Remembering Happy Times Instead of Sticking to Negative Memories After Social Exclusion

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Abstract

Background & Objectives: Previous research shows that difficulty disengaging from negative (self-related) stimuli (i.e. negative self-referential processing; NSP) is a vulnerability factor for depression (Gotlib & Joormann, 2010) and contributes to its recurrence (LeMoult, Kircanski, Prasad, & Gotlib, 2017). The Emotional Reversal Learning Task (ERLT) was designed to investigate this, and we examined its construct validity by inducing social rejection, an etiological process of depression, within the ERLT model. We expected excluded participants to have difficulty disengaging from NSP.

Methods: We administered Cyberball to 130 participants randomly assigned to the excluded or included condition. Participants then completed the ERLT: They chose a valence option (positive or negative), retrieved a memory of the same valence, and then were rewarded or punished for their valence choice. For the first phase, retrieving a negative memory was probabilistically rewarded, and this action-outcome contingency was twice reversed during the task. We used Q-learning models to analyze learning rates.

Results: Excluded participants had no more difficulty disengaging from NSP than included participants: Bayesian computational modeling identified no difference between conditions regarding learning that retrieving negative memories was punished. Exploratory analyses found that excluded participants learned the association between retrieving positive memories and reward quicker than included participants, however.

Limitations: Doubts remain regarding whether participants fully understood action-outcome contingencies, and we did not explicitly check whether participants truly retrieved memories, which could have affected results.

Conclusions: We did not find support for the construct validity of the ERLT when using social exclusion to model depressogenic development within the ERLT.

Keywords: depression, social exclusion, reinforcement learning, Q-learning.

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1. Introduction

Negative self-referential processing (NSP) involves persistent negative thoughts about the self and has been implicated in both the occurrence and maintenance of depression (Gotlib & Joormann, 2010; LeMoult & Gotlib, 2018; Connolly et al., 2016). It has been specifically linked with the recurrence of depression for patients in remission, as well (LeMoult et al., 2017). It is still unclear, however, how this negativity bias develops and why it starts. A learning theory account characterizes depression as a set of maladaptive behaviors that could have distinct underlying pathologies, rather than as one cohesive biological syndrome (Ramnerö, Folke, & Kanter, 2016). This theory proposes that NSP may be initially reinforced by reward in the environment, which increases its frequency of occurrence (Ramnerö et al., 2016). For example, negative self-thinking could be perceived as beneficial or “rewarding” if expressing negative thoughts increases comfort and social support from others, or if NSP is perceived as leading to better self-understanding. Studies on self-verification motivation support this, suggesting that people with depression seek out negative appraisals from peers, to reinforce that their own negative self-views are reliable and coherent (Giesler, Josephs, & Swann, 1996; Swann, Krull, & Pelham, 1992). In addition, Tamir and Mitchell (2012) suggested that people find the combination of self-disclosure (i.e. thinking about the self) and sharing that information especially rewarding. Together, these findings suggest that people with depression tend to seek out confirmation of their negative self-views from others, and that they feel rewarded for sharing and verifying these views. These positive experiences that lead individuals to perceive NSP as rewarding would reinforce NSP at least in the short term. However, NSP has detrimental long-term consequences; for example, if an

individual communicates mainly by expressing negative self-thoughts, then social support may cease or even turn into social rejection (Ramnerö et al., 2016). After NSP has been learned and established, it might become more difficult to stop engaging in it. Indeed, individuals in remission from Major Depression Disorder (MDD) still tended to engage in NSP, and NSP at baseline predicted recurrence of a depressive episode over the next three years (LeMoult, Kircanski, Prasad, & Gotlib, 2017).

To operationalize how individuals respond to NSP that is initially rewarded but becomes punished after some time, the Emotional Reversal Learning Task (ERLT) was developed. This task adapts the basics of a reversal learning task, where participants have to learn which stimulus has a higher probability of being rewarded and update their reward prediction according to variable stimulus-reward contingency, since the stimulus linked with reward changes (Izquierdo & Jentsch, 2012). In the ERLT, however, the stimuli are negative and positive self-referential information. Participants have to make a choice between retrieving negative and positive memories, with negative memories being rewarded in the first phase (and positive memories being punished); in the second phase, this contingency is reversed (with negative memories punished and positive memories rewarded); in the third phase, the contingency is reversed again). In this way, the task assesses how quickly participants learn which valence choice (i.e. negative vs. positive memory) is linked with reward, or in other words, how quickly they update their reward expectancy. The ERLT can thus be used to model the flexibility of disengaging from learned NSP when beneficial outcomes change into detrimental ones.

