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Could the impact of emotional states on learning in children vary with task difficulty?



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ABSTRACT

Emotions are known to influence memory, in particular retention and recall, with positive emotions enhancing performances and negative emotions showing mixed effects. Although the influence of emotions on memory is well-established, their precise impact on the learning process remains a matter of debate and investigation. We implemented two experiments with children aged 6 to 8 years to examine how different emotional states affect training with tasks of varying difficulty. In Experiment 1, children were assessed in a letter recognition task and were assigned to positive, negative, or neutral emotional training conditions. Results showed significant performance improvements across all emotional conditions, indicating that emotional states did not differentially affect this task. In Experiment 2, using a more difficult non-word dictation task, significant improvements were found only in the positive and neutral conditions but not in the negative condition, suggesting that task difficulty modulates the impact of emotional states. These findings highlight the importance of considering both emotional states and task difficulty in educational settings. Positive and neutral emotions may facilitate cognitive processes under challenging conditions, whereas negative emotions might hinder them.

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Introduction

Many studies have explored the link between emotions and learning. Academic performance, especially, memory retention and recall, has been shown to be influenced by the emotions experienced by children and adolescents. Emotionally relevant events are better remembered than neutral ones (Hamann, 2001; Kensinger & Corkin, 2003); positive emotional states improve recall and can be important to retrieval cues for long-term memory (Isen et al., 1978, 1987). To further explore this relationship, a functional magnetic resonance imaging study carried out by Osaka et al. (2013) provided evidence that negative and positive emotions modulated working memory through different neural patterns.

Although the influence of emotions on memory is well-established, their precise impact on the learning process remains a matter of debate and investigation. Positive emotions have been linked to enhanced learning and academic achievement, mediated by self-motivation and satisfaction with learning materials (Um et al., 2012). Some authors found that positive mood, personality factors, and feelings of difficulty could be predictive of the estimate of effort (the more positive the mood, the more the willingness to invest effort in the task; Efklides et al., 2006). Therefore, positive emotions can be considered a valuable resource for learning (see also Isen, 1993). Conversely, recent findings (D'Mello et al., 2014) suggest that a negative emotional state, such as confusion, can improve learning outcomes. Moreover, stress, as a negative emotional condition, has been observed to either enhance or hinder learning and memory processes, depending on its intensity and duration (for a review, see Vogel & Schwabe, 2016; see also Decarli et al., 2024, for an investigation on the impact, in particular of negative emotions, on young athletes' performance). Another example of contradictory results is the influence of positive versus negative moods on divergent thinking (for a meta-analysis, see Davis, 2009). For instance, Jiamei et al. (2002) found that children who were in a positive mood condition exhibited greater fluency and flexibility in their thinking compared with those who were in a negative mood condition. Conversely, Russ and Kaugars (2001) reported no significant differences in divergent thinking scores between children in positive versus negative mood conditions, highlighting the inconsistency in findings regarding the impact of mood on creative thinking.

Extensive research has demonstrated the critical role that achievement emotions play in students' well-being and performance (Camacho-Morles et al., 2021; Pekrun & Perry, 2014). According to the control-value theory (see Pekrun, 2006; Pekrun & Linnenbrink-Garcia, 2012; Pekrun et al., 2017), achievement emotions represent a distinct category of emotions that individuals experience in response to academic activities as well as their outcomes (success or failure).

Interestingly, this theory proposes the dimensions of valence and activation for describing distinct emotions. Valence refers to the pleasantness of an emotion, distinguishing between positive emotions (e.g., enjoyment, pride) and negative emotions (e.g., anxiety, anger). Activation (or arousal) refers to the physiological intensity of an emotion, with activating emotions (e.g., excitement, panic) involving high arousal and deactivating emotions (e.g., relief, boredom) involving low arousal. By combining these dimensions, the theory categorizes emotions into four broad groups: positive activating, positive deactivating, negative activating, and negative deactivating (see Pekrun et al., 2017). The former and latter categories of emotions are believed to exert opposite influences on the academic achievement process, with positive activating emotions enhancing academic performance and negative deactivating emotions hindering it. The other two categories of emotions seem to present more variable effects. The control-value theory also posits that two primary appraisals underpin achievement emotions: perceived control and task value (Pekrun, 2006, 2018). Perceived control is the extent to which students believe they can manage and succeed in a task, whereas task value pertains to the significance or usefulness assigned to the task. These appraisals combine to produce various emotions such as enjoyment (high control and high value) as a positive activating emotion, anxiety (low control and high value) as a negative activating emotion, and boredom (low control and/or low value) as a negative deactivating emotion. These constructs are considered immediate individual antecedents of achievement emotions and are shaped by more distant individual and contextual antecedents, including the structure, clarity, and motivational quality of tasks (Pekrun, 2006, 2018; Pekrun & Perry, 2014).

