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Depressive symptoms and persistent negative self-referent thinking among adolescents: A learning account

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ABSTRACT

Learning theories of depression propose that negative thinking is acquired through subsequent rewarding experiences and is often resistant to change even when it becomes associated with punishment. We examined whether this persistency of negative thinking is related to current and future levels of depressive symptoms among adolescents. Persistency of negative self-referent thinking was assessed by means of a decision-making task, namely the emotional reversal learning task. This task offers participants the choice between thinking about negative and positive self-related aspects. Their choice for negative self-referent thinking is initially rewarded but is later punished. Therefore, participants were expected to efficiently switch between negative and positive self-referent thinking, and to internally update their reward expectancy for these thinking options. Results showed that persistency of negative self-referent thinking was related to concurrent levels of depressive symptoms, replicating earlier findings in adults. However, persistency of negative thinking was unrelated to future levels of depressive symptoms. These findings suggest that adolescents with depressive symptoms tend to hold on to the belief that negative self-referent thinking has beneficial consequences, even when it is no longer being rewarded. This tendency should be seen as a concurrent feature of depression, as the predictive value is still in question.

1. Introduction

Negatively biased information processing has been established as a cognitive hallmark of depression. Theories have highlighted negative views of the self, the world and the future among depressed individuals (Beck, 1976; Ingram et al., 1983), and empirical evidence has shown that depressive cognition can be characterized by negative biases in memory, interpretation and attention (Gotlib & Joormann, 2010). Results have also been presented suggesting that the negative biases are most prominent in the processing of self-relevant stimuli (e.g., I am unhappy) – indeed, there is consistent evidence that negatively biased self-referent processing (e.g., "I am untrustworthy" instead of "I am trustworthy") is associated with depressive symptoms and episodes (e.g., Iijima et al., 2017; Mogg & Bradley, 2005; Neshat-doost et al., 1998). More importantly, this biased processing style has been shown to predict the future onset of depression and relapse (LeMoult et al., 2017).

Although the majority of cognitive research into depression has been conducted in adults, several studies have documented a link between a negative self-referent processing bias and depressive symptoms in 12-year-old adolescents (Connolly et al., 2016; Jacobs et al., 2008). Similar to the studies in adults, the processing bias, which was operationalized as an increase in reaction time for negative attributes and enhanced recall of negative attributes about the self, was found to be predictive of current and future levels of depressive symptoms (Connolly et al., 2016). Another interesting finding from developmental research is that this bias interacted with rumination to predict depressive symptoms (Black & Pössel, 2013), which may indicate that the repetitiveness and persistency (i.e., the ruminative components) of negative self-referent thinking are key to understanding cognitive vulnerability to depression. Given that cognitive functions such as attention and memory mature during adolescence (Boelema et al., 2014), it is reasonable to assume that this maladaptive, ruminative processing style is acquired during this (or an even earlier) developmental stage. In the current study, we aimed to expand our knowledge of cognitive vulnerability in

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adolescents on the following two points. First, we specifically targeted the persistency of negative self-referent thinking as a putative predictor of depressive symptoms. Our unique contribution is the operationalization of persistency by means of a behavioral (as opposed to self-report) measure using a modified version of the reversal learning task. Second, we explicitly tested the prospective effect of persistency on future (i.e., two-month follow-up) levels of depressive symptoms.

The behavioral task used here is the emotional and self-referent version of the reversal learning task (Emotional Reversal Learning Task, ERLT). The ERLT was developed to assess the difficulty associated with updating reward expectancy for negative self-referent thinking as an experimental analogy of the "stickiness" of depressive cognition. This decision-making task requires participants to repeatedly choose between thinking about negative and positive aspects of the self, and this choice behavior is experimentally reinforced through economic reward and punishment (Fig. 1). A key component of the task is that participants are initially rewarded for choosing the negative valence option (i.e., the choice to think about a negative self-related aspect) – crucially, this contingency is reversed at a later point. Participants are therefore prompted to discard their initially acquired belief that the choice for the negative valence option will be rewarded and are then expected to adapt and choose the positive valence option (cf. Izquierdo et al., 2017). Studies in adults found that concurrent depressive symptoms are associated with a significant delay in updating the reward expectancy and thus in adapting the response according to the contingency reversal (Iijima et al., 2017; Takano et al., 2019). This delay was indexed by a computational parameter, namely a learning rate, reflecting the extent to which people modulate their reward expectancy after obtaining an unexpected result for their chosen response. Depressive symptoms have therefore been found to be associated with a low learning rate for negative self-referent thinking in previous ERLT studies, meaning that the people with relatively high(er) levels of depressive symptoms tend to persist in choosing to think about negative aspects of the self, even when this choice option is no longer rewarded.