Given the role of NSP as a vulnerability factor for depression, we would expect that people with depressive symptoms would continue to choose negative memory retrieval even when this choice is not rewarded anymore (or even actively punished). In other words, we would expect those individuals to take longer to update their reward expectancy after the

contingency reversal, which is represented by a lower *learning rate*. A learning rate is a parameter estimated by the Q-learning model (Watkins & Dayan, 1992) which quantifies, based on participants' choice behavior, their reward expectancy after a prediction error, or unanticipated outcome. Previous research has specifically investigated whether people with depression perform differently on reversal learning tasks compared with control participants, and have concluded that participants with depression show blunted reward responsiveness: they are less likely to respond to or feel motivated by reward (Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008). Reversal learning tasks specifically measure cognitive flexibility (Izquierdo, Brigman, Radke, Rudebeck, & Holmes, 2017), but it thus seems like lower learning rates by participants with depression is not due to impaired cognitive flexibility or reduced learning ability, since their blunted responsiveness is only to reward and not to punishment.

Indeed, previous studies using the ERLT have found that people with high rates of depressive symptoms show lower learning rates for negative self-referent information, especially when it stopped being rewarded. Iijima, Takano, Boddez, Raes, and Tanno (2017) found that participants with more depressive symptoms continued to choose to process negative self-referential information, even when it was no longer rewarded. In a study by Takano, Van Grieken, and Raes (2019), participants with more depressive symptoms took longer to update reward expectancies for punished trials when they had to switch from the negative to positive response. Lastly, in a study by Belmans, Takano, and Raes (in prep.), participants with more depressive symptoms showed more difficulty updating reward expectancies when choosing negative was suddenly punished, but they were able to update reward expectancies easily when choosing negative was suddenly rewarded. These studies therefore support that the ERLT has potential diagnostic validity (in the sense of Vervliet & Raes, 2013): individuals with increased depressive symptoms behave differently than

individuals with decreased depressive symptoms, exhibiting lower NSP learning rates (for negative, punished, or negative-punished trials, depending on the ERLT variant used).

Although the evidence seems to be in favor of the validity of the ERLT, further investigations are still warranted to establish its construct validity as a behavioral model of depression. This requires a reconstruction of the etiological processes that are relevant for depression within the model itself (Nestler & Hyman, 2010; Vervliet & Raes, 2013). Thus, in the current study, we examined whether learning rates for NSP (as given by the ERLT) are related to an already-established etiological factor for depression, i.e. social exclusion. The onset of depressive symptoms is crucially linked to a lack of environmental reinforcers (as occurs with isolation stemming from social rejection), leading to a cycle where individuals become more withdrawn and so then decrease their access to positive events and environmental rewards, and experience the resultant decrease in positive emotions and increase in negative ones, and withdraw even more (Ramnerö et al., 2016). In addition, learning theory posits that since rejection involves a lack of positive reinforcement, rejection itself also yields negative emotions (anger, sadness, and frustration), as well as self-referential negative dialogues to attempt to make meaning of the negative situation (Ramnerö et al., 2016). Rejection thus often leads to a removal from environmental rewards as well as NSP, both of which are associated with the onset of depressive symptoms.

This relationship between rejection, including developmental forms such as childhood neglect, and depressive symptoms is also supported by empirical research. Rejection is an established risk factor for developing depression: peer rejection robustly leads to loneliness, sadness and externalizing behaviors, and parental rejection increases the risk for depression (Van Orden & Joiner, 2013). Rejection sensitivity, when an individual expects and perceives rejection even when it is objectively absent, is also a predictor of depression (Ayduk, Downey, & Kim, 2001). In addition, experimentally inducing social exclusion consistently

increases depressed mood and decreases positive mood and self-esteem (Hartgerink, Van Beest, Wicherts, & Williams, 2015), all of which are key symptoms of depression. Thus, given the theoretical and empirical associations between rejection, NSP, and depression, we expected that induced social exclusion would be associated with lower learning rates of NSP. This would (at least partially) explain why individuals with increased levels of depressive symptoms start NSP: after experiencing negative circumstances which lower their self-esteem and produce a negative mood, they would have more difficulty disengaging from NSP.

Van Orden and Joiner (2013), as well as Williams (2007), explain that individuals who have repeatedly experienced rejection, especially during developmental periods such as with adverse childhood events, are more likely to develop depression in adulthood. In addition, since rejection is linked with NSP, repeated exposure to rejection would likely lead to NSP becoming a mental habit, especially since chronically thwarted goals, as perpetuated by abuse or trauma, are characterized as an environmental situation likely to lead to NSP (Watkins & Nolen-Hoeksema, 2014). Empirical evidence also supports this: previous victimization, such as with repeated bullying, increases sensitivity to rejection (Gao, Assink, Liu, Chan, & Ip, 2019; Lansu, van Noorden, & Deutz, 2017; Ruggieri, Bendixen, Gabriel, & Alsaker, 2013). Child abuse specifically is associated with increased rejection sensitivity, with especially high associations for emotional abuse and emotional neglect, potentially because these are early and overt forms of rejection (Erozkan, 2015). In addition, childhood emotional abuse and neglect are specifically associated with the later development of depression (Spinoven et al., 2010). Moreover, adverse childhood events have been theorized to foster negative biases about the self that are likely to become salient when experiencing later negative life events (Beck, 2008). This led us to expect that the frequency of childhood emotional abuse and neglect would moderate the relationship between exclusion and learning rate for NSP. As NSP is a theorized vulnerability factor for depression, we expected that

depressive symptoms would also moderate the relationship between exclusion and learning rate.