The primary outcome associated with achievement emotions is academic performance, influenced by motivational and cognitive processes (Pekrun, 2018; Pekrun & Perry, 2014). A recent meta-analysis revealed that enjoyment linked to learning activities correlates with improved performance, whereas boredom correlates with decreased achievement (Camacho-Morles et al., 2021). However, the effects of other emotions, such as anxiety, show mixed results. Anxiety can distract from a task but can also motivate external regulation to prevent failure (Pekrun, 2018; Pekrun & Perry, 2014). The control-value theory asserts that these relationships are relatively consistent across different individuals and contexts (Pekrun, 2006, 2018; Pekrun & Perry, 2014).

Considering the complexity of emotions and their varied impacts on learning, it is essential to examine mediating factors that may influence this relationship. A key factor is emotion regulation, broadly defined as the ability to recognize emotions and apply strategies to modify them in order to achieve specific goals. Learning to regulate emotional expressions according to environmental expectations has been shown to predict both immediate and long-term academic success, including grades and achievement scores (Eisenberg et al., 2005; Hill & Craft, 2003). Early emotion regulation skills help children to manage emotional responses to classroom challenges, supporting sustained attention and task engagement (Eisenberg et al., 2005; Graziano et al., 2007). Moreover, a recent study highlighted the importance of beliefs about the malleability of emotions and their role in influencing achievement emotions and regulation strategies in primary school children. Raccanello et al. (2022) found that malleability beliefs significantly influence mathematics-related achievement emotions through the mediation of emotion regulation.

Task difficulty can be considered another influencing factor. For example, a study on shame and pride in young children found that task difficulty significantly modulates these emotional responses (Lewis et al., 1992). Specifically, 3-year-old children displayed more shame when they failed easy tasks compared with difficult ones, whereas pride was more pronounced when they succeeded on difficult tasks rather than easy ones. To our knowledge, this study provides the only systematic evidence on how task difficulty modulates emotional states, highlighting its critical role in shaping children's emotional responses during learning. Therefore, our current study aimed to fill an important gap in the scientific literature by further exploring how task difficulty affects the relationship between emotional states and learning outcomes.

Aims and hypotheses

Easier tasks require less effort, motivation, control, and concentration. Conversely, more challenging tasks demand greater effort, motivation, and concentration. Whereas positive emotions can enhance the learning process, negative emotions can impair it. This view aligns with the control-value theory, which suggests that emotions affect performance by influencing cognitive resources and motivation (Pekrun, 2006; Pekrun et al., 2017).

The novelty of this study lies in its focus on the interaction between emotional states and task difficulty in young children, a topic that has received very little attention in the scientific literature. Indeed, whereas previous research has extensively examined the role of emotions in academic performance (e.g., Camacho-Morles et al., 2021; Pekrun & Perry, 2014), our study specifically investigated how different emotional states influence learning outcomes across tasks of varying difficulty. Therefore, we aimed to provide a deeper understanding of how emotional states can either facilitate or hinder learning, depending on the complexity of the task.

Specifically, we hypothesized the following:

- Hypothesis 1: Positive emotions will favor performance in both easy and difficult tasks.
- Hypothesis 2: Negative emotions will hinder performance's enhancements, particularly in difficult tasks, due to increased cognitive load and stress.
- Hypothesis 3: Neutral emotional states will produce similar results in both easy and difficult tasks.

