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Depression and affective flexibility: A valence-specific bias

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ABSTRACT

Depression might be associated with poor affective flexibility, defined as the ability to switch between emotional and non-emotional aspects of a stimulus. However, it is unclear whether affective inflexibility in depression is valence-specific, whether it predicts future depressive symptoms, and whether affective flexibility following a stressor, compared to before a stressor, better predicts depressive symptoms. Before and after a stressor, participants (N = 300) completed an affective switching task during which they categorized pictures either by the valence or by the number of humans present in the pictures. Slower shifting from emotional aspects of negative material before stress was uniquely associated with higher levels of prospective depressive symptoms. This negative bias in affective flexibility may hinder disengagement from negative information, thereby exacerbating depressive symptoms.

Recent theories posit that major depressive disorder (MDD) is characterized by low flexibility (see Kashdan & Rottenberg, 2010 for review), especially in experiencing emotions. In addition, rumination, a prominent vulnerability factor and a strong correlate of MDD, represents an inflexible cognitive style (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). MDD is also characterized by an inflexible attributional style for negative events (Sweeney, Anderson, & Bailey, 1986). Thus, depression is associated with an inflexible experience of emotions, thoughts, and attributions.

Depression may also be characterized by cognitive inflexibility, the ability to inhibit irrelevant tasks and to shift to a relevant task according to contextual demands (Miyake et al., 2000; Scott, 1962). Psychologically flexible individuals can identify situational demands and utilize top-down strategies accordingly (Fleeson, 2001). In contrast, individuals with poor cognitive flexibility rely on bottom-up, automatic responses regardless of context (Baumeister, 2002). Despite the promising theories, the findings on cognitive flexibility in depression are mixed. Whereas some studies found individuals with MDD had difficulty shifting between rules on cognitive tasks (e.g., Lee et al., 2013), other studies did not (e.g., Vergara-Lopez, Lopez-Vergara, & Roberts, 2016).

For depression, however, affective flexibility, the ability to shift between emotional and non-emotional tasks according to situational demands (Genet & Siemer, 2011; Malooly, Genet, & Siemer, 2013), may be more relevant. For instance, individuals with impaired affective flexibility might experience difficulty disengaging from irrelevant emotional information. Consequently, poor affective flexibility can prolong the processing of negative information, resulting in the maintenance or exacerbation of negative mood and thoughts, contributing to depressive symptoms.

Indeed, individuals with MDD exhibit difficulty shifting from negative information. On an emotional Wisconsin Card Sorting Task (WCST; Heaton, 1981), participants with MDD made more perseverative errors for negative words, whereas controls made more errors for positive words (Deveney & Deldin, 2006). Similarly, on a modified go/no-go task (Murphy et al., 1999), participants with MDD responded slower when shifting from sad to happy words, whereas controls responded slower when shifting from happy to sad words (Murphy, Michael, & Sahakian, 2012). Biased affective flexibility was also associated with phenomena that are closely linked to depression. On an affective switching task (AST) where participants switched between categorizing images based on the valence of the content or the number of humans present, greater difficulty shifting from emotional aspects of negative stimuli was associated with lower levels of resilience (Grol & De Raedt, 2018), higher levels of daily rumination (Genet, Malooly, & Siemer, 2011), and worse reappraisal following stress (Malooly et al., 2013).

Other studies linked depression to general impairments in affective flexibility. On an internal shift task (IST) where participants switched between keeping a count of the number of positive versus negative words (affective condition) or food versus household objects (neutral condition), participants with MDD had higher error rates, longer reaction times (RTs), and larger switch costs (SCs; RTs on switch trials – RTs on repetition trials) for the affective condition compared to controls (Lo

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& Allen, 2011). Similarly, participants with MDD had larger SCs than controls for both the affective and non-affective conditions (De Lissnyder, Koster, Everaert, et al., 2012).

Not all studies demonstrated lower affective flexibility in depression. Women with a history of MDD and controls did not differ in their performance on an emotional WCST (Aker, Harmer, & Landrø, 2014). Similarly, performance on the IST was unrelated to depressive symptoms in non-clinical samples (e.g., Koster, De Lissnyder, & De Raedt, 2013). Thus, evidence is mixed regarding whether affective inflexibility characterizes depression, and if so, whether it depends on the stimulus valence. However, given that depression is characterized by a preferential processing of negative information (see Gotlib & Joormann, 2010, for review), depression may be associated with a presence of a negative bias (i.e., difficulty shifting from negative stimuli) and/or an absence of a positive bias in affective flexibility (i.e., lack of difficulty shifting from positive stimuli) that may be present in healthy individuals.