The ERLT is based on a learning theoretical account of depression (Ramnerö et al., 2016; Watkins & Nolen-Hoeksema, 2014), which proposes that negative self-referent thinking is a selected action, like any other behavior, controlled by positive and negative reinforcement. As possible positive reinforcement in daily life, people may receive genuine support and concerns from others when they express negative personal thoughts and feelings (Coyne, 1976). Also, thinking a lot about the self and related (negative) themes may sometimes help people to analyze and resolve problems (Treynor et al., 2003; Watkins, 2008). As an example of negative reinforcement, thinking negatively about oneself may reduce emotional distress because one can avoid or ward off even more aversive situations by not taking overt actions (Watkins & Nolen-Hoeksema, 2014). Even though negative self-referent thinking can have beneficial consequences, it has clear adverse effects in many cases. Negative thoughts are known to increase negative affect (e.g., Watters & Williams, 2011) and excessive expressions of negative feelings to others may additionally lead to social rejection (Coyne, 1976). Such punishments should normally extinguish negative self-referent thinking (even with occasional reinforcement). However, previous research findings suggest that the nominal flexibility in behavioral adjustment (e.g., Behrens et al., 2007) is impaired in depression, as depressed individuals tend to stick to a particular thought and way of thinking (Davis & Nolen-Hoeksema, 2000; Koster et al., 2011). In line with these findings, the ERLT was developed to specifically assess this inflexibility in adjusting action selection for negative (and positive) self-referent thinking; that is, to capture how persistent people are in choosing to engage in negative self-referent thinking particularly when this action is no longer appropriate, i.e. no longer rewarded.

In summary, we aimed to provide experimental evidence that the persistency of negative self-referent thinking, as assessed by the ERLT, is predictive of depressive symptoms among adolescents. We hypothesized that a low learning rate, representing a delay in updating reward expectancy for negative self-referent thinking, would be associated with high levels of depressive symptoms at baseline (Hypothesis 1) and at a two-month follow-up timepoint (Hypothesis 2). Although the primary interest was to see how adolescents would update their reward expectancy for the negative valence choice following punishment, the modeling approach adopted here allowed for the exploration of learning rates for other conditions as well; specifically, 2 × 2 learning rates were computed for each valence (i.e., negative and positive) and outcome (i.e., reward and punishment). And, thus, we examined whether these learning rates (e.g., fast learning of the negative valence choice after receiving reward) would also be associated with depressive symptoms.

2. Methods

2.1. Participants

Our sample consisted of adolescents in the last two years of three secondary schools in Belgium. In total, 145 participants (49 [34 %] boys and 96 [66 %] girls) completed all baseline measures. At the two-month follow-up, five students did not participate because they were absent at the school on the day of assessment. The age range at baseline was 16 to 19 years ($M = 17.08$; $SD = 0.76$). Sample size calculation was based on a Cohen's d effect size of $d = 0.82$ ($r = 0.38$) for a correlation between depressive symptoms and the learning rate, as observed in previous studies in adults (Iijima et al., 2017). Power analysis with G*power (Erdfelder et al., 2009) indicated a required sample size of 58 to detect a significant effect under alpha = 0.05 and power = 0.80. We aimed to oversample participants because we expected that there would be some attrition at follow-up and that the prospective effects would be smaller than the cross-sectional effects that have been reported in previous