We tested these hypotheses with two experiments involving children aged 6 to 8 years. The age range of our sample was chosen for ensuring that children can fully understand and regulate their emotional expressions, as supported by the developmental findings in the literature (Cole, 1986;

Kromm et al., 2015). Research has shown that the ability to control emotional expressions and understand display rules improves notably during this age range (Cole, 1986; see also Saarni, 1999). Furthermore, this age range aligns with the developmental milestones where children begin to understand the differentiation between experienced emotions and outward expressions (Josephs, 1994), and by age 8, they can effectively use this understanding in social contexts (Pons et al., 2004). In Experiment 1, participants were randomly assigned to positive, negative, or neutral emotional conditions, and we used standardized video clips to elicit distinct emotional states. Following the exposure to the emotional videos, children engaged in a training session aimed at improving their letter recognition skills. In Experiment 2, we replicated the experimental procedure used in Experiment 1 with a more difficult task, the dictation of non-words (i.e., words that do not exist in the lexicon). Across both experiments, we systematically manipulated the difficulty of the task. Specifically, in Experiment 1, we selected a letter recognition task to ensure that all children were already familiar with the letters they needed to identify. Given their age and educational background, we could confidently assume that all children possessed prior knowledge of these letters. Therefore, we considered this task as an “easy” one. Experiment 2, on the other hand, involved a more complex task (non-word dictation) where children were required to write down words that do not exist in the lexicon. This ensured that none of the children could draw on any existing knowledge to complete the task.

Experiment 1

Method

Participants

A total of 60 healthy children aged 6 to 8 years ($M_{\text{age}} = 6.92$ years, $SD = 0.76$) participated in the study. All participants were recruited from a primary school located in the North of Italy. The study was approved by the ethical committee of the University of Trento, and all procedures were conducted in accordance with the ethical standards laid down by the Declaration of Helsinki. Parents provided their written consent for the study.

Children were randomly assigned to the positive emotional condition ($n = 20$; 11 girls; $M_{\text{age}} = 6.75$ years, $SD = 0.72$), the negative emotional condition ($n = 20$; 13 girls; $M_{\text{age}} = 6.90$ years, $SD = 0.79$), or the neutral emotional condition ($n = 20$; 8 girls; $M_{\text{age}} = 7.10$ years, $SD = 0.79$). The three groups did not differ in terms of age (all $ps > .05$), gender ($p > .05$), or IQ (all $ps > .05$). To ensure that our study was adequately powered to detect meaningful effects, we conducted a power analysis. The analysis was based on a mixed analysis of variance (ANOVA) design with one between-participants factor and one within-participants factor, assuming an expected moderate effect size of .50 and a significance threshold of .05. The results indicated that, with a sample size of 60 participants, the study achieved a power of approximately 96.8%. This falls within the commonly accepted statistical power threshold of 80%. Consequently, the chosen sample size was sufficient to detect significant effects in our data.

Materials

Self-Assessment Manikin (SAM). The SAM (Bradley & Lang, 1994; Lang et al., 2005) is a nonverbal visual questionnaire used to evaluate an individual's emotional responses to different stimuli. In our study, it was implemented to measure the valence dimension, providing a straightforward way to capture emotional reactions without the need for verbal explanation. It comprises a 9-point graphical scale. The scale features stylized figures, usually referred to as “SAM,” depicting distinct emotional states ranging from happy to unhappy. Participants were asked to rate their emotional experience by selecting a position on this scale that best represents their state.

Letters Identification task. In this task (pre- and post-training task; Cornoldi et al., 2009), we assessed children with a subtest taken from a standardized Italian battery aimed at measuring specific precursors of reading and writing abilities in children (see Cornoldi et al., 2009). In the Letter Identification subtest, participants were asked to search for two graphemes (“B” and “L”) among a list of other let-

ters. This test allows for the assessment of children's ability to discriminate between graphemes, to visually search for them, and to use short-term memory. These skills are crucial for the acquisition of reading and writing proficiency. Performance was measured in terms of errors made by the children (i.e., crossing out letters other than B and L or omitting to cross out the two target letters). Children had a maximum time limit to complete the task (i.e., 5 min).

Elicitation and evaluation of emotional states. Six standardized emotional videos were selected from previous studies: two videos to elicit positive emotions, two for neutral emotions, and two for negative emotions (de Freitas Brandão et al., 2016; Essex et al., 2003; Talge et al., 2008; von Leupoldt et al., 2007). The Italian version of the clips was used (see Table 1 for a detailed description). All the videos lasted between 2 and 3 minutes.