Stress may explain the mixed findings on affective flexibility in depression. Acute stress interferes with top-down, goal-directed processes, such as affective flexibility (e.g., Steinhauser, Maier, & Hubner, 2007). For example, higher levels of self-reported negative affect in response to a stressor were associated with higher error rates on an emotional WCST (Shields, Moon, & Slavich, 2017). Furthermore, cognitive biases may be less pronounced unless being activated by stress (De Lissnyder, Koster, Goubert, et al., 2012). For example, the ability to update working memory following, but not before, a stress induction predicted depressive symptoms in college students (Quinn & Joormann, 2015). Along this line, depression-related affective inflexibility may also be more observable following a stressor. Thus, affective flexibility following stress (vs. before stress) may be a better predictor of depressive symptoms.

Differences in the tasks used in prior research may also account for the inconsistent findings. The IST requires shifting of the internal focus between mental categories but not between rules. Shifting between different rules is more challenging than shifting between categories using the same rule (Dajani & Uddin, 2015). Hence, the cognitive demands on the IST may not be sufficient to detect lower affective flexibility in individuals with MDD. In contrast, performance on the AST involves shifting between two rules, and consequently, requires higher cognitive demand. As a result, the AST may be more sensitive to depression-related differences in affective flexibility. However, no studies have used the AST to examine affective flexibility in depression.

The present study addressed these gaps in the literature by examining affective flexibility before and after stress using a longitudinal design. Given that depression is associated with negative biases and an absence of positive biases in other cognitive processes (see Gotlib & Joormann, 2010, for review), we hypothesized that higher levels of depressive symptoms would be associated with slower shifting from emotional aspects of negative stimuli and/or faster shifting from emotional aspects of positive stimuli. Furthermore, given the theoretical support for the importance of affective flexibility following stress in depression (Chajut & Algom, 2003; Quinn & Joormann, 2015), we hypothesized that affective flexibility following stress, compared to before stress, would better predict depressive symptoms.

1. Method

1.1. Participants

A power analysis using G*Power ($f^2 = 0.15$, $\alpha = 0.05$, 95% power) indicated that a sample size of 129 would detect significant main effects of post-stress affective flexibility on prospective depressive symptoms. To account for the attrition for the follow-up and the fact that our hypotheses regarding the cross-sectional relations between depressive symptoms and affective flexibility required detecting a 3-way interaction, we over-recruited the participants. Three hundred participants were recruited from the Psychology Subject Pool at the University of Notre Dame and from the local community in South Bend, IN through online public advertisements and flyers.

1.2. Computer task

1.2.1. Stimuli

One-hundred sixty images (Malooly et al., 2013) from the International Affective Image System IAPS; (Lang, Bradley, & Cuthbert, 2008) were used. Forty images were selected for each of the following categories: negative with one or fewer humans; negative with two or more humans; positive with one or fewer humans; and positive with two or more humans (see Supplementary Material S1 for more information).

1.2.2. Affective switching task (AST)

Affective flexibility was assessed using the AST (Malooly et al., 2013). Participants sorted each image based on either an affective rule (positive or negative in content) or a non-affective rule (presence of one or fewer humans, or two or more humans). The sorting rule was indicated by visual cues presented on either sides of the image (" + " and "–" or "≤ 1" or "≥ 2"). Each image appeared twice during 320 main trials; categorization rules were used in a pseudorandom sequence. The AST was programmed using the E-Prime® 2.0, which recorded participants' responses and RTs.

There were eight trial types: negative affective repetition, negative affective switch, negative non-affective repetition, negative non-affective switch, positive affective repetition, positive affective switch, positive non-affective repetition, and positive non-affective switch trials (see Fig. 1). Negative and positive affective switch trials involved switching from classifying pictures based on the affective rule to the non-affective rule when both images were negative or positive, respectively. Negative and positive affective repetition trials involved repeating the affective rule for consecutive negative or positive images, respectively. Trials with the non-affective rules were similar, except