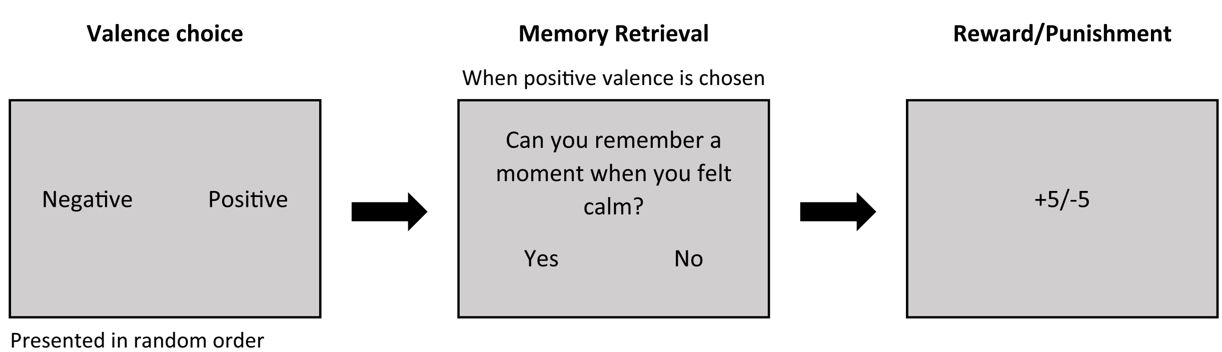

Fig. 1. A schematic flow of a trial of the Emotional Reversal Learning Task
Note: Each trial of the Emotional Reversal Learning Task consists of a valence choice, which is either negative or positive. The valence choice is followed by memory retrieval of a given cue word with the same valence chosen by the participant. After the participant's response or after 20 s, participants will receive either reward or punishment probabilistically depending on their valence choice.

cross-sectional studies in adults.

2.2. Measures

Participants completed the Depression subscale of the Depression Anxiety Stress Scales (DASS-7; Lovibond & Lovibond, 1995), which was used as a measure for depressive symptomatology. The DASS-7 consists of 7 items. Participants are prompted to reflect on the applicability of each item during the past week on a scale from 0 (*not at all*) to 3 (*applies most of the time*). Good validity and reliability have been reported (Lovibond & Lovibond, 1995). The depression subscale in our study had an internal consistency of Cronbach's alpha = 0.84. Additional questionnaires were also administered, but this was not in the context of the main research questions and hypotheses of this paper (For more information, see the supplementary material).

2.2.1. Emotional reversal learning task

In the Emotional Reversal Learning Task (Fig. 1), each trial starts with a valence choice, where participants are asked to choose between positive and negative valence by pressing the "left" or "right" key (the two valence options are presented horizontally with the locations randomized across trials). Next, participants are presented with an emotional cue word that corresponds to the valence they have chosen, and are then asked to retrieve a personal memory that the cue word reminds them of. The instruction for the memory retrieval is worded as follows: "Can you remember a moment at which you felt [agitated]" (different adjectives appear in the bracket across trials). The positive and negative cue words were adapted from a previous study (Takano et al., 2019), and include sets of antonyms with matched valence and arousal selected from a pre-established database of Dutch emotional words (Moors et al., 2013). When participants are able to retrieve a memory, they press the "8" key (and if not, they are instructed to press the "9" key) within 20 s of the presentation of the cue word. Only when participants indicate that they were able to retrieve a memory, do they receive either a reward or punishment, displayed as point tokens (i.e., + 5 and – 5 points). When no memory is retrieved, punishment (– 5 points) is provided. Participants are informed that (a) reward and punishment are provided probabilistically depending on their choice of valence; (b) one of the two valence choices is more likely to be followed by reward than the other valence choice; (c) the contingency can change during the task, although the exact timing of the contingency change is not given; and (d) they will be asked afterwards to describe the memories they claimed to have retrieved during the ERLT. However, in reality participants were not asked to describe their memories at the end.

