Acta Psychologica 173 (2017) 13–20

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

# The distinctive role of executive functions in implicit emotion regulation

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ARTICLE INFO

*Article history:*
Received 31 March 2016
Received in revised form 24 November 2016
Accepted 4 December 2016
Available online xxxx

*Keywords:*
Emotion regulation
Fiction
Executive functions
Working memory

ABSTRACT

Several theoretical models stress the role of executive functions in emotion regulation (ER). However, most of the previous studies on ER employed explicit regulatory strategies that could have engaged executive functions, beyond regulatory processes per se. Recently, there has been renewed interest in implicit forms of ER, believed to be closer to daily-life requirements. While various studies have shown that implicit and explicit ER engage partially overlapping neurocognitive processes, the contribution of different executive functions in implicit ER has not been investigated. In the present study, we presented participants with negatively valenced pictures of varying emotional intensity preceded by short texts describing them as either fictional or real. This manipulation was meant to induce a spontaneous emotional down-regulation. We recorded electrodermal activity (EDA) and subjective reports of emotion arousal. Executive functions (updating, switching, and inhibition) were also assessed. No difference was found between the fictional and real condition on EDA. A diminished self-reported arousal was observed, however, when pictures were described as fictional for high- and mild-intensity material, but not for neutral material. The amount of down-regulation in the fictional condition was found to be predicted by interindividual variability in updating performances, but not by the other measures of executive functions, suggesting its implication even in implicit forms of ER. The relationship between down-regulation and updating was significant only for high-intensity material. We discuss the role of updating in relation to the consciousness of one's emotional state.



## 1. Introduction

Emotion regulation (ER) is the process of modifying the intensity, the duration or the type of a given emotional response in order to maintain an adaptive behaviour. ER can intervene at different moments of the emotion generative process. Accordingly, ER strategies have been classified as antecedent and response focused, corresponding to modulatory processes acting, respectively, before and after a full-fledged emotion response has emerged (Gross, 1998). The former encompasses attentional redeployment and reappraisal, while the latter is described as behavioural suppression (Gross, 2014). While they are commonly considered as respectively adaptive and maladaptive strategies, some studies showed that suppression abilities and emotional avoidance are, respectively, a positive predictor of distress adjustment (Bonanno, Papa, Lalande, Westphal, & Coifman, 2004), and have a long-term adaptive value after real life grief (Bonanno, Keltner, Holen, & Horowitz, 1995).

Reappraisal has been described as an adaptive ER strategy (Aldao, Nolen-Hoeksema, & Schweizer, 2010), and has therefore undergone extensive research compared to other strategies. Previously considered as a unitary construct, recent studies have underlined its complexity. It is now conceptualized as a global term encompassing several mechanisms (Webb, Miles, & Sheeran, 2012). Positive reappraisal seeks to focus on or create a positive aspect or meaning for a stimulus. Detached reappraisal, or "detachment", differs conceptually as it strives to lower the self-relevance of the emotional event, disrupting the relationship between the event and the self, by acting for example, as if one was not personally concerned by the event or the stimulus, but merely a neutral observer.

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http://dx.doi.org/10.1016/j.actpsy.2016.12.001
0001-6918/

Distancing, on the other hand, requires a change in perspective, usually from the first- to the third-person perspective (e.g., to see yourself as a fly on the wall; Kross & Ayduk, 2011; Mischkowski, Kross, & Bushman, 2012). Finally, what could be called fictional reappraisal aims to lower the "realness" of a stimulus by reinterpreting its nature, or by giving it a fictional context (e.g., "it's not blood but ketchup"; Mocaiber et al., 2010; Mocaiber et al., 2011). While most studies asked participants to exert an "unspecified" cognitive reappraisal (although some studies did try tracking the strategies used afterwards; Moser, Most, & Simons, 2010), recent protocols tend to prompt participants to perform a specific subtype, or a combination of subtypes (e.g., detachment and distancing; Koenigsberg et al., 2009; Ochsner et al., 2004). Indeed, Dörfel et al. (2014) suggested that detachment is supported by different neural pathways from those supporting reinterpretation-based strategies, such as fictional reappraisal (note, however, that as the instructions were to "reinterpret the picture so that it no longer elicits a negative response" p. 300, they did not allow for a clear delineation and could also have included features of positive reappraisal). The authors emphasized that only the interpretation-based strategy activated the orbitofrontal cortex and the left ventrolateral prefrontal cortex. They pointed out the role of the anterior part of the latter structure in retrieving conceptual representations from memory and the middle part in selecting the right representation (and inhibiting the others), stressing the complex role of cognitive control in this type of emotion regulation.

In general, neuroimaging studies of ER have consistently reported activation in lateral and medial frontal regions encompassing the dorsal and ventral prefrontal cortex and the anterior cingulate cortex (for a meta-analysis of instructed emotion regulation protocols see Buhle et al., 2014). Interestingly, this fronto-cingular network is involved in domain general cognitive control (Niendam et al., 2012). These findings are in agreement with theoretical models invoking a central role of cognitive control processes in emotion regulation (Bush, Luu, & Posner, 2000; Makowski, Sperduti, Blanchet, Nicolas, & Piolino, 2015; Ochsner, Silvers, & Buhle, 2012; Ochsner & Gross, 2005).