In summary, we investigated the construct validity of the ERLT by experimentally inducing social exclusion. We hypothesized that socially excluded participants would be more likely to have difficulty disengaging from NSP, or in other words stick to negative mental processes (i.e. choosing to retrieve negative memories), than those who were included, even when these negative processes were no longer rewarded. We further hypothesized that this relationship would be moderated by childhood abuse and depressive symptoms; more specifically, increased childhood emotional abuse and neglect, as well as increased depressive symptoms, would be associated with lower learning rates for NSP for socially excluded participants.

2. Materials and Methods

2.1 Participants

One hundred and thirty participants (116 women, 14 men; $M_{age} = 18.7$, $SD = 1.68$ years) were recruited through the Experiment Management system of the Psychology and Educational Sciences faculty at KU Leuven. Participants were mostly students, although community members could also participate, and were compensated with course credit or 8 euros. The only exclusion criteria were age (younger than 17 or older than 25) and non-fluency in Dutch. All participants gave written informed consent. The study was approved by KU Leuven's Social and Societal Ethics Committee. We pre-registered a sample size of 128 on the Open Science Framework, which can be found here: <https://osf.io/jc2u9/>¹; this sample size was based on a desired power of .80, alpha set to .05, and estimated effect size of $d = 0.50$ (moderate effect), calculated in G*power (Erdfelder, Faul, Buchner, & Lang, 2009). As we tested participants in small groups, our final sample size included 130 participants.

¹ We preregistered the hypotheses, methods, and analysis plan of the current study on November 5, 2018.

2.2 Measures

2.2.1 Inventory of Depressive Symptomatology – Self Report (IDS-SR). The Dutch-translated IDS was used to measure current depressive symptoms (IDS-SR; Akkerhuis, 1997). It consists of 30 items, each with four possible individualized answers scored from 0 to 3, in ascending order of symptom severity. Total scores range from 0 to 84, with larger scores indicating higher levels of depressive symptoms. For our sample, the Dutch-translated IDS showed good internal consistency (Cronbach's α of .85).

2.2.2 Childhood Trauma Questionnaire – Short Form (CTQ-SF). The CTQ was used to measure the occurrence and frequency of childhood traumatic events (CTQ-SF; Bernstein et al., 2003). The CTQ contains five subscales of five items each, measuring physical abuse, physical neglect, emotional neglect, emotional abuse and sexual abuse. Items are answered according to a five-point Likert scale, ranging from 1 (never) to 5 (very often). Each subscale yields a total score ranging from 5 to 25, except for the validated Dutch translation of the sexual abuse subscale, which contains only four items and so ranges from 5 to 20 (Thombs, Bernstein, Lobbestael, & Arntz, 2009). All Dutch-language subscales have good known-group validity (Thombs et al., 2009). For our sample, the Dutch-translated CTQ showed good internal consistency for the sexual abuse (Cronbach's α of .90), emotional abuse (α of .84), and emotional neglect (α of .91) subscales. Physical neglect (α of .46) and physical abuse (α of .24) showed very poor internal consistency, however.

2.2.3 Need Threat Scale (NTS). The NTS consists of eight items divided into four subscales (belongingness, control, self-esteem, and meaningful existence; Van Beest & Williams, 2006), as selected and translated by Van Harmelen and colleagues (2014). Participants were instructed to rate how much each statement applied to them on a scale from 1 to 5, with a larger score indicating increased applicability. This yielded a total score from 8 to 40, with lower scores corresponding to more feelings of threat toward belongingness,

control, self-esteem and meaningful existence. These items were used as a manipulation check, to assess the effectiveness of the Cyberball task in inducing social exclusion and its associated threat to belongingness and self-esteem. In our sample, the NTS scale had excellent internal consistency ($\alpha = .94$).

2.2.4 Mood measures. Participants were presented with 8 adjectives (good, relaxed, happy, friendly, bad, tense, sad, and unfriendly; Van Beest & Williams, 2006) and were asked to rate the extent to which each item applied to them using a five-point scale, leading to a total score from 8 to 40. We used the Dutch translations from Van Harmelen and colleagues (2014). These were also included as a manipulation check, to ensure that the Cyberball task successfully induced negative feelings in socially excluded participants. A larger total score indicated an overall more positive mood. In our sample, the mood scale had adequate internal consistency ($\alpha = .73$).

