

## The influence of valence and arousal on reasoning: Affective priming in the semantic verification task

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The aim of the present study was to examine the effects of affective valence and arousal on the reasoning process. Reasoning was measured using a semantic verification task and the influence of valence and arousal was tracked using the affective priming paradigm. Primes were photographs varied on two dimensions – emotional valence (positive, neutral, negative) and arousal (high, low). Forty-nine psychology students participated in the experiment. Results showed that reaction time needed for semantic verification was significantly faster for positive-high arousing in comparison to positive-low arousing condition and for neutral-high arousing in comparison to neutral-low arousing condition, but there were no significant differences in negative low and high arousing conditions. Also, significant differences were found among all three valences in high arousing conditions and there were no such differences in low arousing conditions. These results reveal the importance of both arousal and valence in the research on the influence of emotions on the reasoning process.

*Key words:* reasoning, affective valence, arousal, semantic verification, affective priming

Traditionally, emotions and cognition have been viewed as independent processes. In the last decades a growing body of work focused on the influence of affective states on higher level cognitive processes (for review see Blanchette & Richards, 2010; Pham, 2007). These studies typically examined affective valence, but arousal, as a second dimension of affect (e.g. Lang, Bradley, & Cuthbert, 1997, 1998; Russell, 2003, 2009), was often neglected (Blanchette & Richards, 2010; Hinojosa, Carretié, Méndez-Bértolo, Míguez, & Pozo, 2009; Robinson & Compton, 2006). The goal of the present study was to investigate simultaneous effects of affective valence and arousal on higher level cognitive processes.

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*Acknowledgements.* This research was supported by the Ministry of Education and Science of the Republic of Serbia, Grants No. 179033

Previous research has shown that affective variables have important influence on a number of higher level cognitive processes including: memory retrieval, interpretation, judgment, reasoning and decision-making (Blanchette & Richards, 2010; Oaksford, Morris, Grainger, & Williams, 1996; Pham, 2007). However, although a great number of research investigated the role of different variables in reasoning, there has been little research on the influence of affective states on this process. Oaksford et al. (1996) found that both positive and negative moods, when induced by video clips, impaired performance on the Wason selection task in comparison to neutral mood condition, while Melton (1995) found comparable effects on the syllogistic reasoning task, considering only positive and neutral conditions. Similarly, in the conditional reasoning task participants were more likely to draw invalid inferences in response to emotional, compared to neutral statements (Blanchette, 2006; Blanchette & Richards, 2004). In an fMRI study Goel & Dolan (2003) demonstrated differences in brain activation during reasoning about emotionally salient and emotionally neutral syllogisms.

Working-memory has been proposed as a main mechanism on which the described effects of emotion on reasoning may rely. In this context, investigators have suggested that processing of affective content may take up resources of working-memory used for reasoning in conditions without emotional stimuli (Blanchette, 2006; Blanchette & Richards, 2004, 2010; Oaksford et al., 1996). There are some researchers of working memory and executive functions who advocate for different explanations showing diverse effects of positive and negative emotions. It has been suggested that positive emotional states enhance semantic processing as well as more top-down processing and flexible problem solving. On the contrary, negative states impair semantic processing, while promoting a more stimulus driven and bottom-up processing (e.g. Ashby & Isen, 1999; Gray, 2001; Rowe, Hirsh, & Anderson, 2007).

In the research presented so far the main focus has been on affective valence, although most contemporary models of affect postulate two distinct dimensions of affective processing: valence and arousal (Barrett & Russell, 1999; Clore & Palmer, 2009; Lang et al., 1997; Russell, 2003, 2009). The valence dimension ranges from positive to negative and the arousal varies from activating to deactivating (Russell, 2003, 2009; Barrett & Russell, 1999). In his Circumplex model of emotions Russell (2003, 2009) postulates the core affect concept based on the combination of valence and arousal. Dimensions of valence and arousal are bipolar and each emotion can be understood as the linear combination of these dimensions (Posner, Russell, & Peterson, 2005). Core affect represents a continuous evaluation of one's current state and directs cognitive processing according to the principle of mood congruency. Russell states that core affect is a biological product of evolution and that one of the possible consequences of its functions could be taking up attention and working memory resources.