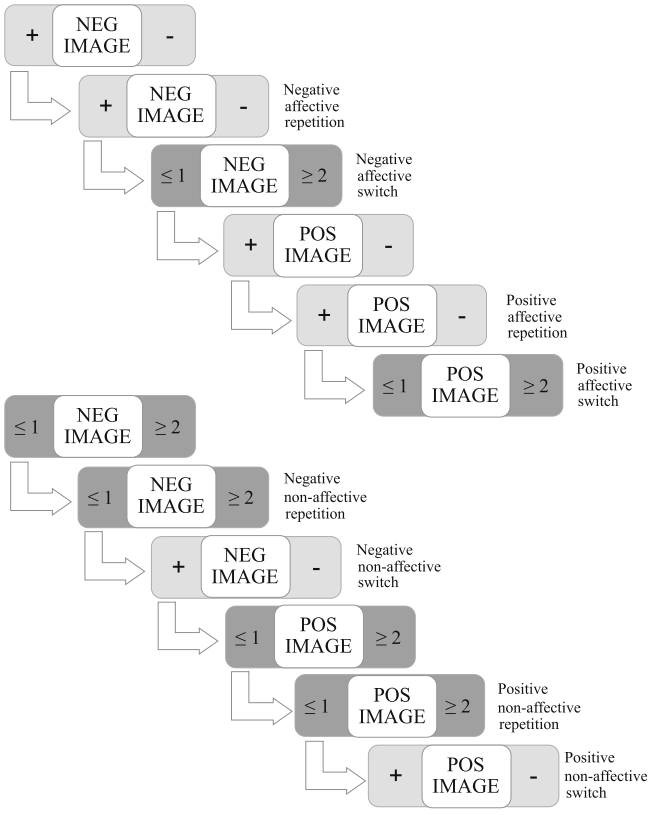

Fig. 1. Illustrations of the eight trial types on the affective switching task.

that the trials involved switching from (i.e., negative and positive non-affective switch) or repeating (i.e., negative and positive non-affective repetition) the non-affective rule.

1.3. Stress induction

The stress-induction procedure included an anagram task and a mental arithmetic task. Participants solved anagrams of various difficulty levels, some of which were unsolvable, under a 30-s time limit per anagram (van Randenborgh, Hüffmeier, LeMoult, & Joormann, 2010). Participants were told to maximize the number of anagrams they successfully solved. During the 5-min mental arithmetic task, participants counted back out loud from the number 2083 by serial subtractions of 13. When participants made a mistake, they were told to start from the beginning. Both tasks have been shown to effectively induce stress (e.g., MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; van Randenborgh et al., 2010).

1.4. Measures

The 20-item Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977) was administered to assess participants' depressive symptoms. The CES-D demonstrated good internal consistency and validity in university and community samples (e.g., Carleton et al., 2013; Van Dam & Earleywine, 2011). In the current study, the Cronbach's α was .89 for the lab session and .87 for the follow-up assessment.

The anxiety item in the Emotional Experience Scale (EES; English & Carstensen, 2014) was used to assess participants' affect. Participants rated their anxiety levels on a 7-point Likert scale (1 = "*not at all*", 7 = "*extremely*") seven times throughout the laboratory session. In the present study, the test-retest reliability of the anxiety item ranged from .70 to .87.

1.5. Procedure

The timeline of the laboratory session is illustrated in Fig. 2. After providing their informed consent, participants completed the AST to assess pre-stress affective flexibility. Next, participants completed a computer task unrelated to the present investigation. After viewing a 5-min nature video to establish baseline affect levels, participants completed the stress induction, followed by the second AST to assess post-stress affective flexibility. After viewing a 5-min nature video, participants completed questionnaires, including the CES-D (Radloff, 1977) to assess baseline depressive symptoms. Participants' anxiety levels were also assessed throughout the lab session. Participants who consented to complete the follow-up survey received an email one-month after the laboratory session with a link to the survey, which included the CES-D. All procedures were approved by the local Institutional Review Board.

1.6. Analytic approach

Trials on which participants responded inaccurately were removed; this affected 7.0% of the pre-stress AST data and 6.5% of the post-stress AST data. Trials with RTs less than 350 ms and greater than 3 standard deviations above the person mean for each trial type were considered outliers and excluded; 1.6% and 1.9% of the remaining data for the pre- and post-stress AST, respectively, were affected. Mean RTs were computed for the eight trial types. Following previous studies using the AST (e.g., Malooly et al., 2013), four SCs (i.e., negative affective, negative non-affective, positive affective, and positive non-affective) were calculated to index affective flexibility by subtracting RTs on repetition trials from RTs on switch trials (e.g., negative affective switch RT-negative affective repetition RT).[1] Thus, higher SCs indicated lower affective flexibility.

2. Results

2.1. Participant characteristics

Of the 300 participants who completed the laboratory session, 220 participants completed the follow-up. Five participants did not have valid AST data due to below 50% accuracy rates ($n = 2$), computer malfunction ($n = 1$), and participants falling asleep ($n = 2$). One additional participant was excluded due to incomplete CES-D data. Thus, data from 294 to 217 participants were included for the cross-sectional and longitudinal analyses, respectively (see Table 1). Independent samples t-tests indicated that participants who did and did not complete the follow-up did not differ significantly in baseline CES-D scores, $t(292) = -1.50$, $p = .135$, 95% CI [-4.00, .54], or any of the SCs, all $ps > .1$, except for marginally higher post-stress positive non-affective SCs in participants who completed the follow-up, $t(292) = 1.92$, $p = .056$, 95% CI [-1.64, 128.20].