Nevertheless, as proposed by Miyake et al. (2000), cognitive control is not a unitary phenomenon, but encompasses at least three different executive processes: switching, updating, and inhibition. Switching corresponds to the ability to flexibly switch between different tasks at hand, updating to the monitoring and continuous manipulation and refreshing of working memory content, and inhibition to the voluntary suppression of prepotent or habitual responses. Only a few studies have investigated the contribution of specific executive functions (EF) to ER efficiency. Schmeichel, Volokhov, and Demaree (2008) showed that participants with higher working memory scores (operation span task) were better able to use suppression and reappraisal to reduce their expressive and subjective emotional reactions. In the same vein, Opitz, Lee, Gross, and Urry (2014) reported that fluid cognitive intelligence (comprising a working memory measure) predicted the efficacy of using reappraisal to modulate emotional response.

Studies employing multiple measures of EF have reported contrasting results. For example, McRae, Jacobs, Ray, John, and Gross (2012), in line with the aforementioned studies, showed that working memory (operation span task) and switching (global/local task), but not inhibition abilities, positively correlated with reappraisal efficiency. On the contrary, in two studies, Gyurak et al. (2009) and Gyurak, Goodkind, Kramer, Miller, and Levenson (2012) reported that only verbal fluency, but not inhibition, working memory (composite score of digit and spatial span) or task switching (TMT), was linked to higher abilities to regulate emotion using suppression. These findings suggest that different EF could be engaged depending on the ER strategy at stake. Working memory could be necessary during reappraisal since the alternative interpretation of the stimuli should likely be held in memory to be effective in modulating the emotional response. Moreover, it should be noted that previous studies employed different working memory measures, reporting that more complex working memory tasks (operation span task) requiring storing and active manipulation were related to ER abilities (Schmeichel & Demaree, 2010; Schmeichel et al., 2008), while performances in simple working memory tasks (digit span) were not (Gyurak et al., 2009, 2012). These findings suggest that complex executive functions could be better predictors of regulatory abilities. Nevertheless, no previous study employed different measures of the same cognitive ability (e.g., working memory) to directly test this hypothesis.

The majority of studies explicitly asked participants to engage in one of the aforementioned ER strategies to modulate their emotional experience. The voluntary deployment of ER could require the mobilization of cognitive resources and be intrinsically effortful (for a recent review see Gyurak, Gross, and Etkin, 2011). It is therefore not clear if the activation of brain structures subserving cognitive control during ER, and the link between executive functions and ER abilities, are due to ER per se, or are linked to the voluntary and effortful nature of these tasks.

Beyond voluntary ER, different forms of implicit ER have been described. These processes differ from explicit forms of ER in that regulation occurs without explicit instructions to modulate the emotional response and the regulatory process remains outside the participants' awareness (Gyurak et al., 2011). For example, several studies have shown that asking participants to verbally label the emotional expression of faces or their emotional reaction elicited by arousing pictures produced an incidental emotional modulation witnessed by diminished emotional subjective rating and decreased activity in brain regions devoted to processing emotion (Burklund, David Creswell, Irwin, & Lieberman, 2014; Lieberman et al., 2007). Interestingly, these studies also showed that implicit ER activated the same frontal regions recruited during reappraisal, suggesting that explicit and implicit ER processes could be subserved by partially overlapping mechanisms.

Contextual cues have also been shown to incidentally modulate emotional response. For example, verbal descriptions presented prior to showing negative pictures and describing the stimuli as more neutral or more negative have been shown to modulate the neural signature and the subjective rating of emotion (Foti & Hajcak, 2008; Macnamara, Foti, & Hajcak, 2009). In particular negative images preceded by a neutral description elicited a reduced late positive potential (LPP) and were judged as less unpleasant.

Other studies showed that describing emotional material as fictional (by means of short texts) could trigger implicit emotion regulation processes (Mocaiber et al., 2011; Mocaiber et al., 2010; Sperduti et al., 2016). Mocaiber et al. (2010) showed that mutilation pictures that were presented as fictional (movie scenes) elicited a smaller LPP compared to similar pictures presented as real. In a further neuroimaging study, using the same manipulation, the authors reported the activation of brain regions associated with emotional processing – amygdala and insula – in the real, but not in the fictional condition (Mocaiber et al., 2011), while the fictional condition triggered activity in prefrontal regions. Oliveira et al. (2009), using a similar protocol, showed an effect of a personality trait (positive affect, measured by the PANAS-T; Watson, Clark, & Tellegen, 1988) on emotion regulation abilities. Only the high positive affect subgroup showed a reduction in physiological arousal, measured by means of electrodermal activity (EDA) and heart-rate deceleration, toward pictures described as fictional. The authors suggested that since positive affect increases cognitive flexibility (Dreisbach, 2006), individuals with high positive affect could be more efficient in modulating their emotion response. In a more recent study, we showed, using more ecologically valid material (movie clips), compared to previous studies employing pictures (Mocaiber et al., 2010, 2011; Oliveira et al., 2009), that scenes presented as fictional were judged as less arousing (Sperduti et al., 2016). Moreover, we reported that modulation of subjective emotion by fictional description was evident for negative, but not for positive scenes. It has to be noted, however, that negative scenes were also judged more arousing than positive ones. Thus, it is not clear if this difference was driven by valence or intensity.