The independence between dimensions of valence and arousal has been shown in different types of research. Psychometric studies in different cultures revealed these two dimensions through factor analyses and multidimensional scaling of self-reported measures (Barrett & Fossom, 2001; Barrett & Russell,

1999; Russell, Lewicka, & Niit, 1989). Psychophysiological research has shown different somatic and behavioral responses to arousal and valence while viewing emotional stimuli (Heller, 1993; Lane et al., 1997; Lang et al., 1998; Lang, Greenwald, Bradley, & Hamm, 1993). Neuroimaging studies provided evidence for two different neural networks underlying the processing of valence and arousal (Colibazzi et al., 2010; Dolcos, LaBar, & Cabeza, 2004; Gerber et al., 2008; Hinojosa et al., 2009; Posner et al., 2009; Posner et al., 2005). In spite of this, the role of arousal in the influence of emotion on higher level cognitive processes remains mostly uninvestigated. In recent research, Blanchette and Leese (2011) used negative and neutral words as emotional stimuli and showed that physiological arousal, operationalized through the skin conductance, was negatively correlated with performance on a deductive reasoning task. There has been research connecting arousal with working memory, executive functions and cognitive control (e.g. Ashby, Valentin, & Turken, 2002; Demanet, Liefvooghe, & Verbruggen, 2011; Kuhbandner & Zehetleitner, 2011; Mather et al., 2006), but due to a small number of studies and different methodologies that have been applied, results still remain unclear. Different explanations of the direction in which arousal could influence higher level cognitive processes have been proposed. One approach suggests that high arousal has detrimental effects on cognitive processing (Blanchette & Leese, 2011), while other authors suggest that it can intensify dedication to current cognitive processes, thus enhancing performance on cognitive tasks (Storbeck & Clore, 2008).

Considering a small number of studies on the influence of emotional valence and arousal on reasoning, in the present study we have examined differential effects of these two dimensions of emotion on the process of reasoning. For the induction of emotional states we have used the affective priming paradigm, which, although broadly used, was not applied in this type of research before. In this paradigm, the influence of emotional context (prime stimuli) on the processing of certain material (target stimuli) is measured (e.g. Fazio, 2001; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Klauer & Musch, 2003). Complex pictures were used as the affective stimuli and were selected from the International Affective Picture System (IAPS) database (Lang, Bradley, & Cuthbert, 2008). IAPS contains normative values of valence and arousal for each picture and these norms have been validated in different countries (for a recent study on a Bosnian sample see Drače, Efendić, Kusturica, & Landžo, 2013). We define reasoning as a higher level cognitive process in which the available information is used to draw inferences (Blanchette & Richards, 2010). We have operationalized this process through the semantic verification task<sup>1</sup>, which has been broadly used in cognitive psychology (e.g. Greene, 1970; Injac & Kostić, 2006; Just & Carpenter, 1971; Wason, 1961). In this task participants evaluate the veracity of presented sentences as fast and as correctly as possible. Specifically, we have used comparative sentences which were varied

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<sup>1</sup> This task can be viewed as the operationalization of both the process of reasoning and the process of judgment. Due to the fact that semantic verification is based on drawing conclusions from the elements given in a sentence in order to evaluate its veracity (Kostić, 2010), we will refer to it as reasoning.

by copula (is/is not), quantifier (greater/less) and veracity (true/false) (e.g. “45 is less than 61”). These sentences were chosen because of their complexity and the absence of any emotional content.

The aim of this study was to investigate the influence of emotional valence and arousal on reaction time and the proportion of errors in the semantic verification task. Based on the previous research on the influence of affect on reasoning we had hypothesized that emotional stimuli of both positive and negative valence will impair performance in the semantic verification task. Considering that the independence of valence and arousal has been demonstrated, we have assumed that these two dimensions could have different effects on the semantic verification task. However, due to the lack of consistent empirical evidence we could not form any grounded hypothesis on the direction in which arousal could influence reasoning. Additionally, we wanted to investigate the relationship between valence, arousal and the properties of sentences in the semantic verification task.

## Method

### Participants

Forty-nine undergraduate students at University of Belgrade gave informed consent to participate in this experiment and received course credit as compensation. All of the participants had normal or corrected-to-normal vision, and all were first year undergraduate psychology students. The sample consisted of 6 males and 43 females; average age was  $20.14 \pm 1.54$ . Participants were tested individually in an experimental room for approximately 20 minutes.