2.2. Stress induction manipulation check

A time x CES-D repeated measures analysis of covariance (ANCOVA) was conducted on the EES anxiety item. A main effect for time was significant, indicating that anxiety levels changed significantly throughout the laboratory session, $F(6, 1716) = 13.60$, $p < .001$, $\eta_p^2 = 0.045$. Follow-up t-tests indicated that anxiety levels increased significantly after the stress induction, $t(291) = 8.91$, $p < .001$, 95% CI [.58, .91], and remained high after the post-stress AST, $t(288) = 6.04$, $p < .001$, 95% CI [.26, .52] [2] As expected, there was a significant main effect of CES-D, $F(1,286) = 77.14$, $p < .001$, $\eta_p^2 = 0.212$, with higher CES-D scores being associated with higher anxiety levels in general. A time x CES-D interaction was not significant, $F(6, 1716) = 0.40$, $p = .880$, $\eta_p^2 = 0.001$, suggesting that changes in anxiety levels did not differ significantly depending on CES-D scores (for more information, see Supplementary Material S2).

2.3. Depressive symptoms

Participants reported minimal depressive symptoms at baseline ($M = 12.67$, $SD = 8.72$, range 0–45, IQR = 12) and follow-up ($M = 12.19$, $SD = 8.02$, range 0–42, IQR = 11). The baseline and follow-up CES-D scores were not significantly different, $t(216) = 0.06$, $p = .952$, 95% CI [-.88, .94].

2.4. Baseline depressive symptoms and affective flexibility

The descriptive statistics are reported in Table 2. To examine the relation between baseline depressive symptoms and pre-stress affective flexibility, a Valence (Negative vs. Positive) x Rule (Affective vs. Non-Affective) x CES-D ANCOVA was conducted on pre-stress SCs. A Valence x Rule interaction was significant, $F(1,292) = 16.71$, $p < .001$, $\eta_p^2 = 0.062$. Follow-up dependent-samples t-tests revealed that negative affective SCs were significantly higher than positive affective SCs, $t(293) = 3.55$, $p < .001$, 95% CI [34.51, 120.35], whereas negative non-affective SCs were significantly lower than positive non-affective SCs, $t(293) = -6.11$, $p < .001$, 95% CI [-161.22, -82.69]. A Valence x CES-D interaction was also significant, $F(1,292) = 1.72$, $p = .008$, $\eta_p^2 = 0.209$, with no significant simple effects, all $ps > .1$. No other findings were significant, including the hypothesized three-way interaction, $F(1,292) = 0.84$, $p = .741$, $\eta_p^2 = 0.114$.

Next, a Valence x Rule x CES-D ANCOVA was conducted on the post-

[1] Parallel analyses were conducted with RTs, which are presented in Supplementary Material S4 and S5.

[2] Not all participants responded every time, resulting in different degrees of freedom.

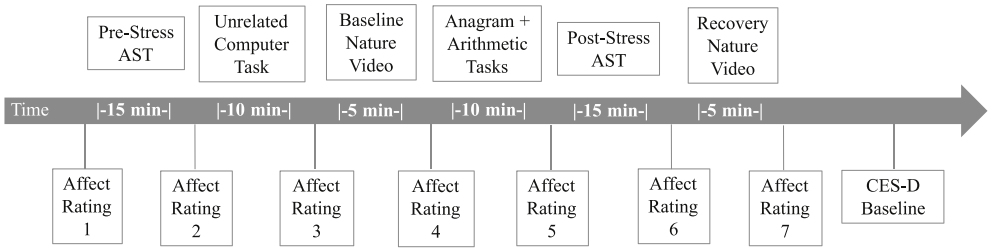

Fig. 2. Timeline of tasks and surveys in the laboratory session.

Table 1
Demographic and symptom information.

Variable	*M(SD)/n*(%)
Age	20.48 (2.41)
Gender	
Female	196 (66.7)
Male	97 (33.0)
Marital Status	
Never married	278 (94.6)
Married/Common law	15 (5.1)
Ethnicity	
Caucasian	191 (65.0)
Latin American	32 (10.9)
Asian	27 (9.2)
African American	12 (4.1)
South Asian	12 (4.1)
Other	19 (6.5)
Education	
High school diploma	223 (75.9)
Bachelor's degree	56 (19.0)
Master's or professional degree	13 (4.4)
Other	1 (0.3)

Note. Data from one participant was missing due to incomplete data for the demographic questionnaire.