2.2.5 Cyberball. Cyberball is a widely used social exclusion paradigm that reliably induces feelings of social exclusion, with the associated high levels of negative mood and low levels of positive mood and self-esteem (Williams, Cheung, & Choi, 2000). Cyberball is a virtual ball-tossing game, where participants are randomly assigned to either the Inclusion or the Exclusion condition. In the version we used, participants played a game lasting 30 ball tosses against two other people, who they were told were other participants playing the task on an online platform. In reality, the other two were non-human computer players, tossing the ball according to pre-programmed instructions. In the Exclusion condition, participants received the ball only once at the beginning, while participants in the Inclusion condition received the ball an equal percentage of the time. Cyberball is a validated and frequently-used experimental manipulation of social inclusion and exclusion, reliably yielding feelings of ostracism in excluded participants (Hartgerink et al., 2015).

2.2.6 Emotional Reversal-Learning Task (ERLT). The ERLT measures persistent preference toward negative self-reference (see Figure 1 for an overview). The ERLT consisted of 4 practice trials (without reward or punishment) and 60 main trials. At each main trial of the task, participants were offered two emotional valence options: “negative” or “positive”. After they had chosen a valence options, they were instructed to retrieve a personal episodic memory with the valence of their choice. The memory prompts were adapted from a previous ERLT study (Takano et al., 2019), with each pair of positive and negative antonyms matched for both valence and arousal, as reported in a Dutch database of emotional words (Moors et al., 2013). As such, if participants chose positive as the valence option, they were asked to retrieve a memory in response to a positive prompt (e.g., “Can you remember a moment that you felt “calm”, “competent”, or “hopeful”); if they chose negative, they were asked to retrieve a memory in response to a negative cue (e.g., “agitated,” “incompetent”, “hopeless”). Participants were not instructed to retrieve a new memory every time (and as such not prohibited from retrieving the same memory multiple times), but they did receive a new memory prompt each trial. Participants then indicated whether or not they were able to retrieve a pertinent memory. Following this, participants received feedback of reward or punishment, which took the form of point tokens (e.g. ± 5 points), depending on their valence choice and if they were able to retrieve a memory. The valence-reward probabilistic contingencies followed three phases during the task. During the first phase, *acquisition*, the choice of negative valence was rewarded 80% of the time and punished 20%. During the second phase, called the *first reversal* phase, negative was punished 80% and rewarded 20%. Finally, during the last phase, termed the *second reversal*, the same valence-reward contingencies as during acquisition were applied: negative was rewarded 80% and punished 20%. These probabilities were all reversed for choosing the positive valence across phases (i.e. choosing the positive valence was rewarded 20% of the time during acquisition

and punished 80%, etc.). To motivate memory retrieval, participants were told that failure to retrieve a memory would result in punishment (i.e. -5 points).

Participants were informed that (a) one of the two valence choices was associated with a greater chance of reward, whereas the other option had a greater chance of punishment; (b) this valence-reward association would change during the task (see Supplementary Materials for more information). Participants were also told that the experimenter would ask them to write down a random subset of retrieved memories at the end of the task; this was to motivate participants' truthfulness in reporting a memory retrieval and was not actually implemented. To motivate participants to maximize their points, they were informed that if their points exceeded a certain percentile threshold, they would receive a voucher worth 10 euros.

2.3 Procedure

Participants filled out the IDS and CTQ questionnaires on Qualtrics. Afterward, participants completed the Cyberball task, for which they were randomly assigned to either the Exclusion or Inclusion condition. Immediately after the Cyberball task, participants answered the NTS and mood questions. Subsequently, participants completed the ERLT task. Because the Cyberball exclusion condition and the ERLT might have led to a slight drop in mood, participants took part in a validated mood-lifting procedure at the end of the study (e.g. Hepburn, Barnhofer, & Williams, 2006; Nelis, 2014). Participants were then fully debriefed.

2.4 Statistical Analyses

2.4.1 Q-learning. To estimate learning rates from participants' choice behavior, we used the computational model of Q-learning (Watkins & Dayan, 1992; Sutton & Barto, 1998), in a manner similar to Takano and colleagues (2019). The Q-learning model assumes that participants' choice behavior is determined by their expectancy of reward based on the most recent outcome (i.e. either reward or punishment) of their valence choice. When

participants perceive a large prediction error, their reward expectancy is updated for the next choice. This updating process is known as the Rescorla-Wagner rule (Rescorla & Wagner, 1972):

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

with v signifying the participants' choice made at trial t (i.e., negative or positive valence choice), and with r representing the outcome of the current trial (reward or punishment). The prediction error, given by the difference between the observed outcome $R(t)$ and reward expectancy $Q_v(t)$, is weighted by a learning rate $\alpha_{v,r}$, which reflects the speed of updating the reward expectancy across trials.

2.4.2 Parameter estimation. To obtain optimal individual parameter estimates, we used hierarchical Bayesian methods, characterized by multilevel distribution of parameters where individual-level parameters are drawn from a shared group-level distribution (e.g., Jahfari & Theeuwes, 2017). Parameter estimation was done using RStan (Stan Development Team, 2015). For specific information about parameters, model construction, transformation and priors, see Supplementary Materials.

