehring, Goss, Coles, Meyer, & Donchin, 1993). The reduction in adaptive cognitive control by positive states may be driven by a dampening of the aversive quality of conflict and errors (Van Steenbergen, 2015) and may be driven by neurochemicals such as opioids (Van Steenbergen, Eikemo, & Leknes, in press; Van Steenbergen, Weissman, Stein, Malcolm-Smith, & Van Honk, 2017). Because attachment, more than infatuation, has been associated with positive affect (Fisher, 1998; Gonzaga et al., 2006), opioids (Machin & Dunbar, 2011), and buffering against painful and stressful events (Bourassa, Ruiz, & Sbarra, 2019; Coan, Schaefer, & Davidson, 2006), we predicted that attachment level is negatively associated with adaptive cognitive control in response to conflict and errors.

Materials & methods

Participants

One hundred three young adults who were in love by self-report volunteered to participate. The inclusion criteria were: 18–28 years old, no psychiatric history, native Dutch speaker, not colour blind, love duration of nine months or less. Because infatuation decreases over time and is assumed to only last for 6–18 months and because attachment initially increases over time (Fisher, 1998; Langeslag et al., 2013), this nine month cut-off allowed us to sample sufficient variation in infatuation and attachment levels. Twenty participants were excluded for one or more reasons: reported duration of romantic feelings at the end of the experiment was more than nine months ($n = 12$), data loss due to a technical error ($n = 1$), post-error slowing and post-error accuracy could not be calculated because participants did not make any errors ($n = 4$), or data were characterised by extreme outliers (i.e. more than 3 interquartile ranges below/above the 25th/75th percentile) in the interference effect in accuracy ($n = 1$) or in post-error accuracy ($n = 5$). Ultimately, 83 participants (17–27 yrs, $M = 21.5$, 37 men) yielded useable data. A power analysis in G-Power software version 3.1.6 revealed 85% power to detect the effect size of the relationship between love and interference control ($r = .318$) in the previous study (Van Steenbergen et al., 2014) at a two-sided alpha level of 5%. This study was approved by the local ethics committee. Participants provided written informed consent at the start of the testing session and were debriefed at the end. Participants were remunerated with course credit or a chance to win a romantic night for two.

Procedure

Participants completed a Stroop-like task (Schmidt & Weissman, 2014), see Figure 1(a). Trials consisted of a distractor (133 ms), a blank screen (33 ms), a target (133 ms), and a second blank screen (1700 ms). The distractor consisted of three identical words ("Left", "Right", "Up", or "Down"; 48-point Courier New font) stacked vertically at the centre of the display. The target was a single word at the centre of the display ("Left", "Right", "Up" or "Down"; 77-point Courier New font). Participants pressed a key on a computer keyboard to identify the target as quickly and accurately as possible. Specifically, participants pressed F (left middle finger), G (left index finger), J (right middle finger), or N (right index finger) to indicate that the target was "Left", "Right", "Up" or "Down", respectively. Response time recording started at target onset. The word "Error" (60-point Courier new font) appeared for 200 ms following incorrect responses and response omissions (i.e. the absence of a response to the target within 1500 ms of target onset). To avoid stimulus and response repetitions in consecutive trials, the Left-Right and Up–Down tasks were presented alternately. To avoid contingency learning, distractor-target pairs were presented equally often in every block of trials. The task was presented on a 15-inch monitor (1280 × 1024 px @ 60 Hz) using E-Prime software. Stimuli appeared in white on a black background. Participants performed a block of 24 practice trials, which was repeated if accuracy was below 80%. The task proper consisted of two blocks of 96 test trials. Block were separated by self-paced breaks.

Subsequently, participants completed the previously developed and validated IAS (Langeslag et al., 2013) to assess infatuation and attachment levels. This questionnaire consists of a 10-item infatuation scale (e.g. "I become tense when I am close to ___." and "My thoughts about ___ make it difficult for me to concentrate on something else.") (Chronbach's alpha current sample = .85) and a 10-item attachment scale (e.g. "I feel that I can count on ___." and "___ can reassure me when I am upset.") (Chronbach's alpha current sample = .91). Participants indicated to what extent they agreed with each of the statements at that moment on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). The sum score on each scale can range from 10 (not infatuated/attached at all) to 70 (extremely infatuated/attached).

Finally, participants completed some general questions (Langeslag & Van Strien, in press), such as the gender of their beloved, for how long they had known their beloved, and for how long they had had romantic feelings for them. They also indicated whether they were involved in a romantic relationship with their beloved and its duration. Total duration of the testing session was approximately 20 min.