Procedure

The experimental session took place in a quiet computer room of the school, and participants were divided into small groups (maximum of 10 children per group) under the experimenters' supervision. Although the children participated in groups, we ensured that each child was well-separated from other group members and completed all tasks individually. The study was conducted in a controlled environment, where children were given clear instructions and performed the tasks independently, which allowed us to control and adequately manipulate their emotional states. Moreover, the emotional induction procedures (via emotional videos) were standardized, and individual responses were collected after each task, ensuring that the group setting did not influence the validity of the emotional manipulation or the results.

During the pre-training phase, all participants were assessed with the Letters Identification task (Cornoldi et al., 2009). Afterward, participants were shown a movie clip based on their assigned condition (positive, negative, or neutral). The movie clips were projected on an interactive whiteboard. Children were then asked to rate how the clips made them feel by using the SAM (Bradley & Lang, 1994; Lang et al., 2005), and the first training session began. This session was followed by a second activity, a second emotional movie, another SAM questionnaire, and a second training session (see Fig. 1). The decision to include a second training session was driven by the aim of providing children with additional learning opportunities. Finally, children were asked to complete the post-training evaluation. At the end of the testing phase, an additional positive video was shown to conclude the experiment in a positive state.

Training for the Letters Identification task

During the training sessions, children were presented with multiple sets of three lines of letters. Within each set, they were asked to identify and mark the letters B and L. This exercise aimed to improve their letters recognition skills.

Table 1

Video clips shown for the elicitation of positive, negative, and neutral emotional states

Valence	Video and reference literature	Year	Start	End
Positive	<i>The Jungle Book</i> (von Leupoldt et al., 2007)	1967	25:21	28:21
	<i>101 Dalmatians</i> (Essex et al., 2003)	1961	15:20	18:20
Neutral	<i>The Last Unicorn</i> (de Freitas Brandão et al., 2016)	1982	0:00	3:00
	<i>The Snowman</i> (Talge et al., 2008)	1982	0:00	3:00
Negative	<i>The Lion King</i> (de Freitas Brandão et al., 2016; Essex et al., 2003)	1994	35:55	37:55
	<i>Bambi</i> (Gross & Levenson, 1995)	1942	41:01	43:01

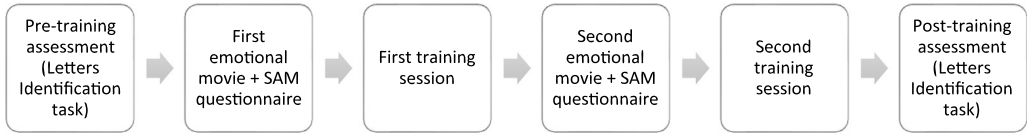


Fig. 1. Schematic representation of the procedure.

Results

We report both frequentist and Bayesian analyses using the free software R. We used the “BayesFactor” package with default priors (Morey et al., 2015) for computing Bayesian analyses, and we report Bayes factors (BFs) expressing the probability of the data given the alternative hypothesis (H_1) relative to the null hypothesis (H_0). We describe the evidence associated with BFs as “anecdotal” ($1/3 < BF < 3$), “moderate” ($BF < 1/3$ or $BF > 3$), “strong” ($BF < 1/10$ or $BF > 10$), “very strong” ($BF < 1/30$ or $BF > 30$), or “extreme” ($BF < 1/100$ or $BF > 100$).

Manipulation check

A preliminary analysis was computed to assess the effectiveness of the elicitation of different emotional states. We compared the SAM scores after the elicitation of the videos to assess whether the children experienced the target emotion in each condition (positive, negative, or neutral). The scores were not categorized into specific ranges (e.g., positive, negative, or neutral) but instead were directly compared to confirm that the emotional responses aligned with the intended elicitation. In line with this, children exhibited distinct emotions based on the content of the video clips. Specifically, children who were exposed to positive clips showed more positive scores in the SAM questionnaire compared with those who were exposed to negative clips [SAM scores for the positive experimental condition: $M = 2.05$, $SD = 1.05$; SAM scores for the negative experimental condition: $M = 6.12$, $SD = 2.21$; $t(38) = -7.44$, $p < .001$; $BF_{10} = 1.31 \times 10^6$, extreme evidence] and to neutral clips [SAM scores for the neutral experimental condition: $M = 3.82$, $SD = 2.10$; $t(38) = -3.37$, $p = .002$; $BF_{10} = 20.10$, strong evidence]. In addition, children showed more negative scores after viewing negative video clips compared with children exposed to neutral clips, $t(38) = 3.36$, $p = .002$; $BF_{10} = 19.82$, strong evidence.