2.4.3 Model selection. To validate our model, we estimated four variants of the Q-learning models: a) a model with one common learning rate for all trial and response types, b) variable learning rates for punished vs. rewarded trials (e.g. Takano et al., 2019), c) variable learning rates for negative vs. positive response choices (e.g. Iijima et al., 2017), or d) variable learning rates for negative-punished trials, negative-rewarded trials, positive-punished trials and positive-rewarded trials (e.g. Belmans et al., in prep.). The two models with two learning rates (i.e., b and c models) did not converge to stable estimates and were therefore not included in further analyses. In order to examine which of the remaining models (i.e., single vs. four learning rates) better fit the data, we calculated the Root Mean Square Error (RMSE) for observed vs. model-predicted choice responses. The RMSE of the four-

learning rate model was 0.66, 95% CI [0.64, 0.67], while the RMSE of the one-learning rate model was 0.70, 95% CI [0.69, 0.71]. As a smaller RMSE value indicates better comparative performance (Steiger & Lind, 1980), the four-learning rate model fit the data best and was thus used for all subsequent analyses. For all analyses, we focused on the learning rate that corresponded to persisting with NSP even when it was not rewarded; for the four-learning rate model, this was the negative-punished learning rate.

2.4.4 Moderation analyses. To investigate possible moderation of learning rates by depressive symptoms and frequency of childhood trauma, we conducted a two-step regression analysis. The first regression model included Cyberball as the main predictor, as well as the IDS and CTQ subscale scores as moderator variables, to see if the potential moderators had an effect on learning rate when controlling for Cyberball condition. To then see if these variables moderated the effect of exclusion on negative-punished learning rate, we conducted a second step, where we added the interaction of each moderator with Cyberball condition to the first model. If the coefficient for both interaction terms significantly differed from zero, then that variable indeed moderated the relationship of social exclusion to negative-punished learning rate (Hayes & Rockwood, 2017).

3. Results

The overall rate of memory retrieval was $M = .89$, $SD = 0.09$. Table 1 shows descriptive information about participants' negative choice frequency per phase as well their IDS and CTQ scores, and Table 2 shows correlations with the negative-punished learning rate and other ERLT measures.

3.1 Manipulation Check: ERLT

To ensure that participants successfully changed their choice behavior in response to the ERLT contingency reversals, we conducted a one-way repeated-measures ANOVA on the frequency of negative valence choice across the three phases. There was a significant effect

of ERLT phase, $F(2,384) = 14.88, p < .001, \eta^2 = 0.095$. We then conducted post-hoc Bonferroni-corrected comparisons and found that participants significantly decreased their frequency of choosing the negative option, $t(258) = 7.69, p < .001, d = 0.95$, from the acquisition phase to the first reversal. Participants then significantly increased their frequency of choosing the negative option, $t(258) = -7.24, p < .001, d = 0.90$, from the first reversal phase to the second.

3.2 Manipulation Check: Cyberball

Participants in the Included condition scored significantly higher on the NTS, $t(122.75) = 17.47, p < .001, d = 3.06$, than those in the Excluded condition (for group means, see Table 1). There was also a difference between Cyberball conditions for mood scores, $t(128) = 9.75, p < .001, d = 1.71$. Excluded participants rated themselves as having lower mood than Included participants. This suggests that the Exclusion condition of Cyberball successfully lowered both mood scores and need threat scores.

3.3 Group Differences: Sticking to the Negative

We found no evidence that the Included and Excluded conditions differed on their learning rates for negative punished trials, $t(126.45) = -1.80, p = .07, d = 0.32$ (see Figure 3).

3.4 Moderator Regression Analyses

Since there was no evidence of any interaction terms in the regression analysis significantly differing from zero (see Table 3), there was no evidence for IDS or CTQ moderating the effect of social exclusion on negative-punished learning rate.

3.5 Exploratory Analyses: Other learning rates

We also investigated, post-hoc, if there were differences between the Cyberball conditions for the other three learning rates in the final model with two-sided t-tests. There was no evidence of a difference between conditions for learning rates for positive-punished trials, $t(127.82) = -1.36, p = .18, d = -0.24$, or for negative-rewarded trials, $t(124.41) = -1.34$,

$p = .18$, $d = -0.24$. However, for the positive-rewarded trials, excluded participants showed a significantly higher learning rate than included participants, $t(125.87) = -2.33$, $p = .01$, $d = 0.41$. We also investigated whether depressive symptoms moderated this relationship with a regression model, with positive-rewarded learning rate as the outcome and IDS scores and Cyberball condition, as well as their interaction, as predictors, but found that no predictors significantly affected the positive-rewarded learning rate. We confirmed that CTQ subscales also do not affect positive-rewarded learning in the same manner (see Supplementary Materials). Further exploratory analyses confirmed that although the current study included a low frequency of choosing the negative during acquisition ($< 50\%$), this did not affect acquisition. These analyses can be found in the Supplementary Materials, as well as analyses confirming there were no differences in learning rates based on gender.