### Stimuli

Pictures used in the experiment were selected from the International Affective Picture System database and used as primes (Lang et al., 2008). Numbers of the IAPS pictures are given in the Appendix. Thirty primes were divided into six equal categories that were obtained through intersection of the factors of emotional valence (positive, neutral or negative) and arousal (high or low), thus five pictures were placed in each category. Previously obtained ratings (Lang et al., 2008) were used for the selection of affective pictures. The mean valence of the primes (on the scale ranging from 1 to 9) was:  $7.62 \pm .41$  (positive),  $4.68 \pm .80$  (neutral) and  $2.54 \pm .52$  (negative). Univariate ANOVA revealed significant differences between categories,  $F(5, 29) = 124.14$ ,  $p < .01$ ; Tukey HSD tests revealed significant differences between every pair of categories,  $p < .01$ . The mean arousal of the primes was:  $4.00 \pm .42$  (low) and  $6.26 \pm .64$  (high),  $t(28) = -11.47$ ,  $p < .01$ . Further on, univariate ANOVA showed no significant differences between valences of the positive-high and positive-low, negative-high and negative-low, nor between neutral-high and neutral-low. No significant differences were revealed between arousals of the positive-high, neutral-high and negative-high, nor between positive-low, neutral-low and negative-low. Also, we have controlled for the luminance of the selected pictures and conducted a univariate ANOVA which showed no significant differences in luminance between six conditions (valence  $\times$  arousal).

Sentences were varied by copula (is/is not), quantifier (greater/less) and veracity (true/false) and used as targets (e.g. “45 is less than 61”)<sup>2</sup>. 240 sentences were constructed for

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2 Sentences used in the experiment were in Serbian (e.g. „45 je manje od 61“).

the purpose of this experiment, hence 30 sentences per eight categories (copula×quantifier×veracity). Two-digit numbers were used in all of the sentences. Distances between numbers used within a sentence were random. Univariate ANOVA revealed no significant differences in distances between numbers across six conditions (valence×arousal).

### Design

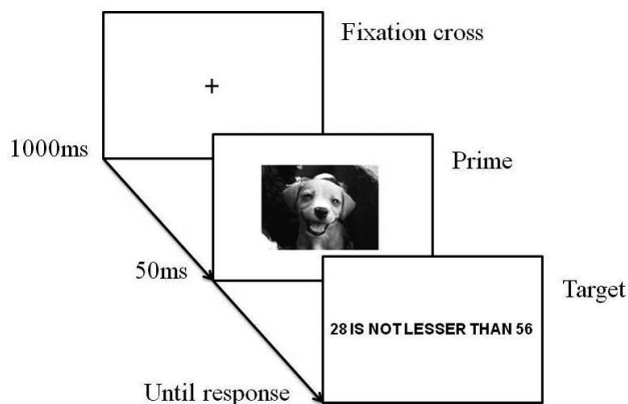
The experiment had a 2×3 factorial design. Independent within-participant factors were valence (positive vs. neutral vs. negative) and arousal (high vs. low). Dependent variables were reaction time (RT) and proportion of errors (PE). 40 sentences were ascribed to the six conditions, obtained through the intersection of the two independent factors. Out of those 40 sentences, five belonged to the each category of target sentences described above.

### Apparatus and Procedure

Participants were tested individually in experimental room for 20 minutes. Stimuli were presented on a 15-inch CRT monitor and the viewing distance was approximately 80cm. The experiment was constructed and presented in the Super Lab Pro 4.0 software. Responses were recorded using a Cedrus RB-530 response box.

Average height of the presented pictures was 604 pixels and the average length was 500 pixels. In the resizing procedure the original height×length ratio was kept. Sentences were presented in Arial font (black uppercase; size 28). Stimuli were presented at the center of the screen on a white background.

The experiment consisted of a practice phase (10 trials) and a test phase. Each trial consisted of a fixation cross (1000ms) and the prime picture (50ms) followed by the target sentence (see Figure 1). The target remained on the screen until the participant gave a response (maximum response time was set to 3000ms). The inter-trial interval was set to 1500ms. Each of the primes was presented once in each of the eight target categories making a total of 240 trials. Trials were presented in random order. The participants were instructed to look at the prime pictures and then to read target sentences and evaluate their veracity as quickly and as correctly as possible. They responded by pressing either the right key with the right finger or the left key with the left finger. The response keys with the labels *true* or *false* were counterbalanced across participants.



*Figure 1.* Experimental procedure. A fixation cross was shown, followed by a picture prime after which a sentence for verification was shown. Participants evaluated the veracity of the sentence by pressing one of the response keys. The picture in this figure is not from the IAPS database and was not used as a stimulus in this experiment.

