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Spontaneous emotional regulation under experimental emotional condition: The role of working memory

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Abstract

The present research studied the bidirectional effects of working memory (WM) capacity and emotional regulation; that is, the effect of WM capacity on spontaneous emotional regulation and whether the emotional valence to be regulated has a differential impact on performance in a second WM task. Participants (79) first completed a WM span task (Digit Span), then a self-report emotional intelligence task, which was followed by randomly assigned mock Positive-feedback, Negative-feedback, or No-feedback. In the Negative-feedback and Positive-feedback conditions, a dummy report based on participants' responses to the Trait Meta Mood- 21 was shown on the screen. After that, participants completed another WM task (Running Span). An ordinary least squares multiple linear regression was used to evaluate the predictive power of WM span and experimental condition on post-feedback test performance. The model yielded a significant effect on post-feedback test performance for Negative-feedback and a marginal significant effect for the interaction of this parameter with WM span. The results showed that participants in the Negative-feedback condition performed worse than those assigned to other conditions, and individuals with a higher WM capacity were less susceptible to negative experimental stimuli.

KEYWORDS
emotion, emotional regulation, working memory

INTRODUCTION

Emotional regulation is a process that determines how individuals are influenced by their emotions, when and how they experience them, and how they express them (Gross, 1998). It consists of mechanisms that intervene in regulating emotional experiences, their intensity, and the way in which they manifest. It is also suggested that these processes can be either automatic or intentional. Emotional regulation can modify the generative process of emotion at different times (Gross, 1998). Gross (2002) suggests that there are two main types of strategies regarding emotional regulation: reappraisal and suppression. In temporal order, reappraisal comes first and can modify the trajectory of the entire emotional response by modifying the appraisal that triggers the emotion. Suppression consists in the diminishing of emotional expressions, but without affecting the emotional experience itself. These two strategies have different characteristics and consequences. The implementation of a suppression strategy may result in memory inhibition, which is not evident when utilizing the cognitive reappraisal strategy. In field studies on emotional regulation, experimental manipulations are applied with the aim of recreating situations found in natural contexts. The goal is to observe instances of spontaneous emotional regulation, which are not specifically instructed by the experimenter. This approach allows for the identification of the mechanisms that characterize emotional management (Doré et al., 2016).

Working memory (WM) is a temporary, capacity-limited, simultaneous information processing system in the service of complex cognitive tasks (Baddeley, 2017; Baddeley et al., 2020). The interaction of emotion and cognition is a relevant topic in multiple disciplines (Schmeichel & Tang, 2015). In line with this, WM is relevant in the regulation of emotional states (Ferrell et al., 2020; Hofmann et al., 2012; Jasielska et al., 2019; McRae et al., 2012; Rutherford et al., 2016; Schmeichel & Tang, 2015; Yoon et al., 2018). WM may play a role in suppressing stimuli that can elicit emotional responses (Schmeichel & Tang, 2015). Alternatively, it has also been suggested that WM plays a part in reappraisal, facilitating the adoption of neutral evaluations of emotional stimuli (Schmeichel & Tang, 2015). For example, updating can help maintain the intention to suppress emotions in the presence of stimuli that would otherwise trigger emotional responses, and can also help maintain and generate nonemotional appraisals of emotional events (Schmeichel & Tang, 2015). It should be noted that most studies on emotional regulation and WM have involved experiences or emotional stimuli with negative valence. WM would be responsible for holding in line an alternative interpretation of these stimuli or for suppressing an emotional response. Both mechanisms in which WM would participate, suppression and reappraisal, coincide with those proposed by Gross (2002) in emotional regulation. In a review of this topic, Hofmann et al. (2012) concluded that WM was linked to self-regulatory ability owing to its role in sustaining goals, maintaining attentional focus, and decreasing the number of intrusive thoughts. For Pe et al. (2013, 2015), the WM updating ability is considered a crucial mechanism for emotional regulation. WM would be involved in the ability to regulate emotional states because WM enables the encoding of new information and the updating of the current attentional focus; individuals with high updating capacity would have a more flexible and adaptive response (Pe et al., 2015).