Analyses

The interference effect in RT was calculated by subtracting RT on congruent trials from RT on incongruent trials. The interference effect in accuracy, in contrast, was calculated by subtracting accuracy on incongruent trials from accuracy on congruent trials, so that lower values of the interference effects in both RT and accuracy reflect better cognitive control. The conflict adaptation effect in RT was assessed by subtracting the interference effect following incongruent trials from the interference effect following congruent trials. This can be expressed mathematically by $(cI - cC) - (iI - iC)$, where small letters indicate the congruency of the previous trial and capital letters indicate the congruency of the current trial. The conflict adaptation effect in accuracy, in contrast, was calculated as $(iI - iC) - (cI - cC)$, so that higher values of the conflict adaptation effects in both RT and accuracy reflect better adaptive cognitive control.

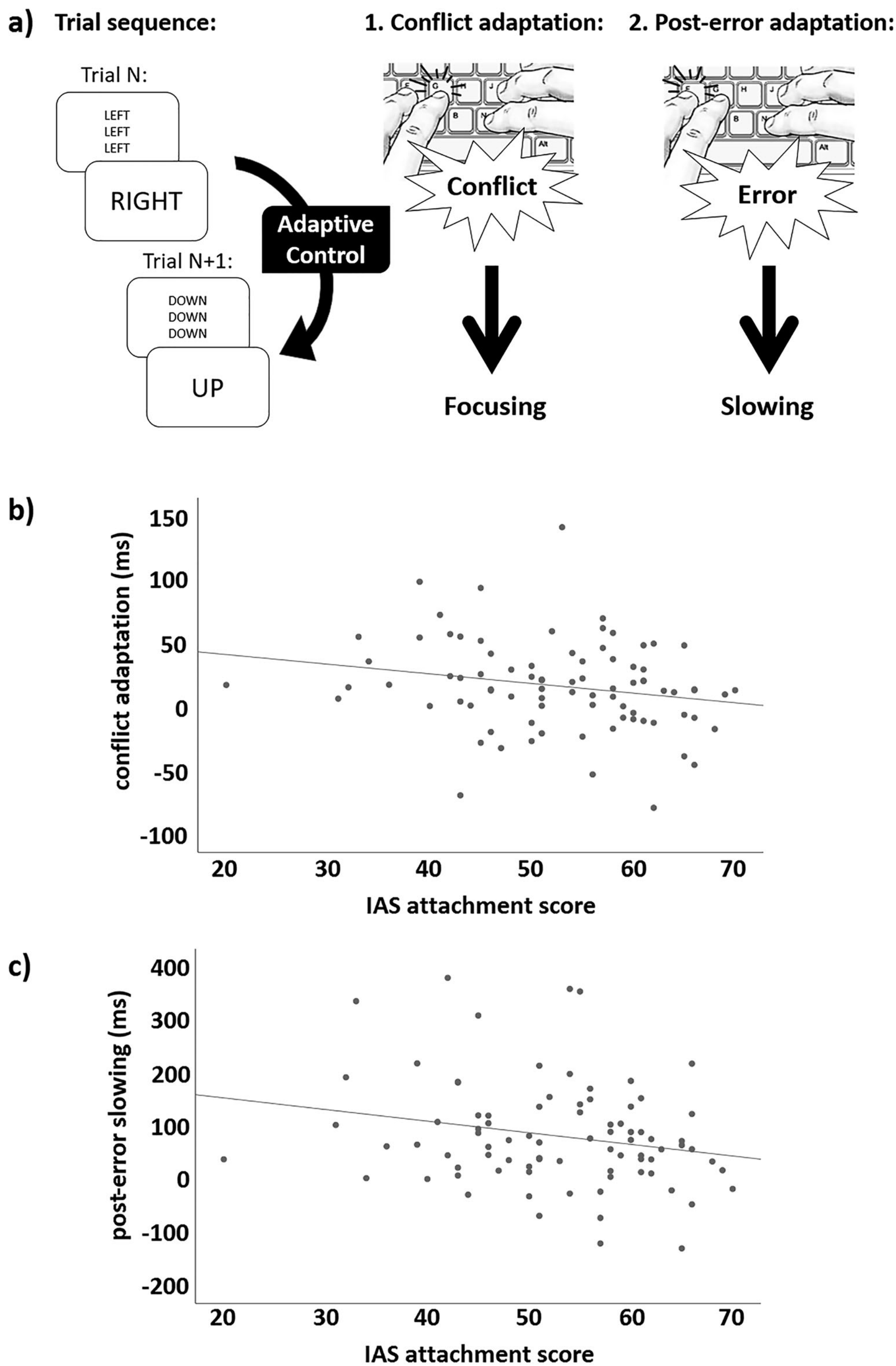

Figure 1. (a) The Stroop-like task (b) Scatterplot of the correlation between the conflict adaptation effect in RT and the IAS attachment score (c) Scatterplot of the correlation between post-error slowing and the IAS attachment score.