Effects of emotions on performance

We performed an ANOVA with emotion (positive, negative, or neutral) as a between-participants factor and pre-/post-training as a within-participants factor. We found a main effect of pre-/post-training, $F(1, 57) = 44.85$, $p < .001$, $\eta_g^2 = .15$, whereas we did not find an effect of emotion, $F(2, 57) = 2.80$, $p = .07$, $\eta_g^2 = .07$, or an interaction between emotion and pre-/post-training, $F(2, 57) = 0.59$, $p = .55$, $\eta_g^2 = .005$. Children showed significant improvements in all emotional conditions [positive emotion: $M_{pre} = 4.40$, $SD = 2.78$; $M_{post} = 1.55$, $SD = 1.70$; $t(19) = 4.82$, $p < .001$; $BF_{10} = 241.01$, extreme evidence; negative emotion: $M_{pre} = 6.00$, $SD = 3.89$; $M_{post} = 3.60$, $SD = 2.72$; $t(19) = 4.12$, $p = .001$; $BF_{10} = 58.89$, very strong evidence; neutral emotion: $M_{pre} = 4.50$, $SD = 3.39$; $M_{post} = 2.60$, $SD = 1.98$; $t(19) = 2.83$, $p = .01$; $BF_{10} = 4.81$, moderate evidence]. Specifically, children made significantly fewer errors in the post-training compared with the pre-training. Moreover, we performed a mixed ANOVA to assess the effect of age on our data. We did not find a main effect of age, $F(1, 54) = 1.15$, $p = .29$, $\eta_g^2 = .02$, or any significant interactions with other variables (all $ps > .05$). Our results indicate that the training intervention had a positive impact on children’s abilities, as evidenced by the significant decrease in errors across all emotional conditions (see Fig. 2). Contrarily, the absence of significant effects of emotion, as well as the interaction between emotion and pre-/post-training, suggests that the training was equally effective across different emotional states.

Experiment 2

In Experiment 1, we observed improvements in children’s performance across all experimental conditions. Experiment 2 introduced a more challenging task designed to assess a different level of dif-

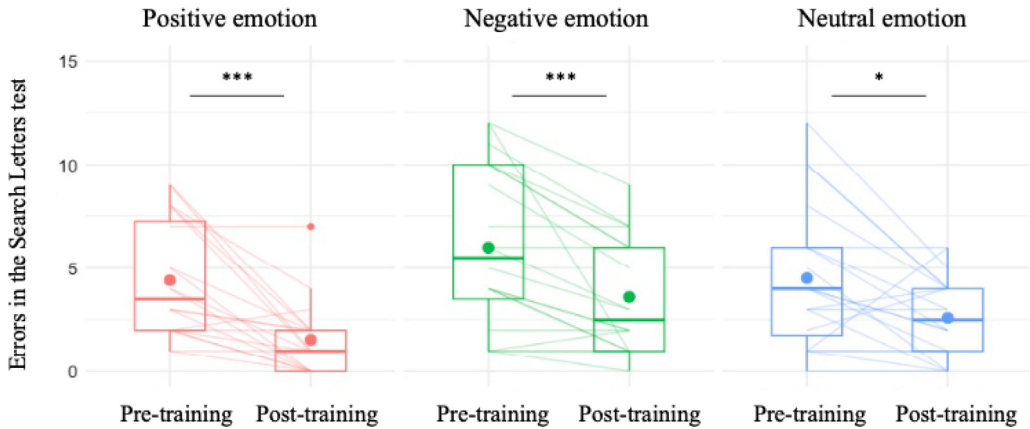


Fig. 2. Errors for the Letters Identification task in each emotional condition (positive, negative, and neutral) in Experiment 1. Asterisks indicate the p values obtained computing the t test between pre-training and post-training. * $p < .05$; *** $p < .001$.

faculty. Specifically, this task evaluated the children's ability to write non-words—that is, words that do not exist in the lexicon—to further investigate how emotional states interact with task complexity.