Schmeichel et al. (2008) demonstrated that WM was related to two critical aspects of emotional regulation: the capacities to suppress and reappraise emotions. It was also concluded that WM was associated with emotional response control and the ability to regulate both positive and negative emotional experiences. However, a potential confounding factor may arise owing to the fact that participants responded to a specific set of instructions, and individuals with higher cognitive abilities tend to perform better at following instructions (Schmeichel & Tang, 2015). To overcome this limitation, in a subsequent study, Schmeichel and Demaree (2010) assessed spontaneous regulation capacity in relation to WM and instructions and feedback. Participants were asked to complete an emotional intelligence questionnaire in addition to a WM measure. They were randomly assigned to a group that received Negative-feedback on their emotional abilities or to a control group. They then completed a disguised measure of self-enhancement and a self-report measure of affect. These self-enhancement responses, a way to maintain a self-positive view in reaction to negative feedback, were considered emotional regulation strategies. Results showed that participants with a higher WM capacity showed less negative affect and more self-enhancement following Negative-feedback. Thus, the authors concluded that WM was related to more effective emotional regulation. As seen by Schmeichel and Demaree (2010), individuals with a higher WM capacity not only are able to manage multiple streams of information but also have a greater capacity to manage their emotional responses. It is worth noting that the effect of this kind of emotional context on WM performance itself has not been analyzed.

Coifman et al. (2021) investigated the link between WM and emotional regulation capacity, with a focus on whether WM tests could predict objective indicators of spontaneous negative-emotion regulation. These indicators were measured through behavioral displays and autonomic activation during an in-lab emotion provocation, as well as through daily life experience sampling. The results showed a significant correlation between individual WM capacity and emotional regulation capacity, suggesting that those with a higher WM capacity also had a better spontaneous emotional regulation capacity. The authors concluded that this finding aligns with theoretical and empirical evidence that WM updating during emotional contexts plays a crucial role in emotion regulatory processing.

Curci et al. (2013) investigated the effect of rumination after a traumatic experimental condition and its relationship with WM capacity. A decrease in test–retest performance was observed in the group that had been exposed to negative stimuli, being greater in the low-WM group. The authors argue that rumination following traumatic exposure uses WM resources, interfering with individuals' ability to perform other tasks. In contrast to the work of Schmeichel et al. (2008) and Schmeichel and Demaree (2010), the effect on WM capacity was evaluated after the presentation of a stimulus with the capacity to elicit an emotional response, but this stimulus was not a threat to self-esteem as in the work by Schmeichel and Demaree (2010).

The aim of the present study is to answer some of the questions raised by the literature. Overall, up to this point, the mechanisms of emotional regulation in which WM is involved seem to be emotional response suppression and cognitive reappraisal. However, research has focused mostly on negative emotion, and has not examined the role of emotional valence. Furthermore, studies have failed to analyze the potential impact of emotional stimuli on WM performance in relation to WM capacity. This study followed the experimental manipulation proposed by Schmeichel and Demaree (2010), assessing spontaneous emotional regulation by exposing participants to feedback about themselves with different emotional valence. The participants performed a WM task, then an emotional intelligence task with mock feedback (negative, positive) or No-feedback, and then performed a different WM task. The objectives of the study were: (1) to analyze the effect of WM capacity on spontaneous emotional regulation, and (2) to examine whether the emotional valence of stimuli differentially affected performance on the second WM task. The hypotheses of this work were: (1) that participants with a higher WM capacity would have better spontaneous regulation and would suffer less impairment in the negative post-feedback tests, and (2) that the effects of the emotional intervention in WM post-feedback performance would be different depending on the valence of the feedback.

TABLE 1 Descriptives for age by Experimental Condition.