Thus, the intensity of the material can possibly modulate the impact of implicit fictional reappraisal on the down-regulation of emotional responses. Indeed, emotion regulation can vary depending on the intensity of the material. A series of studies have shown that in order to effectively adapt emotion regulatory goals, people tend to adopt a distraction strategy when confronted with high negative intensity material, while they are more prone to engage in reappraisal when dealing with low negative intensity situations (Sheppes et al., 2014; Sheppes, Scheibe, Suri, & Gross, 2011; Sheppes & Levin, 2013). According to these authors, early attentional disengagement prevents emotional information from gathering force, and is more effective with high-intensity emotional material, while reappraisal is sufficient to manage low-intensity material and has greater benefits in terms of long-term adaptation. Moreover, the two strategies are considered to differ in terms of cognitive costs, with distraction being less demanding than reappraisal, which requires the active generation and maintenance of an alternative explanation that is often in conflict with the actual emotional situation. Still, a study that prompted participants to use reappraisal to regulate emotion elicited by high- and low-intensity emotional stimuli reported that reappraisal of high-intensity pictures produced a greater reduction in negative affect, compared to low-intensity ones, even if the down-regulation of the emotional response was significant for both kinds of stimuli (Silvers, Wager, Weber, & Ochsner, 2014). It has to be noted, nevertheless, that reappraisal in the high-intensity condition was accompanied by greater activity in several prefrontal regions, probably denoting, in accordance with the aforementioned studies, a greater recruitment of executive functions when employing this strategy, above all when dealing with highly arousing material.

To date, the effect of intensity on implicit forms of ER, and the impact of different executive functions on the efficiency of this process have not been tested. To fill this gap, we presented participants with negatively valenced pictures of varying emotional intensity selected from the International Affective Pictures Systems (IAPS; Lang, Bradley, & Cuthbert, 1997). Each stimulus was preceded by a short text describing it as either fictional or real. In other words, we provided reappraised interpretations specific to each stimulus. Thus, contrary to most previous studies we gave specific cues to reinterpret the stimulus, rather than general instructions (e.g., real vs. fake) which require participants to generate their own personal alternative interpretation. This procedure has a twofold purpose: 1) it strives to lower the cognitive demand associated with the task, since producing an alternative interpretation in conflict with the initial appraisal of the stimulus is a cognitively demanding process. However, either generating or prompting a specific interpretation requires participants to activate and maintain the alternative meaning. Thus, even in our protocol, high-level executive processes should play a pivotal role; 2) it prompts an implicit (participants are not aware of the regulatory nature of the task), rather than an explicit emotion regulation process (participants know that they have to reduce their emotion experience). Distinct executive functions - inhibition, switching, working memory capacity and updating - were assessed by standard neuropsychological tests. We recorded subjective rating of intensity, as well as electrodermal activity (EDA). The rationale for this choice was that EDA is considered as a good physiological indicator of the arousal dimension of emotions (Sequeira, Hot, Silvert, & Delplanque, 2009).

Based on the aforementioned literature we made three main hypotheses: 1) we expected to find a greater emotional response for pictures presented as real; 2) we expected that the difference between the emotional response toward real and fictional pictures would be greater for stimuli of higher intensity; 3) we predicted that participants showing higher implicit emotional regulation abilities (difference in emotion reaction between the real and the fictional condition) would have better executive scores. In particular, since ER has been shown to require more cognitive and neuronal resources when facing highly arousing stimuli, we expected that the link between ER and executive functions would be more pronounced for high-intensity material.

## 2. Materials and methods

### 2.1. Participants

Thirty-seven participants took part in the experiment. Three participants were excluded from the analyses due to technical problems. Thus, the final sample was composed of 34 healthy participants (26 females; mean age 22.24 $\pm$ 2.94). All participants signed an informed consent form in accordance with the declaration of Helsinki, and the study was approved by the local ethics committee of the University Paris Descartes. All participants were right-handed and reported having no psychiatric or neurological history.

### 2.2. Materials

Forty images were selected from the IAPS database (Lang et al., 1997). Thirty-six were used as experimental stimuli and four as controls. The 36 experimental stimuli were divided into three categories according to their intensity: 12 “Neutral” (intensity between 1 and 3), 12 “Mild” (intensity between 4 and 5), and 12 “High” (intensity between 6 and 7). The “Mild” and the “High” images were taken from the negative subset of the IAPS. Four images were chosen for their abstract pictorial content (e.g., picture no. 7238 represents yellow and blue spheres of varying radius on a black background) and were employed as a manipulation check. The criteria for selecting the 36 images were the following: 1) The image had to be plausible when presented either as real or as fictional[2], and 2) we selected pictures with a variety of content (e.g., not only mutilations or car crashes in the high intensity category) to avoid material-related biases. For a complete list of the selected images see Supplementary Material 1.

We created two descriptive texts for each image, one presenting it as real (e.g., *Body of an injured man*) and the other one as fictional (e.g., *Injury makeup on a man*). There was no difference in the length of the sentences across the two conditions ($t(70) = -0.21$, $p = 0.83$). The 4 abstract images were preceded by a meaningless sentence containing a pseudo-word (e.g., *Summer lacks glogne*).[3]

### 2.3. Procedure

The study was divided into three phases: EDA recording during presentation of the images, each of which was preceded by a short description, then the executive functioning testing, and finally recording of the subjective emotional rating during a second presentation of the images.