The contingency changes twice during the task, so that there are three phases of 20 trials (60 trials in total): (a) acquisition phase, where the negative choice is rewarded at a probability of 80 % and punished at 20 %; (b) first reversal phase, where the negative choice is more likely to be punished (80 %) than rewarded (20 %); and (c) the second reversal phase, where the negative choice is again more likely to be rewarded (80 %) than punished (20 %), and vice versa for the positive choice. We did not explicitly train each participant to the same level of acquisition. This was because: (a) previous research suggested that 20 trials would be sufficient to achieve a good level of acquisition (Iijima et al., 2017), and substantial individual differences in the acquisition phase were therefore not expected; (b) the task was designed to be as short as possible in order to keep adolescents motivated; and (c) individual differences in the level of acquisition can be, if present, modeled by the learning rates, which were then statistically controlled in our main (multiple regressions) analyses. To motivate participants to retrieve a memory, they are informed that they will receive a punishment (−5 points) if they are not able to retrieve a memory. This punishment replaces the probabilistic reward/punishment they would receive if they were able to retrieve a memory. Prior to the main trials, participants complete four practice trials. Participants are informed that if the total amount of points that they obtain during the task exceeds a certain criterion, they would receive a voucher (worth €10). However, they are not explicitly instructed to maximize their total amount of points. In order to prevent participants' reward devaluation during the task, the exact criterion is not mentioned.

2.2.2. Procedure

Participants were tested collectively in a classroom at school. Following written consent, all participants completed a booklet of questionnaires, including the DASS. After filling out the questionnaires, they read the instructions for the ERLT on the computer screen and completed the ERLT. At the end of the experiment, all participants received a mood-lifting procedure (Hepburn et al., 2006; Nelis, 2014), as engaging in the retrieval of negative memories could lead to a small decline in mood. Adolescents were collectively tested again two months later in order to reassess participants during the same school year and therefore prevent high drop-out. All participants filled out the same booklet of questionnaires again – the ERLT was not re-administered at this second visit. Following the completion of the questionnaires, participants were debriefed, and the vouchers were given to participants who had exceeded the criterion on the ERLT. The study was approved by the Social and Societal Ethics Committee of KU Leuven (G-2018 01 1089/G-2018 01 1090).

2.2.3. Statistical analyses

The statistical analysis consisted of two parts. First, we modeled participants' choice behavior to estimate the learning rates for individual participants, i.e., the delay in updating reward expectancies. Second, we tested the association between the updating delay and depressive symptoms (at baseline and at follow-up).

2.2.4. Q-learning model

Participants' choices in the ERLT were modeled by a Q-learning algorithm (Sutton & Barto, 2012), with which the four learning rates of interest for each participant were estimated. The Q-learning model assumes that participants implicitly or explicitly estimate the probability of receiving reward for each valence choice at each trial (i.e., reward expectancy) and update their reward expectancy based on the most recent outcome (reward or punishment) of their choice. When participants perceive a large discrepancy between the expected and actual outcome (i.e., prediction error), they typically make a large adjustment to their reward expectancy. This updating process is referred as the Rescorla-Wagner Rule (Rescorla & Wagner, 1972), which was formulated in our analyses as follows:

$$Q_v(t+1) = Q_v(t) + \alpha_{v.r}(R(t) - Q_v(t))$$

Here, the current reward expectancy, $Q_v(t)$, is updated by the prediction error, defined as the difference between the outcome and the current expectancy, $R(t) - Q_v(t)$. Reward expectancy was defined for each valence choice (denoted as v, taking either "positive" or "negative"). The prediction error is weighted by the learning rate, $\alpha_{v.r}$, which determines the extent of adjustment in each update of reward expectancy. We assumed that the learning rate varied across positive versus negative valence choices (Iijima et al., 2017) and punished versus rewarded trials (denoted as r; Dombrovski et al., 2010), which resulted in four learning rates to estimate. For example, the learning rate for trials in which the negative valence in chosen and is followed by reward will be denoted by $\alpha_{negative.\ reward}$. The probability of choosing the negative choice at a given trial, $P_{neg}(t)$, was represented by a softmax function of the difference in reward expectancy between the two valence options:

$$P_{neg}(t) = \frac{1}{1 + e^{\left(-\beta\left(Q_{v=neg}(t) - Q_{v=pos}(t)\right)\right)}}$$

The balance between exploitation and exploration was controlled by β, with a smaller value indicating that exploitation is more encouraged. Hierarchical Bayesian (HB) estimation was performed using Rstan to obtain optimal parameter estimates for each participant (Hoffman & Gelman, 2014; Stan Development Team, 2015). We found no convergence issues in the parameter estimation, and our model fitted the data well (and better than alternative models) – the technical details can be found in the supplementary materials, including the prior distributions, sampling method and model selection process.