2.5. Prospective depressive symptoms and affective flexibility

We examined the unique associations between affective flexibility and depressive symptoms by entering both negative and positive affective SCs in a single model. The baseline CES-D scores were entered in Step 1, the pre-stress negative and positive affective SCs were entered in Step 2, and the post-stress negative and positive affective SCs were entered in Step 3. Not surprisingly, the baseline CES-D scores significantly predicted follow-up CES-D scores, $R^2 = 0.44$, $F(1,215) = 165.36$, $p < .001$. Importantly, the addition of the pre-stress affective SCs significantly improved the model, $\Delta R^2 = 0.019$, $\Delta F(1,213) = 3.71$, $p = .026$, with higher pre-stress negative affective SCs significantly predicting higher follow-up CES-D scores, $b = 0.003$, $t = 2.58$, $p = .011$. However, the addition of the post-stress affective SCs did not significantly improve the model, $\Delta R^2 = 0.009$, $\Delta F(1,211) = 1.75$, $p = .177$. Thus, greater difficulty shifting from affective aspects of negative pictures before the stressor uniquely predicted higher follow-up depressive symptoms.

Similarly, both negative and positive non-affective SCs were entered in one model. Again, the baseline CES-D scores significantly predicted follow-up CES-D scores, $R^2 = 0.44$, $F(1,215) = 165.36$, $p < .001$. Neither the pre-stress non-affective SCs in Step 2, $\Delta R^2 = 0.006$, $\Delta F(2,213) = 1.05$, $p = .351$, nor the post-stress non-affective SCs in Step 3, $\Delta R^2 < .001$, $\Delta F(2,211) = 0.022$, $p = .978$, significantly improved the model. Thus, shifting from non-emotional aspects of the images did not predict follow-up depressive symptoms.

Table 2
Mean, standard deviation, and Pearson correlations for CES-D scores and switch costs ($n = 294$).

	1	2	3	4	5	6	7	8	9	10
1. Time 1 CES-D	–									
2. Time 2 CES-D	.66**	–								
3. Pre-Stress NASC	−.06	.05	–							
4. Pre-Stress NNSC	−.02	−.07	−.05	–						
5. Pre-Stress PASC	.02	−.05	.15*	.03	–					
6. Pre-Stress PNSC	−.00	−.04	−.01	.11	−.08	–				
7. Post-Stress NASC	−.10	−.05	.21**	.09	.07	.10	–			
8. Post-Stress NNSC	.04	.03	.17**	.15*	.19**	−.04	.08	–		
9. Post-Stress PASC	−.05	-.17*	−.11	.04	.06	.09	−.09	−.09	–	
10. Post-Stress PNSC	.01	−.01	.16**	.10	.04	.38**	.17**	.16**	.04	–
Mean	12.67	12.19	232.30	88.89	154.87	210.84	125.25	181.64	129.95	160.36
SD	8.72	8.02	311.51	266.70	258.04	244.01	220.13	236.64	229.84	249.82

Notes. * = $p < .05$, ** = $p < .01$. AST = Affective Switching Task. CES-D = Center for Epidemiological Studies Depression Scale. NASC = negative affective switch cost, NNSC = negative non-affective switch cost, PASC = positive affective switch cost, PNSC = positive non-affective switch cost. SD = standard deviation.

stress SCs to examine the association between baseline depressive symptoms and post-stress affective flexibility. A main effect of Rule was significant, $F(1,292) = 11.80$, $p = .001$, $\eta_p^2 = 0.044$, with higher SCs for the non-affective rule ($M = 171.00$, $SE = 10.80$) than the affective rule ($M = 127.60$, $SE = 8.83$). No effects involving CES-D were significant, including the hypothesized three-way interaction, $F(1,292) = 1.01$, $p = .466$, $\eta_p^2 = 0.134$. Thus, baseline CES-D scores were not associated with pre- or post-stress affective flexibility.

3. Discussion

The present study investigated the association between affective flexibility and depressive symptoms. We hypothesized that (1) higher depressive symptoms would be associated with slower shifting from emotional aspects of negative stimuli and/or faster shifting from emotional aspects of positive stimuli, and that (2) affective flexibility following (versus before) a stressor would better predict prospective

depressive symptoms. Our findings demonstrated that pre-stress affective flexibility predicted future depressive symptoms. Specifically, slower shifting from emotional aspects of negative stimuli prior to the stressor was uniquely associated with higher levels of depressive symptoms at follow-up. However, post-stress affective flexibility did not predict prospective depressive symptoms.

In the current study, neither pre- nor post-stress affective flexibility was associated with current depressive symptoms. Similarly, updating emotional content in working memory, a construct closely related to affective flexibility (Miyake et al., 2000), was unrelated to current depressive symptoms (Quinn & Joormann, 2015). Thus, biases in top-down cognitive processes may be more strongly associated with future (vs. current) depressive symptoms. The reason for such diverging associations is unclear, which calls for more research.