Post-error slowing was calculated using a method that prevents confounding by global fluctuations in task performance over time (e.g. due to motivation or attention) (Dutilh et al., 2012). Specifically, we isolated triplets of trials in which errors were preceded and followed by a correct trial and individual mean post-error slowing scores were calculated by subtracting mean RT pre-error from mean RT post-error. Post-error accuracy was calculated by subtracting mean accuracy post-correct from mean accuracy post-error using trials from the entire data set. Higher values of post-error slowing and post-error accuracy reflect better adaptive cognitive control.

For the RT analysis, we excluded the first trial of each block, incorrect trials, and trials that followed incorrect trials. Based on the remaining data, we then excluded outliers (i.e. correctly-performed trials with RTs greater than 2.5 *SDs* from their condition-specific mean, calculated for each participant separately). For the accuracy analysis, we excluded the same trials with the exception of incorrect trials and RT outliers.

Then, one sample *t*-tests against 0 were conducted to test whether participants showed the typical interference, conflict adaptation, and post-error effects in RT and accuracy. Finally, Pearson correlation coefficients were computed between the IAS infatuation and attachment scores on the one hand, and the cognitive control variables (i.e., interference effect in RT, conflict adaptation effect in RT, and post-error slowing) on the other hand. An alpha level of 5% (two-sided) was used.

Results

Sample characteristics

Seventy-five participants had an opposite-sex beloved and eight a same-sex beloved. On average, participants reported to have known their beloved for 11.5 months (range = 0.3–84.0) and to have had romantic feelings for them for 3.8 months (range = 0–9.0). The mean IAS infatuation sum score was 32.5 (range = 14–59) and the mean IAS attachment sum score was 52.5 (range = 20–70). These scores indicate that each participant experienced at least some level of infatuation and/or attachment and confirmed that the sample displayed a wide range of infatuation and attachment levels. Moreover, the IAS infatuation and attachment scores were not correlated, $r(81) = -.037$, $p = .739$, which confirms that these scales tap into distinct constructs. Finally, 50 participants were in a relationship with their beloved and 33 were not. Average relationship duration was 3.6 months (range = 0.3–9.0). See the supplementary material for a consideration of some of these sample characteristics as control variables.

Task performance

See Table 1 for an overview of task performance.

Interference effect

The interference effect was significant, $t(82) = 19.2$, $p < .001$, indicating that participants responded slower on incongruent than congruent trials. The effect was not driven by a speed-accuracy trade-off because participants also made more errors on incongruent than congruent trials, $t(82) = 6.1$, $p < .001$.

In contrast to the prediction, the interference effect was not correlated with infatuation level, $r(81) = -.018$, $p = .872$, or attachment level, $r(81) = .028$, $p = .798$.

Table 1. Overview of task performance.

Measure	*M*	*SD*	95% *CI*
Grand average RT (ms)	560.8	75.3	[544.6–577.0]
Grand average accuracy (%)	93.9	4.4	[93.0–94.9]
RT cC (ms)	520.0	79.7	[502.8–537.1]
RT cI (ms)	598.7	79.3	[581.7–615.8]
RT iC (ms)	531.2	77.7	[514.5–547.9]
RT iI (ms)	593.4	76.5	[577.0–609.9]
RT interference effect (ms)	70.5	33.5	[63.3–77.7]
RT conflict adaptation effect (ms)	16.5	35.4	[8.9–24.1]
Accuracy cC (%)	95.6	4.5	[94.6–96.5]
Accuracy cI (%)	91.5	7.2	[89.9–93.0]
Accuracy iC (%)	95.6	4.4	[94.7–96.6]
Accuracy iI (%)	93.2	6.0	[91.9–94.5]
Accuracy interference effect (%)	3.3	4.9	[2.2–4.3]
Accuracy conflict adaptation effect (%)	1.7	6.8	[0.2–3.1]
RT pre-error (ms)	544.5	95.3	[524.0–565.0]
RT post-error (ms)	626.5	120.0	[600.7–652.3]
Post-error slowing (ms)	82.0	99.2	[60.6–103.3]
Accuracy post-correct (%)	93.9	4.5	[93.0–94.9]
Accuracy post-error (%)	96.4	5.4	[95.2–97.5]
Post-error accuracy (%)	2.4	4.5	[1.5–3.4]

Note: *M* = mean, *SD* = standard deviation, *CI* = confidence interval, cC, cI, iC, and iI = lower case letters indicate the congruency of the previous trial and upper case letters indicate the congruency of the current trial.

Conflict adaptation effect

The conflict adaptation effect was significant, $t(82) = 4.2$, $p < .001$, indicating that the interference effect was reduced after incongruent compared to congruent trials. This effect was not driven by a speed-accuracy trade-off because the interference effect in accuracy was also reduced after incongruent compared to congruent trials, $t(82) = 2.2$, $p = .031$.