2.2.5. Multiple regression analyses

The four estimated learning rates were entered into multiple regression analyses predicting the baseline (Hypothesis 1) and follow-up (Hypothesis 2) levels of depressive symptoms. To establish the prospective effect of the learning rate(s), the baseline levels of depressive symptoms were controlled for when predicting the follow-up levels. Age and gender were entered in each model as control variables.

3. Results

As a manipulation check, we first examined participants' performance on the ERLT. The rate of memory retrieval for positive and negative cue words was $M = 0.87$ ($SD = 0.33$) and $M = 0.86$ ($SD = 0.34$), respectively. Table 1 shows the mean frequencies of negative choices for each phase of the ERLT trials (i.e., acquisition and first- and second-reversal phases). As expected, a repeated-measures ANOVA indicated significant changes in choice behavior across the three phases, $F(2,288) = 21.34$, $p < .001$, $\eta^2 = 0.129$, characterized by the significant decrease in negative choices between the acquisition and first reversal phase, $t(142) = 5.95$, $p < .001$, $d = 0.49$; and by the significant increase between the first and second reversal phase, $t(142) = -5.21$, $p < .001$, $d = -0.43$ (p-values were Bonferroni-corrected for multiple tests). Descriptive statistics of depressive symptoms, ERLT measures and age as well as their correlations are shown in Table 1. Gender differences for ERLT measures are displayed in Table 2.

The first hypothesis pertained to the cross-sectional relations between learning rates and baseline depressive symptoms. In that context, we estimated a multiple regression model where baseline depressive symptoms were predicted by all four learning rates (Table 3). In line with Hypothesis 1, the results indicated a significant negative effect of $\alpha_{negative.\ punishment}$, implying that depressive symptoms are associated with a significant delay in reducing reward expectancy for the negative choice after punishment was provided. The association between depressive symptoms and $\alpha_{negative.\ punishment}$ is visualized by a scatterplot (Fig. 2A). This scatterplot may suggest that the association might be biased by some influential outliers. To investigate how big of an influence these participants had on the results of the regression analysis, we computed a Cook's distance (D) for each participant. This index provided, however, no evidence for influential datapoints (all $Ds < 1$). Additionally, we performed a robust linear regression analysis, and found that the results were unchanged; namely, $\alpha_{negative.\ punishment}$ was significantly negatively related to depressive symptoms (Table 4).

A parallel multiple regression analysis was performed to address the second hypothesis related to the prospective relations between learning rates and depressive symptoms at the second measurement point two months later. In this analysis, follow-up levels of depressive symptoms were predicted by all four learning rates while controlling for the baseline levels of depressive symptoms (Table 3). Contrary to Hypothesis 2, the results indicated a null effect for $\alpha_{negative.\ punishment}$ (Fig. 2C). However, $\alpha_{negative.\ reward}$ showed a significant negative effect, indicating that a delay in increasing reward expectancy for the negative choice after being rewarded is predictive of a residual increase in depressive symptoms at the two-month follow-up (Fig. 2D).

Table 1
Means, standard deviations, and correlations with confidence intervals ($N = 145$).

Variable	M	SD	Correlation depressive symptoms T1	Correlation depressive symptoms T2
1. Depressive symptoms T1	4.64	3.80		
2. Depressive symptoms T2	4.03	3.52	0.66** [0.55; 0.74]	
3. Acquisition	0.46	0.18	0.26** [0.11, 0.41]	0.07 [−0.09; 0.24]
4. Reversal1	0.37	0.20	0.38** [0.23, 0.51]	0.26* [0.10; 0.41]
5. Reversal2	0.45	0.20	0.19* [0.03, 0.34]	0.06 [−0.11; 0.23]
6. $\alpha_{negative.\ reward}$	0.25	0.17	0.18* [−0.01; 0.33]	−0.03 [−0.20; 0.14]
7. $\alpha_{negative.\ punishment}$	0.68	0.14	−0.28** [−0.42; −0.12]	−0.11 [−0.27; 0.06]
8. $\alpha_{positive.\ reward}$	0.60	0.15	−0.13 [−0.29; 0.03]	−0.12 [−0.28; 0.05]
9. $\alpha_{positive.\ punishment}$	0.39	0.21	0.08 [−0.09; 0.24]	0.03 [−0.13; 0.20]
10. Age	17.08	0.77	0.01 [−0.15; 0.18]	−0.09 [−0.25; 0.08]