Method

Participants

A total of 60 healthy children aged 6 to 8 years ($M_{\text{age}} = 6.9$ years, $SD = 0.76$) participated in the study as in Experiment 1. Children were randomly assigned to the positive emotional condition ($n = 20$; 11 girls; $M_{\text{age}} = 7.15$ years, $SD = 0.74$), the negative emotional condition ($n = 20$; 13 girls; $M_{\text{age}} = 6.8$ years, $SD = 0.69$), or the neutral emotional condition ($n = 20$; 8 girls; $M_{\text{age}} = 6.85$ years, $SD = 0.81$). As in Experiment 1, the three groups did not differ in terms of age (all $ps > .05$) or gender ($p > .05$).

Materials

Non-words dictation task. This task (pre- and post-training task; Cornoldi et al., 2022) was taken from the BVSCO-3, a widely used Italian battery for assessing writing skills in children. This task aimed to assess participants' ability to accurately write non-words (i.e., words that do not exist in the Italian lexicon). Participants were presented with 32 non-words and instructed to write each non-word immediately after hearing it.

Procedure

The procedure was the same as in Experiment 1.

Training for the dictation of non-words

The training phase was implemented using a PC (13.3 inches, 1920×1080 resolution). Each session began with a blank image being displayed for 2000 ms, followed by a cross appearing at the center of the screen for 1000 ms. Participants were then presented with the words previously tested during the pre-training phase. The non-words were displayed one at a time on the screen, accompanied by their corresponding written spelling.

Results

Manipulation check

As in Experiment 1, we performed an analysis to test the effectiveness of the video clips in the elicitation of emotional states. Also in this case, children showed distinct emotions based on the content

of the video clips. In particular, children who were exposed to positive clips showed more positive scores in the SAM questionnaire compared with those who were exposed to negative clips [SAM scores for the positive experimental condition: $M = 1.82$, $SD = 1.27$; SAM scores for the negative experimental condition: $M = 5.40$, $SD = 2.44$; $t(38) = -5.82$, $p < .001$; $BF_{10} = 1.24 \times 10^4$, extreme evidence] and to neutral clips [SAM scores for the neutral experimental condition: $M = 2.87$, $SD = 1.78$; $t(38) = -2.14$, $p = .04$; $BF_{10} = 1.82$, anecdotal evidence]. Children showed more negative scores after viewing negative video clips compared with children exposed to neutral clips, $t(38) = 3.74$, $p = .001$; $BF_{10} = 47.15$, very strong evidence.

Effects of emotions on performance

We performed an ANOVA with emotion (positive, negative, or neutral) as a between-participants factor and pre-/post-training as a within-participants factor. We found a main effect of pre-/post-training, $F(1, 57) = 28.57$, $p < .001$, $\eta_g^2 = .01$, and a main effect of emotion, $F(2, 57) = 3.40$, $p = .04$, $\eta_g^2 = .103$. Moreover, we found a significant interaction between emotion and pre-/post-training, $F(2, 57) = 3.31$, $p = .04$, $\eta_g^2 = .003$. Children showed significant improvements in the positive and neutral emotional conditions (see Fig. 3) [positive emotion: $M_{pre} = 6.05$, $SD = 3.95$; $M_{post} = 3.80$, $SD = 4.02$; $t(19) = 4.85$, $p < .001$; $BF_{10} = 253.58$, extreme evidence; neutral emotion: $M_{pre} = 9.50$, $SD = 7.09$; $M_{post} = 7.95$, $SD = 6.71$; $t(19) = 3.07$, $p = .006$; $BF_{10} = 7.52$, moderate evidence], but not in the negative emotional condition [negative emotion: $M_{pre} = 9.75$, $SD = 6.31$; $M_{post} = 9.20$, $SD = 7.05$; $t(19) = 1.25$, $p = .22$; $BF_{10} = 0.46$, anecdotal evidence]. As in Experiment 1, we performed a mixed ANOVA to assess the effect of age on the outcomes. We found only a main effect of age, $F(1, 54) = 44.19$, $p < .001$, $\eta_g^2 = .44$, with younger children making more errors (6-year-olds: $M = 14.50$, $SD = 5.69$) compared with older children (7-year-olds: $M = 4.96$, $SD = 3.75$; 8-year-olds: $M = 3.87$, $SD = 2.40$). This difference is likely attributable to the nature of the tasks. In Experiment 1, prior knowledge of letters was already established across all age groups, making age less relevant to performance on this relatively simple task. However, Experiment 2 required children to engage with more complex unfamiliar words, where age-related cognitive development and literacy skills likely had a more pronounced impact. These results support our experimental manipulation (i.e., that the tasks in the two experiments differed significantly in terms of difficulty).