Experimental condition	Age
N	
No-feedback	21
Negative-feedback	33
Positive-feedback	25
Mean	
No-feedback	25.1
Negative-feedback	25.8
Positive-feedback	26.8
Median	
No-feedback	24
Negative-feedback	25
Positive-feedback	25
Standard deviation	
No-feedback	4.73
Negative-feedback	5.36
Positive-feedback	6.19
Minimum	
No-feedback	20
Negative-feedback	20
Positive-feedback	19
Maximum	
No-feedback	38
Negative-feedback	39
Positive-feedback	39

METHOD

Participants

The sample consisted of 79 participants (age *Mean* = 26, *SD* = 5.45, *Min* = 19, *Max* = 39). All were residents of the Metropolitan Area of Buenos Aires, Argentina. All participants were native Spanish speakers and signed an informed consent form before taking part in the experiment. Sampling was non-probabilistic. Participants were recruited through an online invitation sent to contacts obtained from the Faculty of Psychology of the University of Buenos Aires. Table 1 presents the descriptive statistics of the Age variable categorized by Experimental Condition.

The sample calculation was conducted using the Pwr package (v 1.3–0; Champely et al., 2020) in the statistical software R. The post hoc analysis revealed that a sample size of 79 participants would yield a statistical power of 0.8 for the current study design, with an effect size of 1.4 standard deviation units for every unit change in the continuous variable, and a significance level of 5% (alpha).

Materials

BIMeT(V) (Barreyro et al., 2019). This is a set of computerized tests composed of: Digit Span, Letter Span, Running Span, and Letter Digit Span. Considering the research objective, only two tests were included, as they assess WM.

The Digit Span test is designed to evaluate how much verbal information can be stored in short-term memory or working memory. The test involves displaying numbers from 1 to 9 on a computer screen one at a time, with a 2000-ms display time and a 1000-ms interval between each number. There are two training trials, consisting of a two-digit and a three-digit series, followed by 24 test trials divided into three trials per level. Participants are required to remember between two and nine digits per trial and must indicate which numbers were presented in the exact order they appeared when the word "recall" is displayed. The test is stopped when the participant fails to recall two trials at the same level, and one point is awarded for each correct trial. The test had a Cronbach's alpha of .81 and sufficient indicators of validity (see Barreyro et al., 2019).

The Running Span test, on the other hand, measures both storage capacity and the concurrent processing of verbal information in working memory. Participants are informed that a series of letters will be presented, but they are not told how many or that they will be expected to remember the last "x" letters. Depending on the level, they must remember the last two to six letters out of three to nine presented. Each letter appears on the screen for 1000 ms, with a 500-ms interval between stimuli. There are two training trials consisting of a two-letter and a three-letter series, followed by 18 test trials divided into three trials per level. Participants are required to remember between two and seven letters per trial and must indicate the last "x" letters presented in the exact order they appeared when the word "recall" is displayed. The test is discontinued when the participant fails to recall two trials at the same level, and one point is awarded for each correct trial. The test had a Cronbach's alpha of .78 and sufficient indicators of validity (see Barreyro et al., 2019).

Trait Meta-Mood Scale (Calero, 2013). This instrument is administered as part of the manipulation. The emotional conditions to which participants are assigned are the feedback they receive based on their responses to the Trait Meta Mood- 21 (TMMS-21). This scale assesses perceived emotional intelligence through three dimensions: attention to feelings, clarity of feelings, and mood repair. The scale incudes 21 items (seven for each dimension), with five response options (from "*totally agree*" to "*totally disagree*"). The scale shows adequate reliability indexes by internal consistency (Cronbach's alpha): .81 (attention), .86 (clarity), and .85 (mood repair). Likewise, adequate indicators of validity were found (see Calero, 2013).

Procedure

Participants were told that the objective of the study was to analyze the relationship between emotional processes and cognitive ability. They were tested in a lab room free of noise and distractions. Participants completed the computerized tests, which had an approximate duration of 40 minutes. First, they completed Digit Span and, immediately after, the TMMS-21. Afterwards, participants were randomly assigned to one of three experimental conditions: Positive-feedback, Negative-feedback, and No-feedback. In the feedback condition they received a dummy TMMS-21 report on the screen. Negative-feedback consisted in the following statement:

> "Your responses indicate that you lack some of the emotional skills that are basic to psychological well-being. You are likely to have difficulty establishing healthy relationships and sustaining them over time, primarily due to your lack of empathy and your level of selfishness. Also, you lack resources that would allow you to adequately cope with frustrations or other types of difficulties that are inevitable in life."