## Results

Reaction times that were above or below 2.5 SD of the reaction time for the specific trial were excluded from further analyses (1.30%) in order to deal with outliers. Further on, conditions in which participants gave incorrect responses (13.54%) were excluded from the analyses of the reaction time as a dependent variable. Repeated Measures ANOVAs were conducted on the mean reaction times for trials and for the proportion of errors separately. Valence (positive vs. neutral vs. negative) and arousal (high vs. low) were used as within-subjects variables.

3×2 Repeated Measures ANOVA for reaction times as the dependent variable revealed a statistically significant main effect of valence,  $F(2, 96) = 8.56, p < .01, \eta^2 = .15$ . Planned comparisons analysis indicated that RTs for positively primed targets ( $M=1657, SD=215$ ) were faster than RTs to either neutral ( $M=1679, SD=210$ ) or negative ones ( $M=1688, SD=211$ ) which showed no significant difference. Also, the main effect of arousal was found to be significant  $F(1, 48) = 33.10, p < .01, \eta^2 = .41$  and indicated that RTs for targets primed with low arousing stimuli ( $M=1269, SD=156$ ) were slower than high arousal ones ( $M=1243, SD=162$ ). The interaction between valence and arousal was significant  $F(2, 96) = 10.50, p < .01, \eta^2 = .18$  (see Figure 2). Planned comparisons revealed that RTs needed for sentence verification when targets were primed with positive-high arousing stimuli were faster than RTs for targets primed with positive-low ones,  $p < .01$ . Also, RTs needed for verification were faster for targets primed with neutral-high stimuli than RTs for targets primed with neutral-low ones,  $p < .01$ . Such differences were not found between RTs for targets primed with negative-high and negative-low stimuli. Further on, planned comparisons revealed significant differences between RTs needed for verification when targets were primed with high arousing stimuli of all the three valences. RTs for targets primed with positive-high stimuli were faster than the ones primed with neutral-high stimuli,  $p < .01$ , and negative-high stimuli,  $p < .01$ ; targets primed with neutral-high stimuli were faster than the ones primed with negative-high stimuli,  $p < .05$ . On the other hand, there were no statistically significant differences on RTs needed for verification of targets primed with low arousing stimuli of all the three valences.

3×2 Repeated Measures ANOVA for the proportion of errors as the dependent variable failed to produce significant main effects of valence and arousal. Also a significant interaction between these two factors was not found.

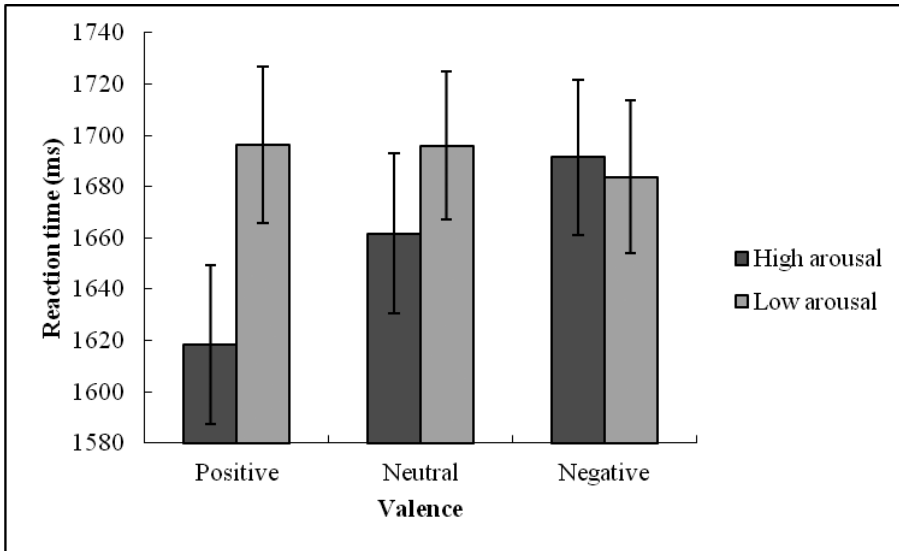


Figure 2. The graph represents the interaction between valence (positive vs. neutral vs. negative) and arousal (high vs. low) when RT is taken as the dependent variable. Error bars show standard errors.