According to the developmental psychopathology framework (Howe, Reiss, & Yuh, 2002), the relations between depressive symptoms and vulnerability factors become stronger later in the developmental trajectory of depression. Thus, the link between affective inflexibility and depressive symptoms may be weak in earlier stages, resulting in non-significant findings in sub-clinical samples. Indeed, support for the association between affective inflexibility and depression is stronger in clinical samples (Deveney & Deldin, 2006; Murphy et al., 2012). The use of a non-clinical sample may have obscured any significant associations between current depressive symptoms and affective flexibility in the present study; future research should examine affective flexibility in clinical and high-risk samples using a longitudinal design.

Contrary to our hypothesis, post-stress affective flexibility did not predict depressive symptoms better than pre-stress affective flexibility. This finding is in contrast with a study that found an association between prospective depressive symptoms and post-stress, but not pre-stress, performance on an emotional N-back task (Quinn & Joormann, 2015). It is possible that the completion of the AST in and of itself was stress-inducing (see Supplementary Material S2 for more information). That is, performance on the pre-stress AST in the current study may also reflect affective flexibility under stress, obscuring the distinction between pre- and post-stress affective flexibility. More studies are needed to understand the effects of stress on affective flexibility in depression.

Biased affective flexibility may contribute to depression by increasing rumination. Slower shifting from negative aspects of stimuli may lead to prolonged processing of negative information, which can increase rumination (e.g., Joormann & D'Avanzato, 2010; Koster, De Lissnyder, Derakshan, & De Raedt, 2011). Indeed, slower shifting from emotional aspects of negative images on the AST was correlated with higher levels of daily rumination (Genet, Malooly, & Siemer, 2013). Rumination also fully mediated the association between negative affective SCs on the IST and depressive symptoms one year later (Demeyer, De Lissnyder, Koster, & De Raedt, 2012).

Affective inflexibility may also influence other cognitive biases, such as interpretation and memory biases (Everaert, Grahek, & Koster, 2017; Hirsch, Clark, & Mathews, 2006). Prolonged processing of negative material resulting from difficulty shifting from emotional aspects of negative stimuli can lead to a negative interpretation of the situation, which in turn may lead to a negative recall of the event (Koster, Fox, & MacLeod, 2009; Tran, Hertel, & Joormann, 2011). Thus, more negative thoughts and memories may be available, which can further activate depressive schemata. Ultimately, this cycle of biased information processing could worsen depressive symptoms.

A number of methodological features strengthen our conclusions. First, the sample size of the study was determined based on a power analysis and was considerably larger than similar studies using non-clinical samples. Second, our prospective design allowed the examination of affective flexibility in relation to current and prospective depressive symptoms. Finally, the AST may be a better measure of affective flexibility as defined by shifting between multiple rules or tasks (Miyake et al., 2000) than other tasks employed in previous studies, which were likely confounded by other cognitive processes. For example, in addition to affective flexibility, the go/no-go task (Murphy et al., 1999) requires response inhibition, and the WCST (Heaton, 1981) requires abstract reasoning.

Several limitations are worth noting. As discussed earlier, the use of a non-clinical sample and the stress-inducing nature of the AST may have obscured associations between biased affective flexibility and depressive symptoms. Second, although we used a frequently employed stress induction procedure, it is different from stressful life events that tend to trigger depression. Third, similar to other bias indices based on difference scores (e.g., attentional bias scores from the dot-probe task; e.g., Schmukle, 2005), the split-half reliability for the SCs in the current study was subpar (see Supplementary Material S3). Although the analyses using the SCs and the RTs yielded consistent results, the current findings should be interpreted with caution. Furthermore, the contextual demands of cognitive tasks are less complex than that of real-life situations. Thus, future research should focus on improving measures to capture affective flexibility more reliably and in a more ecologically valid manner.

Notwithstanding these limitations, the present study is the first to examine valence-specific biases in affective flexibility before and after a stressor in relation to both current and prospective depressive symptoms. Slower shifting from emotional aspects of negative material prior to the stressor uniquely predicted higher follow-up depressive symptoms. This negative bias in affective flexibility may make it difficult to disengage from negative information, thereby exacerbating depressive symptoms. Further research on the mechanisms by which this bias maintains depressive symptoms could help identify novel treatment targets for depression.

Declaration of competing interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2019.103502.

References

Aker, M., Harmer, C., & Landrø, I. I. (2014). More rumination and less effective emotion regulation in previously depressed women with preserved executive functions. *BMC Psychiatry*. https://doi.org/10.1186/s12888-014-0334-4.

Baumeister, R. F. (2002). Ego depletion and self-control failure: An energy model of the self's executive function. *Self and Identity, 1*, 129–136. https://doi.org/10.1080/152988602317319302.