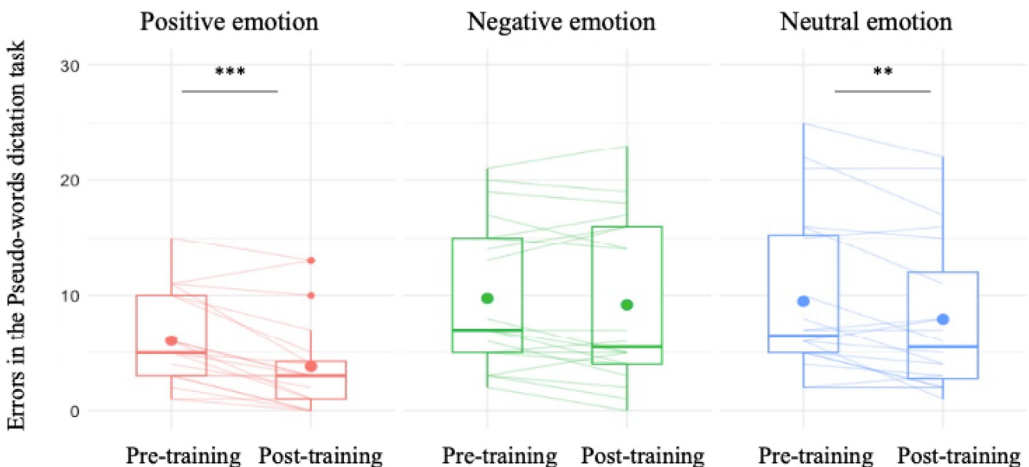


Fig. 3. Errors for the non-words dictation task in each emotional condition (positive, negative, and neutral) in Experiment 2. Asterisks indicate the p values obtained computing the t test between pre-training and post-training. ** $p < .01$; *** $p < .001$.

General discussion

Despite the growing body of research on the interaction between emotional states and cognitive processes in children, little attention has been given to understanding how emotional states influence learning outcomes in tasks of varying difficulty, particularly in educational settings. Task difficulty plays a critical role in influencing not only cognitive performance but also emotional responses, as demonstrated by Lewis et al. (1992), who found that children displayed more shame when failing easy tasks and more pride when succeeding at difficult ones. Whereas many studies have examined the role of emotions in academic performance (e.g., Camacho-Morles et al., 2021; Pekrun & Perry, 2014), few have explored how these emotional states specifically affect performance across tasks of varying complexity. Building on this foundation, our study sought to fill a critical gap in the literature by exploring how task difficulty interacts with emotional states to influence children's learning outcomes. Indeed, the primary objective of our study was to investigate how different emotional states (positive, negative, or neutral) influence the improvements in specific tasks with different levels of difficulty. Specifically, in Experiment 1, we assessed children aged 6 to 8 years in a letter recognition task under positive, negative, or neutral emotional conditions. We found significant improvements across all emotional conditions comparing their performance in pre- and post-training sessions. This suggests that children's emotional states might not affect their performance's improvements in this task. In Experiment 2, we replicated the design used in the previous experiment, with a focus on assessing children's ability to accurately write non-words (i.e., words that do not exist in the lexicon). Interestingly, we found significant improvements in the positive and neutral emotional conditions but not in the negative emotional condition.