4. Discussion

The goal of the current study was to examine if social exclusion led to difficulty disengaging from NSP, to assess the construct validity of the ERLT task. Although our manipulation checks confirmed that the Cyberball manipulation effectively produced feelings of rejection, we did not find support for our main hypothesis. Indeed, we found no evidence that Cyberball condition led to differences in the learning rate for negative-punished ERLT trials, and so did not find support for the construct validity of the ERLT task. Although it is possible that this was due to a suboptimal operationalization in our choice of risk factor for depression (i.e. rejection), this is unlikely since there was also no significant correlation between IDS scores and learning rates (see Table 2). This was especially unexpected as previous studies have shown negative correlations with depressive symptoms and learning rates for negative and/or punished trials in ERLT tasks (Iijima et al., 2017; Takano et al., 2019).

We also found no evidence for childhood abuse or depressive symptoms as moderators, which is logical since there was no primary effect of social exclusion on negative-punished learning rate. The only variable that had a significant association with negative-punished learning rate was physical neglect, but this CTQ subscale had very poor internal reliability.

In our exploratory analyses, we found a significant association of social exclusion with positive-rewarded learning rate: Specifically, excluded participants showed a higher learning rate and so were quicker to learn when positive trials were rewarded. Individuals with depression, however, typically respond less to reward in probabilistic learning tasks (Pizzagalli et al., 2008). We did not explicitly assess current or past diagnoses of depression in our sample, and so cannot make firm conclusions regarding whether these previous findings are supported by our research; however, in our sample, depressive symptoms did not moderate how quickly participants learned to associate retrieving positive memories with reward.

Overall, this finding that excluded participants were quicker to learn the positive-reward association could be interpreted as a type of mood repair strategy, where social exclusion leads to enhanced striving for positive memories, as a defense against the rejection-prompted negative mood and lowered self-esteem. Recalling positive memories does lead to an improved mood (Gillihan, Kessler, & Farah, 2007) and is a common strategy to repair negative moods (Josephson, Singer, & Salovey, 1996; Rusting & DeHart, 2000). Effective strategies to bolster threatened needs after social exclusion include positive refocusing, a cognitive emotion regulation strategy that involves bringing one's attention to a positive distraction, and self-affirmation, recalling important values and positive characteristics of the self (Timeo, Riva, & Paladino, 2019). Self-affirmation in particular is linked with lower aggression after social exclusion (e.g. Baldwin et al., 2010). Since recalling positive

memories fits into both of these categories, it is likely a helpful coping strategy following social exclusion. Researchers have suggested that both of these coping strategies might be more easily implemented or impulsively used than other strategies, although no prior research has explicitly investigated this (e.g. Timeo et al., 2019). The current study provides support for this suggestion, with excluded participants more quickly learning that retrieving positive autobiographical memories is associated with reward.

4.1 Limitations

There were some methodological weaknesses with the ERLT variant used. When negative memory retrieval was rewarded, participants only chose it at close to chance level (unlike in previous studies, i.e. Iijima et al., 2017; Takano et al., 2019), suggesting that some participants might not have completely understood the task. Furthermore, although we told participants we would randomly ask them for memories retrieved during the task, we did not actually do so and had no way to assess whether participants actually retrieved memories. If participants were not truly retrieving memories, then they were not engaging in NSP, meaning the task would not accurately gauge whether participants had difficulty disengaging from NSP. We also did not check participants' rejection sensitivity (Downey & Feldman, 1996), as we assumed it would be related to childhood abuse which was hypothesized as a moderator (Erozkan, 2015). However, if individuals' rejection sensitivity differed from the frequency of childhood abuse they experienced, then it would be rejection sensitivity that moderated the relationship between social exclusion and difficulty disengaging from NSP. If we had measured rejection sensitivity, we would be able to observe whether it indeed reflected childhood abuse or not, and whether it played an additional role in the association between social rejection and NSP.

4.2 Future Research

Further investigations into difficulty disengaging from NSP and ways to accurately measure it, such as with the ERLT, remain important, since NSP is an important vulnerability factor of depressive symptomatology that can yield insight into how and why depressive symptoms develop. Improving ERLT methodology can focus on enhancing instructions (such as including more graphics, explaining complex terminology in simpler words, giving additional examples and practice trials, and explaining instructions one-on-one) and methods to check participants' understanding of the task (such as with multiple choice questions about the task's key instructions). Also important is to explicitly gauge whether participants truly retrieved a memory, such by randomly asking them to report the memory they retrieved. Future studies could use an alternative operationalization of a depressive risk factor, such as a learned helplessness manipulation (see: Diener, 2013; Hooper & McHugh, 2013), to further investigate the validity of the ERLT. With methodological improvements and further investigations into its reliability and validity, the ERLT has potential not only to measure difficulty disengaging from NSP, but also to model the acquisition of NSP. This would allow insight into how depressive symptoms develop and worsen, as well as how treatments affect the tendency to engage in NSP. In addition, future research should replicate and further investigate participants' mood repair strategies after experiencing social exclusion.