The study took place in a quiet experimental room whose temperature was kept at about 24 degrees. Participants were told that they would see a series of emotional images preceded by a short description. They were instructed to read the descriptions carefully. To ensure that they followed the instructions they were warned that they would see some images preceded by a strange title (the 4 abstract images), and that they should press the space bar whenever they read one of these titles.

During the first phase, subjects wore acoustically isolating headphones to reduce possible noise that could induce artefacts in the EDA signal, and the light in the room was turned off to facilitate concentration on the stimuli. The sequence of events was as follows: the descriptive texts were presented for 5 s. After a variable interval (7–10 s, in 1 s steps), an image was presented for 6 s (as for the validation of the IAPS database), and was followed by another variable interval (16–19 s, in 1 s steps) to allow the EDA to return to baseline. During this phase, EDA was

[2] Several images in the IAPS database are obviously a set-up (e.g., image no. 6313 representing a knife attack). This kind of picture could not have been presented as real. On the contrary, pictures depicting simple objects (e.g., a tea cup) or landscapes are difficult to present as fictional.

[3] Even if pseudo-words could be more salient than real words, we chose to employ this kind of material to create “objectively” meaningless sentences.

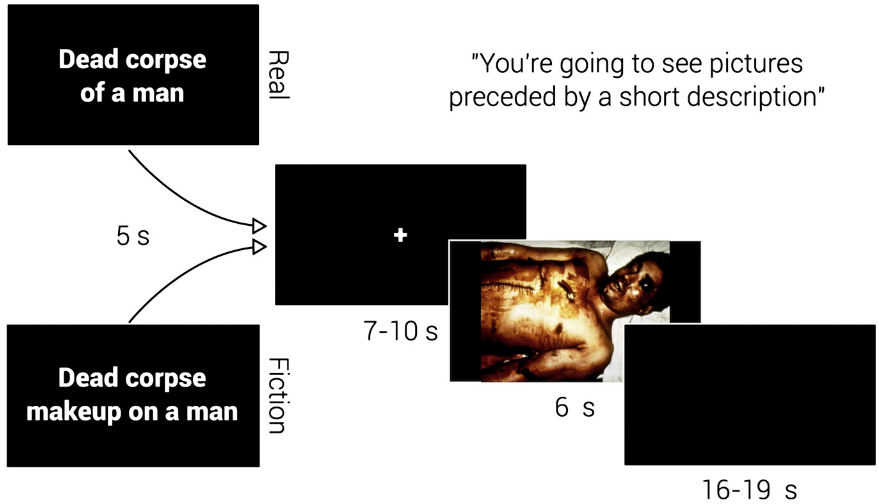


**Fig. 1.** Schematic representation of the experimental protocol. Short texts were presented to the participant for 5 s. After a variable interval ranging between 7 and 10 s, the stimulus was presented for 6 s. After another variable interval (16–19 s), the next trial began.

continuously recorded. Images were randomly presented and the assignment of each image to the real or fictional condition was counterbalanced across participants. For a schematic representation of the protocol see Fig. 1. Stimuli were presented on a 24″ screen. Presentation of the stimuli, recording of data, and synchronization with EDA recording was automatically accomplished using PsychoPy© 1.80.04 (Peirce, 2007).

In the second phase, participants carried out an executive functioning assessment including measures of inhibition (The Stroop task; Stroop, 1935), switching (the Trail Making Test; Reitan, 1955) and two tasks related to working memory: updating (the n-back test; Quinette et al., 2003) and capacity (forward digit span). These executive tests were performed following the guidelines of the French neuropsychological consortium on executive functioning assessment (Godefroy, 2008).

During the third phase, the 36 experimental pictures were presented again and the participants were asked to rate the intensity (0 = Neutral - 7 = Very Intense) of their subjective emotional experience. This time, no descriptive text indicated whether the image was fictional or real. No emphasis was placed on this distinction during the whole experiment to ensure the implicitness of the manipulation.

### 2.4. Data acquisition and analysis

EDA was recorded using the BIOPAC MP150 system (Biopac Systems, Goleta, CA, USA) and AcqKnowledge Software (Version 4.3; Biopac Systems) at 1000 Hz. EDA was measured using two Ag-AgCl electrodes attached to the intermediate phalanx of the index and ring fingers of the non-dominant hand. Isotonic paste (BIOPAC Gel 101) was used as the electrolyte. Electrodes were attached prior to the beginning of the task, and at least 5 min of activity were recorded before starting the experiment in order to allow participants to adapt to the recording equipment, and to allow EDA levels to stabilize (see Fowles et al., 1981).

Analysis of the EDA signal was carried out using AcqKnowledge Software (Version 4.3; Biopac Systems). The tonic EDA signal was first down-sampled at 15.7 Hz, and then a low-pass filter at 1 Hz was applied. Phasic EDA was derived from the tonic signal with the AcqKnowledge© function Smoothing baseline removal with a baseline window of 8 s. Then, the peak of EDA activity for each stimulus was extracted in a time window starting 1 s after the stimulus onset and ending with the stimulus offset. Peak values were finally transformed using the square root function to approach a normal distribution (for a similar method see Silvert, Delplanque, Bouwalerh, Verpoort, & Sequeira, 2004).