Carleton, R. N., Thibodeau, M. A., Teale, M. J., Welch, P. G., Abrams, M. P., Robinson, T., et al. (2013). The center for epidemiologic studies depression scale: A review with a theoretical and empirical examination of item content and factor structure. *PLoS One, 8*(3), e58067. https://doi.org/10.1371/journal.pone.0058067.

Chajut, E., & Algom, D. (2003). Selective attention improves under stress: Implications for theories of social cognition. *Journal of Personality and Social Psychology, 85*(2), 231–248. https://doi.org/10.1037/0022-3514.85.2.231.

Dajani, D. R., & Uddin, L. Q. (2015). Demystifying cognitive flexibility: Implications for clinical and developmental neuroscience. *Trends in Neurosciences, 38*(9), 571–578. https://doi.org/10.1016/j.tins.2015.07.003.

De Lissnyder, E., Koster, E. H. W., Everaert, J., Schacht, R., Van den Abeele, D., & De Raedt, R. (2012). Internal cognitive control in clinical depression: General but no emotion-specific impairments. *Psychiatry Research, 199*(2), 124–130. https://doi.org/10.1016/j.psychres.2012.04.019.

De Lissnyder, E., Koster, E. H. W., Goubert, L., Onraedt, T., Vanderhasselt, M.-A., & De Raedt, R. (2012). Cognitive control moderates the association between stress and rumination. *Journal of Behavior Therapy and Experimental Psychiatry, 43*(1), 519–525. https://doi.org/10.1016/j.jbtep.2011.07.004.

Demeyer, I., De Lissnyder, E., Koster, E. H. W., & De Raedt, R. (2012). Rumination