In line with the predicted direction, attachment level tended to correlate negatively with the conflict adaptation effect, $r(81) = -.214$, $p = .052$, see Figure 1(b). For completeness, we also report the association between infatuation level and conflict adaptation, which was not significant, $r(81) = -.116$, $p = .297$.

Post-error slowing

The post-error slowing effect was significant, $t(82) = 7.5$, $p < .001$, indicating that participants responded slower on trials following than preceding an incorrect response. This effect was driven by cautionary responding rather than an orienting response because participants also responded more accurately on trials following an incorrect compared to a correct response, $t(82) = 4.9$, $p < .001$.

As predicted, post-error slowing was negatively correlated with attachment level, $r(81) = -.220$, $p = .045$, see Figure 1(c). Post-error accuracy, in contrast, did not correlate with attachment level, $r(81) = -.056$, $p = .616$, probably because errors after other errors were rare (3.6%, see Table 1) leading to a floor effect for this measure. For completeness, we report the association between post-error slowing and infatuation level, which was not significant, $r(81) = -.038$, $p = .730$.

Discussion

We tested (1) whether individual differences in infatuation and/or attachment level predict impaired interference control even in the absence of a love booster procedure, and (2) whether individual differences in attachment level predict reduced adaptive cognitive control as measured by conflict adaptation and post-error slowing. Participants who had recently fallen in love completed a Stroop-like task, which yielded reliable indices of interference control (i.e. the interference effect) and adaptive cognitive control (i.e. conflict adaptation and post-error slowing).

In contrast to the previous study (Van Steenbergen et al., 2014), neither infatuation nor attachment level was associated with interference control. In that study, the romantic love level as measured with the PLS was positively associated with interference control measured across Stroop and flanker tasks. Those tasks were completed after a love booster procedure, which could have driven the relationship. The failure to observe an association between infatuation/attachment and interference control in the current study despite its 85% power to detect such an effect supports this suggestion. It may be that love only leads to more distractibility when people are actively thinking about their beloved. Thinking about the beloved or an ex-partner has been associated with poorer performance on short-term memory and reading comprehension tasks (Baird, Smallwood, Fishman, Mrazek, & Schooler, 2013; Langeslag & Van Strien, in press). Future studies could test whether rumination indeed mediates the effect of love on interference control. A limitation of the previous study was that it measured love levels using the Passionate Love Scale (PLS), which does not dissociate between infatuation and attachment (Langeslag et al., 2013). Therefore, the Infatuation and Attachment Scales (IAS) (Langeslag et al., 2013) were used to assess infatuation and attachment level separately in the present study. It could be though that using a different questionnaire contributed to the failure to replicate the previous finding.

Evidence for the hypothesis that attachment level is associated with reduced conflict adaption was weak, as the correlation only approached significance. We do provide the first support for the hypothesis that attachment level is negatively associated with adaptive cognitive control. The negative association between attachment level and post-error slowing suggests that the more people are attached to their beloved, the less they show increases in cognitive control after errors. Because this effect occurred without a love booster procedure, it occurs even when people are not actively reminded to think about their beloved. This finding supports the notion that romantic love is accompanied by cognitive changes that could have implications in daily life.

What mechanism might underlie the association between attachment and reduced adaptive cognitive control after errors? Positive hedonic states reduce adaptive cognitive control, presumably by dampening the aversive quality of conflict (Van Steenbergen, 2015). In addition, administration of the opioid blocker naltrexone increased post-error slowing (Van Steenbergen et al., 2017), suggesting that the opioid system modulates aversive arousal which in turn influences cognitive control. Attachment is associated with reduced negative affect as measured using the Positive and Negative Affect Schedule (Langeslag et al., 2013) and with increased positive affect such as happiness, security, calmness, and comfort (Fisher, 1998; Gonzaga et al., 2006). Attachment to a romantic partner also buffers against stressful events and dampens pain (Bourassa et al., 2019; Coan et al., 2006) and is associated with increased endogenous opioids levels (Machin & Dunbar, 2011). Therefore, positive affect, endogenous opioids, and/or buffering against aversive events might underlie the negative association between attachment and cognitive control after errors.

To conclude, we did not observe the negative association between romantic love and interference control observed in a previous study (Van Steenbergen et al., 2014). We propose that reduced interference control with love might only happen when people are actively thinking about their beloved. In addition, we observed only weak evidence for our prediction that attachment level is associated with reduced conflict adaption. This study does show, however, that attachment level is associated with less post-error slowing reflecting reduced adaptive cognitive control after errors. These findings extend earlier findings showing that attachment to a romantic partner buffers against painful and aversive events, an effect that might be supported by the endogenous opioid system.

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No potential conflict of interest was reported by the authors.

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