The Stroop inhibition score was calculated by subtracting the time of the interference task from the colour naming task (Godefroy, 2008). The Trail Making Test (TMT) score was the difference between time for completing part B and part A. For both tests a lower time corresponds to a better performance. For updating (the n-back task) and capacity (digit span) measures, we kept the maximum span. The former two scores were reversed so that higher scores correspond to better performances.

All statistical analyses were run using the open-source language R 3.3.1 (R Development Core Team, 2008).

## 3. Results

### 3.1. Effect of nature and intensity

In order to test the effect of nature and intensity, we used linear mixed-effects modelling (LMMs; Bates, 2005; Kuznetsova, Brockhoff, & Christensen, 2014). LMMs are statistical models containing both fixed effects (explanatory variables) and random effects (variance components). This framework has been increasingly used in recent years as it has been shown to outperform traditional procedures such as repeated measures ANOVA. LMMs are particularly suited to cases in which experimental stimuli are heterogeneous (e.g., words, images) as they can take into account the variance due to the items. Moreover, LMMs do not depend on limited assumptions about the variance-covariance matrix and can accommodate missing data (Baayen, Davidson, & Bates, 2008; Kristensen & Hansen, 2004; Magezi, 2015). We report 95% confidence intervals based on the estimated local curvature of the likelihood surface (Bates, Maechler, Bolker, & Walker, 2014). We fitted two full linear mixed-effects models designed to predict EDA and subjective intensity. As fixed factor, we entered the nature (real – fictional), nested within the intensity (neutral – mild – high), while items and participants were entered as random factors. Additionally, following recent recommendations (Barr, Levy, Scheepers, & Tily, 2013), fixed factor terms

**Table 1**
Descriptive statistics.

| Intensity | Nature | EDA | Subjective Intensity |
|---|---|---|---|
| Neutral | Real | 0.21 ± 0.24 | 1.69 ± 1.99 |
| Neutral | Fiction | 0.22 ± 0.24 | 1.55 ± 1.91 |
| Mild | Real | 0.28 ± 0.30 | 4.23 ± 2.04 |
| Mild | Fiction | 0.29 ± 0.30 | 3.70 ± 1.99 |
| High | Real | 0.39 ± 0.35 | 4.91 ± 1.78 |
| High | Fiction | 0.35 ± 0.33 | 4.67 ± 1.77 |

were modelled as random slopes over random factors. In particular, all fixed factors were modelled as random slope over participants, and the nature as random slope over items. Correlations between random effects were also modelled. Descriptive statistics for all variables are presented in Table 1. The R code for the linear mixed-effects models is available in Supplementary Material 2.

*3.1.1. EDA*

The overall model predicting EDA successfully converged and explained 38% (the conditional $R^2$), while the fixed factors explained 4% (marginal $R^2$) of the variance of the endogen. The intercept, corresponding to the EDA in the neutral intensity and real nature, was 0.22. Compared to this, the mild and the high intensities resulted in a significant increase in EDA (respectively, $\beta = 0.06$, 95% CI [0.00, 0.12], $p < 0.05$; $\beta = 0.17$, 95% CI [0.09, 0.25], $p < 0.001$). Post-hoc analysis (Tukey) showed that the difference between mild and high intensity (averaged over the two levels of nature) was significant ($d = -0.9$, $p < 0.01$). The effect of fiction was not significant in the neutral, mild or high intensity conditions (respectively, $\beta = 0.01$, 95% CI [−0.05, 0.07], $p > 0.05$; $\beta = 0.01$, 95% CI [−0.06, 0.08], $p > 0.05$; $\beta = -0.03$, 95% CI [−0.11, 0.04], $p > 0.05$). See Fig. 2.

*3.1.2. Subjective intensity*

The overall model predicting subjective intensity successfully converged and explained 67% of the variance of the endogen. The variance explained by fixed factors was 41%. The intercept, corresponding to subjective intensity (measured on a 0–7 scale) in the neutral intensity and real nature, was 1.75. Compared to the intercept, the mild and the high intensity conditions resulted in a significant increase in subjective intensity (respectively, $\beta = 2.57$, 95% CI [1.68, 3.45], $p < 0.001$; $\beta = 4.07$, 95% CI [3.16, 4.99], $p < 0.001$). Post-hoc analysis (Tukey) showed that the difference between mild and high intensity (averaged over the levels of nature) was significant ($d = -1.57$, $p < 0.001$). The fictional condition led to a significant decrease in subjective intensity in the mild and high intensity conditions (respectively, $\beta = -0.56$, 95% CI [−1.00, −0.11], $p < 0.05$; $\beta = -0.48$, 95% CI [−0.90, −0.06], $p < 0.05$), but not in the neutral one ($\beta = -0.10$, 95% CI [−0.52, 0.32], $p > 0.05$). The difference between mild and high intensity remained significant in the fictional condition ($d = -1.59$, $p \leq 0.001$). See Fig. 3.