In order to assess the relationship between valence, arousal and the sentence properties (copula, quantifier and veracity) a  $3 \times 2 \times 2 \times 2$  Repeated Measures ANOVA was conducted on RTs as the dependent variable. All of the five main effects were found to be significant: emotional valence,  $F(2, 80) = 8.97, p < .01, \eta^2 = .18$ , arousal,  $F(1, 40) = 22.06, p < .01, \eta^2 = .36$ , copula,  $F(1, 40) = 601.58, p < .01, \eta^2 = .94$ , quantifier,  $F(1, 40) = 128.76, p < .01, \eta^2 = .76$  and veracity,  $F(1, 40) = 23.48, p < .01, \eta^2 = .37$ . Four-way interaction between arousal, copula, quantifier and veracity was statistically significant,  $F(1, 40) = 11.18, p < .01, \eta^2 = .22$ . In order to further investigate the interaction between the arousal and the sentence properties, we have conducted a planned comparisons analysis comparing high and low arousing conditions across the six copula $\times$ quantifier $\times$ veracity situations. This analysis revealed that the RTs needed for the sentence verification were significantly faster when targets were primed with high arousing stimuli compared to the low arousing ones in three conditions: is-less-false,  $p < .01$ , is not-greater-false,  $p < .05$ , and is not-less-true,  $p < .05$ . Differences in the remaining conditions were not found to be significant. Planned comparisons also revealed that all the RTs were faster for semantically unmarked properties of the sentences in comparison to marked ones: the “is” condition was faster than the “is not” condition, the “greater” condition was faster than the “less” condition and the “true” condition was faster in comparison to the “false” condition, except for the “is not-greater” situation. All of the mentioned differences were significant at the .01 level.

## Discussion

The aim of this study was to investigate the influence of emotional valence and arousal on performance in the semantic verification task. Results revealed significant main effects of emotional valence and arousal, as well as significant interaction between these two factors when reaction time was taken as a dependent variable. However, when the proportion of errors was taken as a dependent variable, there were no significant effects of the two factors and there was no significant interaction between them. Planned comparisons revealed that in the low arousal condition there were no differences in time needed for semantic verification across conditions in which the sentence is preceded by a positive, neutral or negative picture. However, in the high arousal condition, it was found that positive stimuli facilitate reaction time in comparison to neutral stimuli, while negative stimuli inhibited reaction time compared to neutral stimuli. This means that valence had no differential effect on reasoning when stimuli were low in arousal, but the differential effects emerged in the high arousal condition.

Our hypothesis was that emotional valence would impair performance on the semantic verification task. Previous studies in the field of influence of emotions on reasoning showed inhibitory effects of both positive and negative affective states on Wason selection task (Oaksford et al., 1996), syllogistic reasoning (Melton, 1995) and conditional reasoning task (Blanchette, 2006; Blanchette & Richards, 2004). However, our results revealed facilitatory effects of positive and inhibitory effects of negative affective states, but only in the high arousal condition. No effects of valence were found in the low arousal condition. This research is different from previous ones in the methodology of emotion induction, as well as in the reasoning task that was used. This could be one of the reasons for the inconsistencies in the obtained results. On the other hand, it could be noted that the previous studies did not control for arousal in the way that we have done.

As we have previously stated, there has been research suggesting that working-memory could be a mechanism on which the influence of emotions on reasoning relies on. This explanation is based on evidence showing that the process of reasoning is highly reliant upon working-memory (Copeland & Radvansky, 2004) and, further on, suggests that emotional stimuli could take up resources of working-memory needed for reasoning (Blanchette, 2006; Blanchette & Richards, 2004, 2010; Oaksford et al., 1996). At the same time, a number of researchers investigating working-memory and executive functions have argued that there are differential effects of positively and negatively valenced emotions on these processes. In this approach, it was proposed that positive emotions enhance semantic and top-down processing, while negative emotions impair semantic and promote bottom-up processing (e.g. Ashby & Isen, 1999; Gray, 2001; Rowe, Hirsh, & Anderson, 2007). Results of our study are consistent with the idea of distinct effects of positive and negative valence on the process of reasoning, and we could argue that positively valenced stimuli



have led to better semantic processing, while negatively valenced stimuli have impaired processing in the semantic verification task. It is important to stress out that this effect was found only when stimuli were highly arousing. Also, it should be emphasized that this explanatory framework was the result of studies dealing with working-memory and executive functions, so it should be applied to reasoning with caution.