Note. Acquisition, Reversal 1 and Reversal 2 represent the frequency of negative choices (in proportion) for each phase of the ERLT. Values in square brackets indicate the 95 % confidence interval for each correlation.
* $p < .05$.
** $p < .001$.

Table 2
Gender differences for ERLT measures.

Variable	Gender	Mean	SD	p
$\alpha_{negative.\ reward}$	Male	0.201	0.146	0.02
	Female	0.268	0.173	
$\alpha_{negative.\ punishment}$	Male	0.670	0.151	0.75
	Female	0.678	0.136	
$\alpha_{positive.\ reward}$	Male	0.622	0.138	0.34
	Female	0.596	0.159	
$\alpha_{positive.\ punishment}$	Male	0.393	0.195	0.98
	Female	0.392	0.212	

4. Discussion

The current study investigated the persistency of negative self-referent thinking as a potential predictor of depressive symptoms among adolescents. We specifically focused on adolescence because this is a critical period in which most cognitive functions – including depressive cognition – are developed to maturity (Boelema et al., 2014). If depressive cognition is found to be a vulnerability factor for depressive psychopathology during a developmental period in which these processes are still developing, it could be an important target for prevention in this specific age group. The unique contribution here is that we provided behavioral evidence that depressive symptoms are cross-sectionally associated with the persistency of negative self-referent thinking, which was operationalized by a low learning rate in the ERLT, i.e., a delay in updating reward expectancy for choosing to engage in negative self-thinking followed by punishment. In other words, our results suggest that adolescents with depressive symptoms tend to maintain the belief that the negative valence choice (i.e., the choice to think about negative self-related aspects) has a positive consequence even when this valence choice is no longer being rewarded. However, this updating delay was not a significant predictor of future levels of depressive symptoms at follow-up.

Our findings from the cross-sectional analysis were overall in line with previous findings in adults (Iijima et al., 2017; Takano et al., 2019) and also with a learning theoretical account of depression (Ramnerö et al., 2016; Watkins & Nolen-Hoeksema, 2014). It has been proposed that negative self-referent thinking is acquired through subsequent

Table 3
Multiple regression predicting depressive symptoms.

IV	Unstandardized Estimate	*SE*	*Standardized Estimate*	*t*	*p*	95 % CI
DV = Depressive symptoms T1 ($N = 145$, $R^2 = 0.13$)						
Gender	1.03	0.66	0.13	1.55	0.123	[−0.28, 2.34]
Age	0.02	0.41	0.00	0.04	0.972	[−0.80, 0.83]
$\alpha_{negative.\ reward}$	3.28	2.02	0.14	1.62	0.107	[−0.72, 7.27]
$\alpha_{negative.\ punishment}$	−7.17	2.22	−0.27	−3.23	0.002	[−11.57, −2.78]
$\alpha_{positive.\ reward}$	−1.58	2.06	−0.06	−0.77	0.445	[−5.65 2.49]
$\alpha_{positive.\ punishment}$	0.35	1.58	0.02	0.22	0.827	[−2.79, 3.48]
DV = Depressive symptoms T2 ($N = 140$, $R^2 = 0.48$)						
Gender	0.89	0.49	0.12	1.81	0.072	[−0.08, 1.86]
Age	−0.57	0.30	−0.12	−1.90	0.059	[−1.16, 0.02]
Depressive symptoms T1	0.65	0.06	0.68	10.19	< 0.001	[0.52, 0.78]
$\alpha_{negative.\ reward}$	−4.34	1.47	−0.21	−2.94	0.004	[−7.25, −1.42]
$\alpha_{negative.\ punishment}$	1.10	1.81	0.04	0.31	0.543	[−2.47, 4.68]
$\alpha_{positive.\ reward}$	0.15	1.52	0.01	0.10	0.922	[−2.85, 3.15]
$\alpha_{positive.\ punishment}$	0.56	1.16	0.03	0.49	0.628	[−1.73, 2.86]