*3.2. The effect of stimulus intensity on emotion regulation*

In order to test our second hypothesis, we computed, for each participant, the ratio of the differences between the fictional and the real

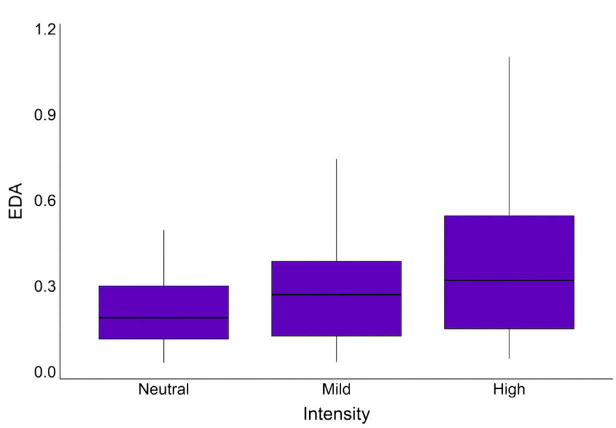


**Fig. 2.** EDA results showing the effect of intensity. Greater EDA activity was observed for mild- and high-intensity pictures compared to neutral ones. The lower and upper "hinges" of the boxes correspond to the first and third quartiles (the 25th and 75th percentiles). The whiskers extend from the hinge of the box to the extreme value that is within 1.5 of the distance between the first and third quartiles.

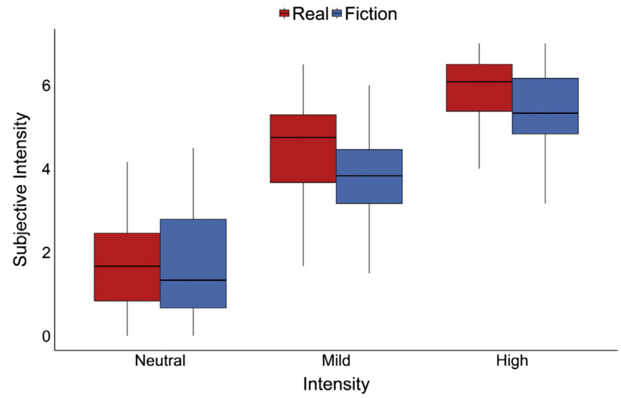


**Fig. 3.** Results showing the effect of fiction on subjective intensity within each condition. Lower subjective intensity was observed for fiction in the mild and the high intensities. The lower and upper "hinges" of the boxes correspond to the first and third quartiles (the 25th and 75th percentiles). The whiskers extend from the hinge of the box to the extreme value that is within 1.5 of the distance between the first and third quartiles.

conditions for EDA and subjective intensity, normalized on their value in the real condition, separately for the high and the mild intensity conditions (a greater difference meaning that the real condition resulted in a higher response than the fictional condition). The *t*-test on this ratio comparing mild- and high-intensity was not significant either for EDA (mean high = 0.01 ± 0.13, mean mild = −0.01 ± 0.13, $t(33) = 0.54$, $p > 0.05$) nor for subjective intensity (mean high = 0.06 ± 0.14, mean mild = 0.02 ± 0.48, $t(33) = 0.46$, $p > 0.05$).

*3.3. The role of inhibition, switching and updating*

In order to investigate the relationship between the effect of fiction and the four executive scores, we ran multiple regressions to predict the ratio of the differences between the fictional and the real conditions for both EDA and subjective intensity. All the scores were centred and scaled. An initial multiple linear regression model comprised the four executive scores (inhibition, switching, updating, and capacity). We then applied a forward and backward stepwise model selection procedure to identify the final model that best fitted the data (based on the AIC).

*3.3.1. EDA*

*3.3.1.1. Mild intensity.* The initial regression model was not significant ($F(4,29) = 0.63$, $p > 0.05$), with a multiple $R^2$ of 0.08. Within this model, none of the executive scores (inhibition, switching, updating and capacity) was a significant predictor (respectively, $\beta = -0.002$, $t = -1.11$, $p > 0.05$; $\beta = 0.001$, $t = 0.45$, $p > 0.05$; $\beta = 0.006$, $t = 0.14$, $p > 0.05$; $\beta = -0.03$, $t = -1.08$, $p > 0.05$). The stepwise procedure revealed that the best model was a constant model (with no other predictors than the intercept).

*3.3.1.2. High intensity.* The initial regression model was not significant ($F(2,29) = 0.69$, $p > 0.05$), with a multiple $R^2$ of 0.09. Within this model, none of the executive scores (inhibition, switching, updating and capacity) was a significant predictor (respectively, $\beta = 0.002$, $t = 0.78$, $p > 0.05$; $\beta = -0.02$, $t = -0.73$, $p > 0.05$; $\beta = 0.008$, $t = 0.18$, $p > 0.05$; $\beta = 0.02$, $t = 1.00$, $p > 0.05$). The stepwise procedure revealed that the best model was a constant model.

*3.3.2. Subjective intensity*

*3.3.2.1. Mild intensity.* The initial regression model was not significant ($F(2,29) = 0.26$, $p > 0.05$), with a multiple $R^2$ of 0.03. Within this model, none of the executive scores (inhibition, switching, updating and capacity) was a significant predictor (respectively, $\beta = 0.001$, $t =$

0.13, $p > 0.05$; $\beta = -0.006$, $t = -0.72$, $p > 0.05$; $\beta = -0.06$, $t = -0.40$, $p > 0.05$; $\beta = -0.05$, $t = -0.52$, $p > 0.05$). The stepwise procedure revealed that the best model was a constant model.