4.3 Conclusion

Social exclusion did not lead to difficulty disengaging from NSP, as had been hypothesized. There was thus no support for the construct validity of the ERLT. There was also no evidence of moderation by depressive symptoms or frequency of childhood abuse. Exploratory analyses found that excluded participants were quicker to learn than included participants when positive trials were rewarded, perhaps as a mood repair strategy. With improvements to the ERLT, further examination into its validity should be conducted, as well as replications of exploratory findings regarding mood repair for excluded participants.

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Conflict of Interest

The authors declare no conflict of interest.

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Figure 1. Trial flow of the Emotional Reversal Learning Task (Panel A) and reward-valence contingencies by phase (Panel B).

Figure 3. Mean Q values (reward expectancies) for the negative (Panel A) and positive (Panel B) valence options. Gray fields indicate standard errors.

Table 1

Mean and SDs of Questionnaires and Task Performance Measures for the ERLT

	Included Group		Excluded Group		Overall	
	M	SD	M	SD	M	SD
IDS	17.20	10.36	18.95	8.41	18.08	9.44
CTQ total	32.00	9.29	34.34	9.39	33.17	9.38
CTQ physical neglect	6.11	1.90	6.20	1.88	6.15	1.88
CTQ physical abuse	5.23	0.55	5.26	0.59	5.25	0.57
CTQ emotional neglect	8.43	3.21	9.74	4.28	9.09	3.83
CTQ emotional abuse	7.66	3.57	8.88	3.82	8.27	3.73
CTQ sexual abuse	4.43	1.55	4.23	0.95	4.33	1.28
Need Threat Scale	26.97	5.22	12.40	4.23	19.68	8.71
Mood Questionnaire	29.32	3.80	21.86	4.86	25.59	5.74
Negative Choice Frequency						
Acquisition	.51	.19	.52	.17	.513	.18
Reversal 1	.35	.18	.34	.16	.343	.17
Reversal 2	.50	.19	.52	.22	.514	.21
Q-learning parameters						
Negative-punished α	.81	.10	.84	.11	.82	.10
Positive-punished α	.62	.19	.67	.20	.64	.20
Negative-rewarded α	.23	.13	.27	.16	.25	.15
Positive-rewarded α	.52	.14	.46	.15	.49	.15

Note. CTQ = Childhood Trauma Questionnaire; IDS = Inventory of Depressive Symptomatology; α = learning rate

Table 2

Correlations between questionnaires and Emotional Reversal Learning Task measures.

	2.	3.	4.	5.	6.	7.	8.	8.	10.	11.	12.	13.
1. IDS	0.49 ****	0.31 ***	0.15	0.16	0.42 ****	-0.07	-0.02	-0.09	-0.05	0.07	0.03	-0.10
2. CTQ : emotional abuse		0.73 ****	0.42 ****	0.44 ****	0.91 ****	0.05	-0.03	0.03	0.04	0.09	0.06	0.08
3. CTQ : emotional neglect			0.30 ***	0.29 ***	0.89 ****	0.12	0.03	0.09	0.13	0.08	0.00	0.13
4. CTQ : physical neglect				0.32 ***	0.45 ****	0.09	-0.04	0.09	0.18 *	0.10	0.04	0.10
5. CTQ : sexual abuse					0.56 ****	0.05	0.10	0.13	0.08	-0.13	-0.12	0.08
6. CTQ : total score						0.10	0.05	0.10	0.11	0.02	-0.03	0.12
7. Phase: acquisition							0.09	0.52 ****	0.55 ****	-0.22 *	-0.05	0.61 ****
8. Phase: reversal 1								0.11	0.04	-0.49 ****	-0.71 ****	0.15
9. Phase: reversal 2									0.60 ****	-0.22 *	-0.04	0.74 ****
10. Negative-rewarded α										-0.11	-0.04	0.38 ****
11. Negative-punished α											0.50 ****	0.05
12. Positive-rewarded α												0.13
13. Positive-punished α												

Note. CTQ = Childhood Trauma Questionnaire; IDS = Inventory of Depressive Symptomatology; α = learning rate

* $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

Table 3

Regression model assessing association of Exclusion Conditions, IDS, and CTQ subscales with negative-punished learning rate, for 130 participants.