Positive-feedback consisted in the following statement:

> "Your responses indicate that you possess a very high level of emotional skills that are basic to psychological well-being. You are likely to be able to establish healthy and lasting relationships with others, mainly because of your high level of empathy and altruism. Also, you have resources that will enable you to cope successfully with frustrations or other difficulties that are inevitable in life."

The three experimental conditions, together with the TMMS-21 scale, are available at the Open Science Framework: Negative, https://osf.io/zh6pe/; Positive, https://osf.io/esn6y;/ and No-feedback, https://osf.io/p3v5z/.

Immediately after the feedback, the participants completed the remaining test, Running Span. At the end of the tests, the participant was informed that the information received was false, given additional information about the study, and offered a piece of candy; the experimenter could continue talking to the participant if he/she showed discomfort.

The study protocol was approved by the Committee on Responsible Behavior in Research, Faculty of Psychology, University of Buenos Aires (06/2017).

Data analysis

Analyses were carried out with R 4.1.3 (R Core Team, 2022). In order to evaluate the effects of WM span and experimental condition on WM performance post-feedback, a multiple linear regression was performed with the method of least squares estimation, with the assumptions of normality, linearity, homoscedasticity, and independence of residues having been checked previously. The model was implemented with nlm4 1.1–32 (Bates et al., 2014). The dependent variable is the Running Span, and the independent variable WM-span is the Digit Span. Both tests evaluate WM—one measure pre-feedback (Digit Span) and the other measure post-feedback (Running Span). Because the emotional condition variable is a multi-categorical variable, dummy variables were generated, using the control group (No-feedback condition) as the base variable. Next, interaction parameters were computed between the dummy variables and the continuous variable WM-span. In addition, after testing the assumptions of homoscedasticity and normality of the residuals, a one-way analysis of variance (ANOVA) was used to analyze whether there were differences between the three emotional experimental conditions.

Descriptive analysis was performed with JAMOVI (The JAMOVI Project 2022).

The data and code to reproduce analyses are available at the Open Science Framework: data, https://osf.io/8q2fh; R code, https://osf.io/zdnq2.

One case with a performance score of zero on all tests was removed.

TABLE 2 Descriptives for WM-span and WM post-feedback by Experimental Condition.

Experimental condition	WM-span	WM post-feedback
N		
No-feedback	21	21
Negative-feedback	33	33
Positive-feedback	25	25
Mean		
No-feedback	6.19	3.29
Negative-feedback	5.97	2.92
Positive-feedback	5.82	3.10
Median		
No-feedback	6.00	3.50
Negative-feedback	6.00	3.00
Positive-feedback	6.00	3.00
Standard deviation		
No-feedback	1.52	0.51
Negative-feedback	1.37	0.73
Positive-feedback	1.62	0.60
Minimum		
No-feedback	2.00	2.00
Negative-feedback	2.00	1.00
Positive-feedback	2.00	1.50
Maximum		
No-feedback	8.50	4.00
Negative-feedback	8.00	4.50
Positive-feedback	8.00	4.50
Skewness		
No-feedback	−0.82	−0.52
Negative-feedback	−1.30	−0.55
Positive-feedback	−0.50	−0.26
Kurtosis		
No-feedback	1.57	0.58
Negative-feedback	2.79	0.61
Positive-feedback	0.01	1.67

TABLE 3 Model Summary.

Parameter	Estimate	Std error	*t*	*p*-value
Intercept	3.04	0.55	5.53	>.01
Positive-feedback experimental condition	−0.83	0.71	−1.18	.24
Negative-feedback experimental condition	−1.68	0.72	−2.35	.02
WM-span	0.04	0.09	0.47	.64
Positive-feedback × WM-span	0.11	0.11	1	.32
Negative-feedback × WM-span	0.22	0.11	1.95	.05

RESULTS

Table 2 shows the descriptive statistics of the variables involved in the model.