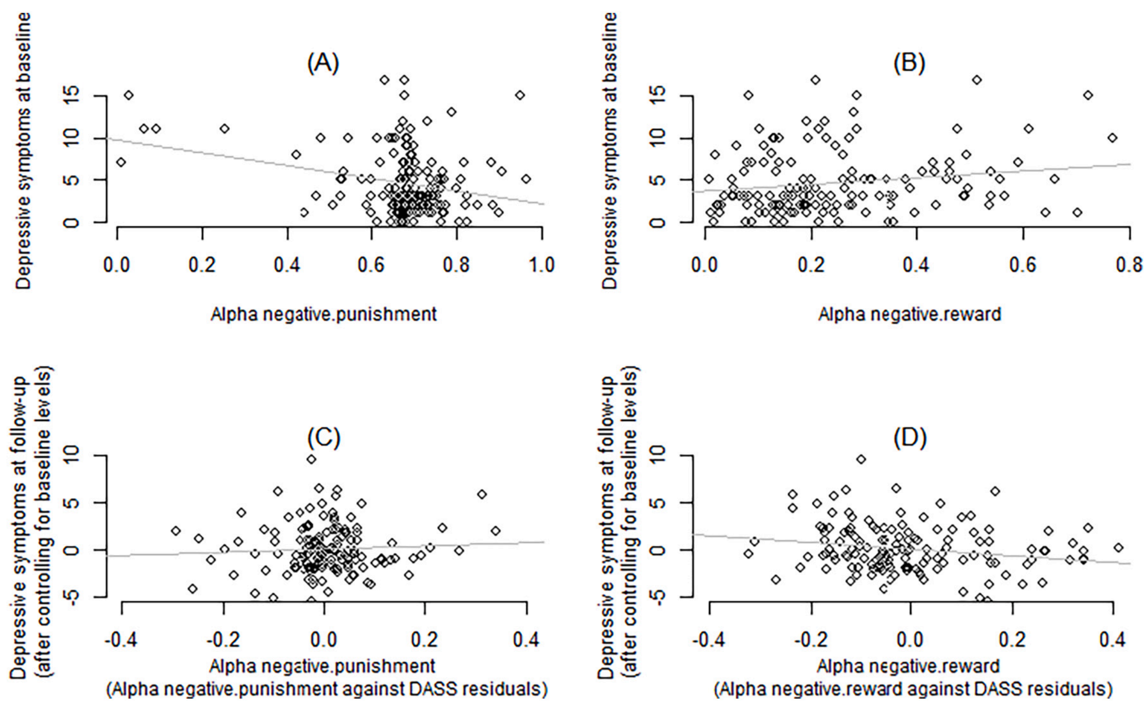

Fig. 2. Depressive symptoms at the baseline and follow-up as a function of learning rates for negative self-referent thinking followed by reward and punishment *Note:* Panel A and B visualize the associations between depressive symptoms at baseline and the learning rate for negative self-referent thinking followed by punishment (A) and the learning rate for negative self-referent thinking followed by reward (B). Panel C and D are partial regression plots displaying the association between depressive symptoms at follow-up and the learning rate for negative self-referent thinking followed by punishment (C) and the learning rate for negative self-referent thinking followed by reward (D) controlled for baseline depressive symptoms.

Table 4
Robust linear regression predicting baseline depressive symptoms.