Independent Variables	β	2.5 %	97.5 %	SE	t	p	Adj R^2
Step 1							0.087
Exclusion	0.019	-0.016	0.054	0.018	1.090	.278	
IDS	0.001	-0.001	0.003	0.001	0.568	.571	
CTQ : Physical neglect	-0.020	-0.033	-0.007	0.006	-3.122	.002	
CTQ: Physical abuse	0.019	-0.014	0.052	0.017	1.147	.254	
CTQ: Emotional abuse	0.004	-0.004	0.012	0.004	0.972	.333	
CTQ: Emotional neglect	0.005	-0.002	0.012	0.004	1.308	.193	
CTQ: Sexual abuse	-0.01	-0.025	0.006	0.008	-1.218	.226	
Step 2							0.053
Exclusion x Physical neglect	0.007	-0.019	0.034	0.013	0.550	.583	
Exclusion x Physical abuse	-0.014	-0.084	0.055	0.035	-0.409	.683	
Exclusion x Emotional abuse	0.001	-0.016	0.018	0.009	0.122	.903	
Exclusion x Emotional neglect	-0.002	-0.017	0.014	0.008	-0.197	.844	
Exclusion x Sexual abuse	0.015	-0.021	0.051	0.018	0.820	.414	

Note. CTQ = Childhood Trauma Questionnaire; IDS = Inventory of Depressive Symptomatology; ΔR^2 = Change in R^2 (explained variance).

Supplementary Materials

Cyberball Suspicions

We did not assess participants' suspicions about the true purpose of Cyberball, as we had preregistered that we would not exclude participants based on their suspicions. This decision was made based on the findings of multiple studies that awareness that the Cyberball players are instructed in their throws, or that the Cyberball players are computerized, does not affect participants' feelings of exclusion (Syrjämäki, Lyyra, Peltola, & Hietanen, 2017; Zadro, Williams & Richards, 2004).

Emotional Reversal Learning Task (ERLT)

Instructions Regarding Reversals

We informed participants before the start of the ERLT task that the valence-reward associations could change. We can find no literature on the overall impact of instruction vs no instruction based on valence-reward associations. In general, studies that include only one reversal typically do not always instruct participants about reversals, to optimally model individual differences (Bai, Katahira, & Ohira, 2014; Dombrovski et al., 2010). However, when Dombrovski and colleagues used a task with multiple reversals (i.e. Dombrovski et al., 2014), they had participants practice extensively perform with 4 reversals, so that participants would be aware that contingencies could change during the actual task. This is the same reasoning behind our decision to instruct participants that there could be changes in valence-reward associations: we wanted to ensure that participants would not perform much worse on the first reversal than on the second, simply because the first reversal was completely unexpected – we thus made sure participants had a similar expectation of the possibility of reversal throughout the task.

Parameter Estimation

All free parameters (exploitation and learning parameters), estimated for each participant, was probit-transformed to follow a normal distribution, with a group-level mean μ and standard deviation σ . Depending on the model, we either assumed that population means were stable across learning rates (if the model included one common learning rate), or that they varied across learning rates (for models with two or more learning rates). For models with two or more learning rates, we sampled probit-transformed individual learning rates, α_{vr} , from $N(\mu_{\alpha, vr}, \sigma)$. The priors for these group means, $\mu_{\alpha, vr}$, followed a normal distribution, $N(0,1)$, as did the prior for the exploitation parameter β . Priors for the standard deviations followed a half-Cauchy distribution, $\text{Cauchy}(0,5)$. Parameter settings were similar to other studies estimating learning rates with similar estimation procedures (Takano et al., 2019). Three Hamiltonian-Monte-Carlo chains were used to check convergence and to see if parameters met the Gelman-Rubin convergence criterion of Rhats approaching 1 (Gelman & Rubin, 1992).

Additional Analyses

Negative Acquisition Frequency

As the frequency of choosing the negative during acquisition, was around 50% — lower than other similar studies (Iijima et al., 2017; Takano et al., 2019) and around chance level — we also decided to run analyses with a subsample of participants, including only those who showed an acquisition rate above 50% for the second half of the acquisition phase. This left only 60 participants: those whose behavior displayed an understanding of the association between negative choice and reward. For this subgroup, there was no significant effect of Cyberball for any of the learning rates; However, since these exploratory analyses involved such a small subgroup, they were underpowered.

Gender Differences

We investigated whether there were any differences between learning rates based on gender. We performed post-hoc t-tests (corrected for multiple comparisons by Bonferroni), and concluded that there was no evidence of a difference based on gender: for the negative-rewarded learning rate, $t(15.99) = -1.94, p = .28$; for the negative-punished learning rate, $t(17.77) = 0.55, p = 1$; for the positive-rewarded learning rate, $t(15.98) = 0.35, p = 1$; or for the positive-punished learning rate, $t(17.61) = 0.138, p = 0.18$.

Child Trauma predicting positive-rewarded learning rate

We investigated whether the different childhood trauma questionnaire (CTQ; Bernstein et al., 2003) subscales moderated the relationship between exclusion and a higher positive-rewarded learning rate. We computed five regression models, with positive-rewarded learning rate as the outcome and predictors including the CTQ subscale in question, Cyberball, and their interaction. All beta coefficients were corrected for multiple comparisons as these were exploratory post-hoc analyses, and we found no evidence that any predictors significantly affected the positive-rewarded learning rate.

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