*3.3.2.2. High intensity.* The initial regression model was not significant ($F(2,29) = 1.14$, $p > 0.05$), with a multiple $R^2$ of 0.14. Within this model, none of the executive scores (inhibition, switching, updating and capacity) was a significant predictor (respectively, $\beta = -0.0004$, $t = -0.17$, $p > 0.05$; $\beta = -0.001$, $t = -0.56$, $p > 0.05$; $\beta = 0.06$, $t = 1.41$, $p > 0.05$; $\beta = 0.002$, $t = 0.06$, $p > 0.05$). However, the stepwise procedure revealed that the best model was that with updating as a unique predictor. This model was significant ($F(1,32) = 4.49$, $p < 0.05$), with a multiple $R^2$ of 0.12. Within this model, a greater updating score was linked to a greater difference of subjective intensity between the fictional and the real nature ($\beta = 0.07$, $t = 2.12$, $p < 0.05$). To test our hypotheses further, we also build a simple regression model with working memory (WM) capacity as unique predictor. This model was not significant ($F(1,32) = 1.41$, $p > 0.05$), and WM capacity was not a significant predictor ($\beta = 0.03$, $t = 1.19$, $p > 0.05$).

Finally, to directly test the interaction between updating and objective intensity suggested by the previous analysis, we ran a regression model on the difference between real and fictional intensities with the objective intensity (mild and high) and WM updating as predictors ($R2 = 0.02$). The interaction between the two predictors was not significant (beta = −0.1, 95% CI [−0.27, 0.07], $p = 0.24$).

## 4. Discussion

Emotion regulation is a fundamental ability to flexibly adapt one's behaviour to contextual situations and personal goals. Voluntary and effortful forms of ER have been the most extensively studied in the neuroscientific domain. However, ER is repeatedly prompted in daily life by continuous encounters with salient emotional situations. Thus, it is unlikely that ER concerns only controlled and effortful processes. Implicit ER may be advantageous in dealing with real-life regulatory requirements (Koole & Rothermund, 2011). In the last few years, renewed interest on this topic has emerged and different forms of implicit ER have been described (Gyurak et al., 2011; Koole & Rothermund, 2011). Even if some studies have reported that implicit and explicit ER may engage at least partially overlapping brain structures (Mocaiber et al., 2011), and that they may similarly depend on cognitive control abilities (Oliveira et al., 2009), to date there has been no systematic study investigating the link between different executive functions and implicit ER.

In the present study, we delivered negative images preceded by short sentences describing the stimuli as real or fictional. Moreover, we administered standard neuropsychological tests to measure inhibition, switching and updating abilities according to recent models of executive functions (Miyake & Friedman, 2012; Miyake et al., 2000).

In line with our first hypothesis and previous findings (Mocaiber et al., 2011; Mocaiber et al., 2010; Sperduti et al., 2016), we reported that pictures preceded by a fictional description were rated as less intense. Our results suggest that presenting negative material as fictional, without any explicit emotional regulation requirement, could be an efficient and sufficient manipulation to trigger implicit emotional regulation processes. On the contrary, we did not find any modulation in EDA response by the fictional context. Previous studies have also failed to report a modulation in peripheral measures of autonomic response (Eippert et al., 2007; Sperduti et al., 2016) during down-regulation of negative material. Interestingly, Eippert et al. (2007) also reported a significant increase in skin conductance response during up-regulation, suggesting that up- and down-regulation of emotion could be differently tracked by autonomic modulation. Nevertheless, a seminal study on emotion down-regulation showed a decrease in EDA (Lazarus & Alfert, 1964). Interestingly, in this study modulation of EDA was greater when the down-regulation instructions were presented before an emotionally arousing film than when they were presented as a commentary during the film. These findings suggest, also according to Eippert et al. (2007, p. 419), that "effective downregulation of autonomic responses might need some preparation". Even if we presented the description before the pictures, our event-related protocol was probably too fast to permit a modulation of EDA. Nevertheless, another possibility is that implicit fictional reappraisal dos not actually modulates physiological arousal. This would be in line with the idea that emotions elicited by appraisal of fictional objects, compared to real objects, would more pertain to what Frijda and Sundararajan (2007) called refined emotions. This kind of emotion would be characterized by detachment and self-reflective awareness, and would mainly activate the subjective component of the emotional reaction (e.g., feeling; Zentner, Grandjean, & Scherer, 2008). This is also coherent with a recent study showing that subjective rating, but not corrugator activation, was modulated by presenting pictures as artworks, as opposed to a non-art reality context (Gerger, Leder, & Kremer, 2014). Thus, it is possible that fictional reappraisal preferentially modulate this component rather than the behavioural or physiological aspects. Further studies, employing different measure are needed to test this hypothesis and to investigate the time course of the effect of emotion regulation strategies on peripheral measures of autonomic response.