IV	Estimate	*SE*	*t*	*p*
DV = Depressive symptoms T1				
Gender	0.64	0.60	1.06	0.29
Age	0.35	0.38	0.91	0.36
$\alpha_{negative.\ reward}$	2.89	1.81	1.60	0.11
$\alpha_{negative.\ punishment}$	−0.02	0.01	−2.24	0.03
$\alpha_{positive.\ reward}$	−2.13	1.82	−1.17	0.24
$\alpha_{positive.\ punishment}$	0.20	1.38	0.14	0.89

rewarding experiences. However, this acquired negative thinking is resistant to change in adolescents susceptible to depression, even when negative self-referent thinking is followed by punishment. This finding indicates that the persistent nature of negative self-referent thinking may be a feature of depressive symptomatology.

Contrary to our second hypothesis, our prospective analysis showed a non-significant effect of the learning rate $\alpha_{negative.punishement}$ on follow-up levels of depressive symptoms. Alongside the significant effect that was found in the cross-sectional analysis, this may suggest that this learning rate captures a concomitant cognitive feature of depression but not a vulnerability factor with causal connection to depression (risk). Still, it is worthwhile to consider methodological factors that may have prevented us from finding a significant prospective effect. For example, the interval between the baseline and follow-up assessment (i.e., two months) might have been too short to observe meaningful changes in depressive symptoms (Cole, 2006). This interval was chosen for a practical reason, i.e. to minimize drop-out in the follow-up session, as it is typically more difficult to maintain participation in this age group for a longer follow-up period.

The prospective analysis did, however, identify a significant (but unexpected) negative effect for another learning rate, $\alpha_{negative.reward}$. This negative effect suggests that a delay in increasing reward expectancy for the negative choice following reward is predictive of an increase in the level of depressive symptoms to follow-up. Although we do not have a ready explanation for this finding, it might be that not choosing for negative self-referent thinking reflects an act of avoiding negative thoughts about the self (Dickson, et al., 2012; Newman & Llera, 2011). Although such avoiding or suppressing of negative thoughts may seem adaptive (in the short run), this might just backfire and lead to an increase in negative self-referent thoughts in the longer run (Wegner et al., 1987).

Of course, our findings should be viewed in light of some limitations. First, we did not ask participants to write down the actual memories they retrieved in the ERLT. Therefore, we cannot be sure that all participants did actually retrieve memories when they indicated they did. As a measure to prevent this behavior, called satisficing (Krosnick, 1991), the experimenter told participants that they would be asked to write down some of their memories at the end of the experiment. We do believe that this instruction was clear for the participants, as some of them asked the experimenter at the end when they would be tested on the memories they claimed to have retrieved during the ERLT. Second, the reinforcement/punishment method used in the ERLT was just a point token system, whereas the learning theory focuses more on social outcomes. In order to increase the ecological validity of the ERLT paradigm, future research may want to consider a social form of reinforcement vs punishment. Third, it is still unclear whether our findings are specific to negative self-thinking or might apply to negative thinking in general (e.g., for negative other-referent thinking) or might apply to a general updating deficit (e.g., non-emotional version). Therefore, future research should explicitly examine if the self-other dimension, negative-positive valence, or general updating deficit (or all three) accounts for the observed effects on depressive symptoms. Similarly, in its current form, the ERLT does not allow us to make a clear distinction between an approach toward the negative response and avoidance of the positive response. Recent research has indicated that besides excessive negative self-referent thoughts, a lack of positive self-referent thoughts may additionally play a role in depressive symptomatology (Dunn & Roberts, 2016). Therefore, it would be interesting for future research to include a neutral self-referent response option to disentangle negative self-referent processing and positive self-referent processing. Fourth, no diagnostic interviews were administered. Therefore, the results cannot be generalized to adolescents with clinical levels of depressive symptomatology. It would be interesting for future research to replicate these findings in a sample of clinically depressed adolescents.

In conclusion, persistent negative self-referent thinking assessed by means of a behavioral paradigm such as the emotional reversal learning task is related to baseline depressive symptoms in an adolescent sample. This finding indicates that it is not only mere self-report of negative self-thoughts that is a feature of depressive cognition but also the persistent nature of the behavior to choose to think about negative self-related aspects such as personal memories. However, as suggested by our prospective findings, this persistency of negative self-referent thinking may not be a vulnerability factor of depressive symptomatology, in the sense that it would be causally involved in depressive symptomatology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2022.103823.

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