The observed differences in children's performance between the two experiments highlight the role of task difficulty in modulating the impact of emotional states. In Experiment 1, the influence of emotional states on performance may be minimal, as evidenced by the consistent improvements observed across all conditions. Conversely, in Experiment 2, where children were engaged in a more cognitively demanding task, we observed distinct effects of emotions on performance; there might be a more pronounced role of emotions in influencing cognitive performance. One possible explanation for these findings is that positive and neutral emotional states may facilitate cognitive processes involved in task execution, such as attention, memory, and problem-solving (see Efklides et al., 2006; Um et al., 2012), thereby enhancing performance in the case of increased task difficulty. On the other hand, negative emotional states may hinder these cognitive processes, leading to a diminished capacity to effectively tackle challenging tasks.

Connected to the previous point, the observed differences in children's outcomes between Experiment 1 and Experiment 2 can be linked to the novelty/familiarity of the stimuli proposed to the participants. Specifically, Experiment 2 introduced a set of stimuli that were novel to the children, engaging them in a context of learning without prior experience or knowledge of the words. In contrast, in Experiment 1, children were engaged in a letter recognition task, a skill they already possessed at some level of familiarity. Their performance improvements across all emotional conditions were driven by a process of reinforcement (a more automatization) of the recognition, whereas in Experiment 2 children's enhancement was driven by a "pure" process of knowledge acquisition, and negative emotional states may have hindered this process.

Our results can also be interpreted in light of the control-value theory (Pekrun, 2006; Pekrun & Linnenbrink-Garcia, 2012; Pekrun et al., 2017). As predicted by this theoretical account, generally positive emotions (both activating and deactivating) have a positive influence on achievement and learning, whereas negative emotions (again both activating and deactivating) have less good influence on achievement and learning. The positive effects of emotions in enhancing learning are well-documented (Isen et al., 1987; Um et al., 2012), and our results support these findings by showing that positive emotional states improved performance, particularly in more challenging tasks such as the non-word dictation in Experiment 2. This outcome aligns with research suggesting that positive emotions boost cognitive resources and promote motivation, which are crucial for engaging with more demanding tasks (Pekrun & Perry, 2014). Moreover, these results align with our Hypothesis 1.

However, the role of negative emotions is more complex. Whereas negative emotional states have been shown to both hinder and enhance learning depending on context (D'Mello et al., 2014; Vogel & Schwabe, 2016), our results suggest that these states may hinder significant improvements in more difficult tasks (supporting Hypothesis 2). This aligns with the control-value theory's prediction that negative emotions deplete cognitive resources and hinder motivation (Pekrun et al., 2017), particularly when the task is cognitively demanding. Thus, our study extends the existing literature by providing more evidence for the worse effects of negative emotional states (compared with positive and neutral ones) when cognitive load is high.

Overall, our results suggest that the interaction between task difficulty and emotional states is a crucial factor to consider in understanding children's cognitive performance. The findings of this study have important implications for educational practices, particularly regarding how emotional states and task difficulty interact to influence learning outcomes. Our results suggest that inducing positive emotions could facilitate learning, especially in tasks with higher cognitive demand, aligning with the broader literature on how positive emotions boost motivation and cognitive resources (Pekrun & Perry, 2014). Conversely, negative emotional states, although sometimes beneficial for certain types of problem-solving (D'Mello et al., 2014), appear to have a more detrimental effect on performance in challenging tasks, likely due to increased cognitive load and stress. This has practical implications for classroom settings, where teachers can design tasks that appropriately balance challenge and emotional support to optimize student performance.

Limitations and future avenues

Our study primarily focused on the interaction between emotional states and task difficulty. However, we did not assess an important element such as perceived competence, which could influence how students appraise and respond to academic challenges. Future studies should address this variable to provide a more comprehensive understanding of the factors that mediate the relationship between emotions and learning outcomes. Moreover, whereas we focused on broad emotional states such as positive and negative emotions, future research could benefit from exploring specific achievement emotions (e.g., enjoyment, anxiety, boredom). These emotions can provide a finer-grained understanding of how emotional responses influence learning.

CRedit authorship contribution statement

Gisella Decarli: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Simone Zasso:** Methodology, Investigation, Data curation. **Laura Franchin:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Data availability

Data will be made available on request.

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Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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