Contrary to our second hypothesis we did not report a significant difference in emotion down-regulation between the high- and mild-intensity conditions. This result is partially incongruent with a recent study showing that when using reappraisal to down-regulate emotion induced by negative material there was a greater decrease in negative affect for high- compared to low-intensity pictures (Silvers et al., 2014). Nevertheless, the authors also reported that the proportional reduction, compared to baseline (watching condition without reappraisal instruction), of negative affect was significant for both high- and low-intensity trials. Moreover, when comparing the two conditions on this proportional change, only a marginal difference, that did not reach significance, was reported. Thus, both studies suggest that emotional down regulation could be effective independently of the intensity of the stimulus. The divergence between our and Silvers et al. (2014)'s findings could be due to the fact that they employed an explicit ER strategy, while here no emotion regulation instructions were given. It is likely that to achieve greater emotional down-regulation when facing high-intensity stimuli, voluntary emotional regulation strategies would be necessary. Our findings partially support this interpretation, since we found that updating performances predicted down-regulation only in the high-intensity condition. However, a supplementary analysis showed that the interaction between stimulus intensity and updating performances in predicting down-regulation was not significant. Thus, the hypothesis of a progressive recruitment of cognitive resources with increasing emotional stimulus intensities should be taken with caution and deserves further studies.

Our principal finding, according to our third hypothesis, is that the amount of emotion regulation, assessed by the difference in the intensity rating between the real and the fictional condition, correlated with updating abilities, but not with inhibition, switching or working memory capacity. This result is consistent with theoretical models of ER, such as those evoking a cognitive control of emotions (Ochsner et al., 2012; Ochsner & Gross, 2005), and extends this link to implicit forms of ER. As discussed in the introduction, studies investigating the link between ER and different executive functions have reported contrasting results. McRae et al. (2012), showed that working memory and set-shifting, but not inhibition abilities, positively correlated with reappraisal efficiency, while Gyurak et al. (2009, 2012) reported that only verbal fluency, but not inhibition, working memory or behavioural flexibility, was linked to higher abilities to suppress a behavioural emotional response. It has to be noted that, even if implicit, ER processes induced by verbal descriptions could be more similar to reappraisal than to suppression. Thus, our results are consistent with a well-documented link between some forms of ER (i.e., reappraisal) and working memory (MacNamara, Ferri, & Hajcak, 2011; McRae et al., 2012; Schmeichel et al., 2008). Moreover, beyond reappraisal, working memory abilities have been shown to modulate the emotion response after negative feedback about one's own emotional intelligence (Schmeichel & Demaree, 2010). The authors reported that after the negative feedback, participants with higher working memory performance showed increased self-enhancement, which is considered as a form of ER to maintain coherence in the personality system (Koole, 2009), and decreased negative affect. Our findings are coherent with these results, and suggest a link between working memory capacity and spontaneous forms of ER.

But why are updating performances and not those on other executive functions related to greater ER? Previous reports have shown that complex measures of working memory, requiring storing and active manipulation of information were related to ER abilities (Schmeichel & Demaree, 2010; Schmeichel et al., 2008). On the other hand, performances in simple working memory tasks (such as the digit span) have been shown not to be predictive of ER abilities (Gyurak et al., 2009, 2012), suggesting that complex executive functions are better predictors of regulatory abilities. Our results are fully in agreement with this interpretation. Indeed, within the two working memory measures, only updating, but not capacity, predicted interindividual differences in ER.

Interestingly, Barrett, Tugade, and Engle (2004) proposed that interindividual differences in performance in complex working memory tasks probably reflect the functioning of an attentional control system that, depending on the theoretical model, has been differently named: *central executive* in Baddeley and Hitch (1974); *supervisory attention system* (SAS) in Norman and Shallice (1986); *executive control* in Posner and DiGirolamo (2000). Attentional control may be necessary, among other functions, in the activation and maintenance of representation, above all when sensory features do not automatically activate these representations. This interpretation is coherent with our findings in that in order to have an effect on emotional reaction toward pictures, the meaning provided by the verbal description preceding the stimuli should be reactivated and maintained.

In conclusion, using an implicit emotional regulation task and measuring executive functions, we showed, for the first time, a direct link between implicit emotion regulation and working memory performances. However, these findings should be considered with caution due to several limitation of our study. First of all, it is not clear to what extent our finding of a link between working memory and ER could be generalized to other implicit types of ER that likely engages alternative cognitive resources (e.g., distraction). Moreover, ER efficacy could probably be better assessed with tasks measuring the ability to flexibly switch between different, and sometimes opposing, ER strategies. Indeed, for example, higher capacity of both suppressing and enhancing expressive behaviour (expressive flexibility) has been shown to predict long-term distress adjustment (Bonanno et al., 2004). Thus, future studies should investigate the link between the ability to adaptively switch between ER strategies and performances in different executive functions. Another limitation is that we only employed EDA as physiological marker of emotion. Nevertheless, emotion could be better characterized as a reaction at multiple level of the organism including the subjective, the physiological (e.g., EDA, heart rate, respiration rate), the behavioural (e.g., motor and facial expressive behaviour), and the neuronal level (e.g., EEG). Future works would benefice in including multimodal recordings to be able to sketch a global fingerprint of emotion modulation due to different ER strategies.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.actpsy.2016.12.001.

## Acknowledgments

This work was supported by the "Agence Nationale de la Recherche" (grant number: ANR-11-EMCO-0008) assigned to J.P. and P.P. We would like to thank Elisabeth Bonjour and Mélanie Souchay for their help in data collection and all the participants, as well as Elizabeth Rowley-Jolivet for proofreading.

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