In the one-way ANOVA, no significant differences were found in the three experimental conditions in post-feedback WM score ($F[2,49.6] = 2.26$, $p = .12$). The regression analysis performed to study the predictive power of WM-span and experimental condition on WM performance post-feedback showed that the model was significant ($F[5,73] = 4.343$, $p < .01$, $R^2 = .23$). When analyzing the effects of each of the predictor variables, WM-span ($\beta = .04$, $t = .47$, $p = .64$), Positive-feedback experimental condition ($\beta = -.83$, $t = -1.18$, $p = .24$) and the interaction parameter WM-span × Positive-feedback ($\beta = .11$, $t = 1.04$, $p = .31$) did not show a significant effect on WM post-feedback. The Negative-feedback experimental condition ($\beta = -1.68$, $t = -2.35$, $p = .02$) showed a significant effect on WM performance after feedback. Additionally, the interaction parameter WM-span × Negative-feedback ($\beta = .22$, $t = -1.94$, $p = .05$) exhibited a marginally significant effect. Table 3 displays a summary of the model.

DISCUSSION

This study analyzed the bidirectional effects of WM capacity and emotional regulation; that is, the effect of WM capacity on spontaneous emotional regulation, and whether the emotional valence to be regulated differentially affected performance on a second WM task. The paradigm used involved a first WM-span test, followed by an emotional manipulation (Positive-feedback, Negative-feedback, or No-feedback), and a final WM test. Two hypotheses were tested: (1) Participants with a higher WM capacity would have better spontaneous emotional regulation and suffer less impairment in the Negative post-feedback tests, and (2) the effect on WM performance post-feedback would differ depending on the valence of the feedback. Both hypotheses were partially confirmed.

Although no significant differences were found in the ANOVA among the three emotional conditions, the linear regression model revealed a significant effect of the negative emotional condition on post-feedback WM measures. These results indicate that participants assigned to the Negative-feedback emotional condition were the worst performers on the post-feedback WM performance.

Moreover, a marginally significant interaction was observed between the negative emotional condition and WM ability, providing support for the first proposed hypothesis. These findings are in line with previous studies by Coifman et al. (2021), Curci et al. (2013), Schmeichel and Demaree (2010) and Yoon et al. (2018), showing that individuals with higher WM capacity were less susceptible to negative experimental stimuli. As proposed by Hofmann et al. (2012), WM might be linked to self-regulatory capacity owing to its role in maintaining attentional focus and decreasing the number of intrusive thoughts.

The paradigm employed in this study did not directly evaluate emotional regulation using psychometric measures. Instead, it utilized an experimental manipulation (Curci et al., 2013; Doré et al., 2016; Schmeichel et al., 2008) involving stimuli that had the potential to impact participants' self-esteem (Schmeichel & Demaree, 2010). Considering the criticisms surrounding the psychometric approach (Pérez-Sánchez et al., 2020), the incorporation of a convergent experimental approach offers essential evidence in the study of emotional management. This study makes a contribution to our understanding of the interplay between cognitive and emotional variables. It builds upon previous research and advances the experimental paradigms used in those studies.

As for the limitations of this study, the first one is that emotional regulation was not assessed in direct form. Future research could include a combined assessment of emotional regulation, where an emotional stimulus is administered to elicit a spontaneous emotional reaction and a self-report measure is administered to confirm the emotional effect or response. Another limitation is the possibility that the observed effect of negative emotion might be attributed to surprise or self-analysis (e.g., "Did I really do that badly on the test?"), which may not necessarily have an emotional component. A convergent self-report measure would be useful in this regard. Another limitation is the low number of participants, which restricts the statistical power to detect effects and interactions. Future research might look to replicate this study with larger samples.

AUTHOR CONTRIBUTIONS

Alejandra Daniela Calero: Conceived and designed the analysis, collected data, performed data analysis and wrote the paper; Jésica Formoso: Collected data and contributed to data analysis; Juan Pablo Barreyro: Conceived and designed the experiment; Irene Injoque-Ricle: Conceived and designed the experiment; Débora Inés Burin: Contributed with manuscript writing and critical editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

DATA AVAILABILITY STATEMENT

Data and code supporting this study are openly available from a permanent repository linked in the manuscript.

ETHICS STATEMENT

This human study was reviewed and approved by the Committee on Responsible Behavior of the Faculty of Psychology of the University of Buenos Aires in agreement with the Declaration of Helsinki.

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