mediates the relationship between impaired cognitive control for emotional information and depressive symptoms: A prospective study in remitted depressed adults. *Behaviour Research and Therapy*. https://doi.org/10.1016/j.brat.2012.02.012.
Deveney, C., & Deldin, P. (2006). A preliminary investigation of cognitive flexibility for emotional information in major depressive disorder and non-psychiatric controls. *Emotion*. https://doi.org/10.1037/1528-3542.6.3.429.
English, T., & Carstensen, L. L. (2014). Emotional experience in the mornings and the evenings: Consideration of age differences in specific emotions by time of day. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2014.00185.
Everaert, J., Grahek, I., & Koster, E. H. W. (2017). Individual differences in cognitive control over emotional material modulate cognitive biases linked to depressive symptoms. *Cognition & Emotion*. https://doi.org/10.1080/02699931.2016.1144562.
Genet, J. J., Malooly, A. M., & Siemer, M. (2013). Flexibility is not always adaptive: Affective flexibility and inflexibility predict rumination use in everyday life. *Cognition & Emotion, 27*(4), 685–695. https://doi.org/10.1080/02699931.2012.733351.
Genet, J. J., & Siemer, M. (2011). Flexible control in processing affective and non-affective material predicts individual differences in trait resilience. *Cognition & Emotion, 25*(2), 380–388. https://doi.org/10.1080/02699931.2010.491647.
Gotlib, I. H., & Joormann, J. (2010). Cognition and depression: Current status and future directions. *Annual Review of Clinical Psychology, 6*, 285–312. https://doi.org/10.1146/annurev.clinpsy.121208.131305.
Grol, M., & De Raedt, R. (2018). The effect of positive mood on flexible processing of affective information. *Emotion, 18*(6), 819. https://doi.org/10.1037/emo0000355.
Heaton, R. K. (1981). *A manual for the Wisconsin card sorting test.* Western Psychological Services.
Hirsch, C. R., Clark, D. M., & Mathews, A. (2006). Imagery and interpretations in social phobia: Support for the combined cognitive biases hypothesis. *Behavior Therapy*. https://doi.org/10.1016/j.beth.2006.02.001.
Howe, G. W., Reiss, D., & Yuh, J. (2002). Can prevention trials test theories of etiology? *Development and Psychopathology, 14*(4), 673–694. https://doi.org/10.1017/S0954579402004029.
Joormann, J., & D'Avanzato, C. (2010). Cognition & emotion lecture at the 2009 ISRE meeting: Emotion regulation in depression: Examining the role of cognitive processes. *Cognition & Emotion*. https://doi.org/10.1080/02699931003784939.
Kashdan, T. B., & Rottenberg, J. (2010). Psychological flexibility as a fundamental aspect of health. *Clinical Psychology Review, 30*(7), 865–878. https://doi.org/10.1016/j.cpr.2010.03.001.
Koster, E. H. W., De Lissnyder, E., & De Raedt, R. (2013). Rumination is characterized by valence-specific impairments in switching of attention. *Acta Psychologica*. https://doi.org/10.1016/j.actpsy.2013.09.008.
Koster, E. H. W., De Lissnyder, E., Derakshan, N., & De Raedt, R. (2011). Understanding depressive rumination from a cognitive science perspective: The impaired disengagement hypothesis. *Clinical Psychology Review, 31*(1), 138–145. https://doi.org/10.1016/j.cpr.2010.08.005.
Koster, E. H. W., Fox, E., & MacLeod, C. (2009). Introduction to the special section on cognitive bias modification in emotional disorders. *Journal of Abnormal Psychology*. https://doi.org/10.1037/a0014379.
Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International affective picture system (IAPS): affective ratings of pictures and instruction manual.* Gainesville: University of Florida Tech Rep A-8.
Lee, R. S. C., Redoblado-Hodge, M. A., Naismith, S. L., Hermens, D. F., Porter, M. A., & Hickie, I. B. (2013). Cognitive remediation improves memory and psychosocial functioning in first-episode psychiatric out-patients. *Psychological Medicine, 43*(6), 1161–1173. https://doi.org/10.1017/S0033291712002127.
Lo, B. C. Y., & Allen, N. B. (2011). Affective bias in internal attention shifting among depressed youth. *Psychiatry Research, 187*(1–2), 125–129. https://doi.org/10.1016/j.psychres.2010.10.001.
MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology*. https://doi.org/10.1037/0021-843X.111.1.107.
Malooly, A. M., Genet, J. J., & Siemer, M. (2013). Individual differences in reappraisal effectiveness: The role of affective flexibility. *Emotion, 13*(2), 302–313. https://doi.org/10.1037/a0029980.
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*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734.
Murphy, F. C., Michael, A., & Sahakian, B. J. (2012). Emotion modulates cognitive flexibility in patients with major depression. *Psychological Medicine*. https://doi.org/10.1017/S0033291711002418.
Murphy, F. C., Sahakian, B. J., Rubinsztein, J. S., Michael, A., Rogers, R. D., Robbins, T. W., et al. (1999). Emotional bias and inhibitory control processes in mania and depression. *Psychological Medicine, 29*(6), 1307–1321. https://doi.org/10.1017/s0033291799001233.
Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking rumination. *Perspectives on Psychological Science, 3*(5), 400–424. https://doi.org/10.1111/j.1745-6924.2008.00088.
Quinn, M. E., & Joormann, J. (2015). Control when it counts: Change in executive control under stress predicts depression symptoms. *Emotion, 15*(4), 522–530. https://doi.org/10.1037/emo0000089.
Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement, 1*(3), 385–401. https://doi.org/10.1177/014662167700100306.
van Randenborgh, A., Hüffmeier, J., LeMoult, J., & Joormann, J. (2010). Letting go of unmet goals: Does self-focused rumination impair goal disengagement? *Motivation and Emotion*. https://doi.org/10.1007/s11031-010-9190-9.
Schmukle, S. C. (2005). Unreliability of the dot probe task. *European Journal of Personality: Published for the European Association of Personality Psychology, 19*(7), 595–605.
Scott, W. A. (1962). Cognitive complexity and cognitive flexibility. *Sociometry*. https://doi.org/10.2307/2785779.
Shields, G. S., Moons, W. G., & Slavich, G. M. (2017). Better executive function under stress mitigates the effects of recent life stress exposure on health in young adults. *Stressforskningsrapporter*. https://doi.org/10.1080/10253890.2017.1286322.
Steinhauser, M., Maier, M., & Hübner, R. (2007). Cognitive control under stress: How stress affects strategies of task-set reconfiguration: Research article. *Psychological Science, 18*(6), 540–545. https://doi.org/10.1111/j.1467-9280.2007.01935.x.
Sweeney, P. D., Anderson, K., & Bailey, S. (1986). Attributional style in depression: A meta-analytic review. *Journal of Personality and Social Psychology, 50*(5), 974. https://doi.org/10.1037//0022-3514.50.5.974.
Tran, T. B., Hertel, P. T., & Joormann, J. (2011). Cognitive bias modification: Induced interpretive biases affect memory. *Emotion*. https://doi.org/10.1037/a0021754.
Van Dam, N. T., & Earleywine, M. (2011). Validation of the center for epidemiologic studies depression scale—revised (CESD-R): Pragmatic depression assessment in the general population. *Psychiatry Research, 186*(1), 128–132. https://doi.org/10.1016/j.psychres.2010.08.018.
Vergara-Lopez, C., Lopez-Vergara, H. I., & Roberts, J. E. (2016). Testing a "content meets process" model of depression vulnerability and rumination: Exploring the moderating role of set-shifting deficits. *Journal of Behavior Therapy and Experimental Psychiatry, 50*, 201–208. https://doi.org/10.1016/j.jbtep.2015.08.002.