Due to a small number of relevant studies, we could not form any specific hypothesis on the direction of the arousal's influence on reasoning. Blanchette and Leese (2011) showed that physiological arousal is negatively correlated with the performance on a deductive reasoning task. However, their research included only neutral and negative stimuli and since it was correlational it was not possible to determine whether the arousal had influenced the process of reasoning. In our research high arousal was found to enhance semantic verification in the condition of positive or neutral valence, but there was no such effect in the condition with negatively valenced stimuli. Further analyses has revealed that only arousal, but not the emotional valence, had interacted with the sentence properties (copula, quantifier and veracity) in the semantic verification task. High arousal enhanced semantic processing compared to low arousal, but only when two of the semantically marked sentence properties (is not, less and false) were used in the target sentence. This effect did not occur in conditions in which all three properties were unmarked, nor in conditions with one unmarked property. Also this effect was not found in the condition with three marked properties. Taking into account that semantically marked properties are more cognitively complex and require more processing time (e.g. Givón, 2001), our results suggest that high arousal enhanced semantic verification in the situations of high, but not maximum sentence complexity. It could further be argued that arousal interacts with complexity of the reasoning task. Still, further research is needed in order to investigate this interaction in a more clear way and to elaborate cognitive mechanisms on which these effects could rely on.

Considering that the independence of valence and arousal has been demonstrated in psychometric (e.g. Barrett & Russell, 1999), psychophysiological (e.g. Lang et al., 1998) and neuroimaging studies (e.g. Posner et al., 2005), we hypothesized that these two dimensions could have different effects on the semantic verification task. Dimensional theories of emotions, such as Russell's Circumplex model of affect, postulate the independence between dimensions of affective valence and arousal (Russell, 2003, 2009). Although these theories are broadly used, to our knowledge there is a surprisingly small number of studies that have taken into account both of these dimensions when investigating the influence of emotions on higher level cognitive processes. Our research revealed interactive influence of valence and arousal on reasoning. In the present study, high arousal has enhanced semantic verification in the condition with positively valenced stimuli and impaired verification in the condition with negatively valenced stimuli in comparison to the neutral condition. These results are in line with the idea that positive and negative emotional valences promote different styles of cognitive processing (semantic or stimulus driven), while arousal

influences the degree of dedication to the current processing style, serving as information about its importance or urgency (Storbeck & Clore, 2008). High arousal might have positive effects on the process of reasoning, but these effects could be masked in the situation of negative valence due to detrimental effects of negative emotions on higher level cognitive processes. This could be the reason why enhancement of semantic processing by the arousal can be shown only in the conditions of positive and neutral valence.

### Conclusion

Although there is a growing number of studies investigating the influence of emotions on higher level cognition, there is still no broadly accepted theoretical framework that could explain the mechanisms underlying such influence. One of the reasons for such a situation could be the traditional division between emotions and cognition. For example, although there are a number of theories of emotions that differentiate affective valence from arousal, such distinction is rarely taken into account by cognitive psychologists.

Our research has revealed the importance of including both dimensions of emotions, affective valence and arousal, in the study of the interplay between emotions and cognition. We argue that this distinction is valid not only for studying emotions per se, but also for the investigation of the influence of emotions on cognitive processes such as reasoning.

This study is, to our knowledge, one of the first in which arousal and valence were taken as separate factors in the investigation of the influence of emotions on the process of reasoning. As such, it has its limits, primarily due to the absence of a strong theoretical model from which a grounded hypothesis could have been drawn. In this context our research is, in a way, exploratory and, because of this, there is not much empirical evidence with which our results could have been compared.

Further research should be directed towards validating the obtained results in different types of reasoning tasks. Also, in the present study we have induced emotions by visual stimuli and it would be significant to explore whether this structure of effects would be replicated with verbal or auditory stimuli. In these ways it would be possible to investigate the generality of the results obtained in this experiment.

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## **Appendix**

Numbers of the IAPS pictures used as primes in the Experiment:

- Positive – High Arousal: 4220, 4608, 5621, 7502, 8200
- Positive – Low Arousal: 1750, 2341, 5760, 5780, 7325
- Neutral – High Arousal: 1390, 5950, 7560, 7640, 8117
- Neutral – Low Arousal: 6000, 7130, 8010, 9010, 9390
- Negative – High Arousal: 3071, 3150, 3400, 9300, 9405
- Negative – Low Arousal: 2490, 2590, 9000, 9280, 9290