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# Independent effects of relevance and arousal on deductive reasoning

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## ABSTRACT

Emotional content can have either a deleterious or a beneficial impact on logicity. Using standard deductive-reasoning tasks, we tested the hypothesis that the interplay of two factors – personal relevance and arousal – determines the nature of the effect of emotional content on logicity. Arousal was assessed using measures of skin conductance. Personal relevance was manipulated by asking participants to reason about semantic contents linked to an emotional event that they had experienced or not. Findings showed that (1) personal relevance exerts a positive effect on logicity while arousal exerts a negative effect, and that (2) these effects are independent of each other.

## KEYWORDS

Reasoning; emotion; relevance; trauma; cognition

## Highlights

- We tested the effects of arousal and relevance of emotional content on logicity.
- Arousal exerts a negative effect while relevance exerts a positive effect.
- These two effects are independent of each other.

Reasoning, and more specifically logical deduction, is a uniquely human talent that has allowed the creation of highly developed societies characterised by complex technologies, advanced medicine and sophisticated economies. Surprisingly, however, individuals do not reason as logically as they ought to (Chater & Oaksford, 2001). Suboptimal logical-deduction performance has been attributed to a number of factors, including lack of motivation or utility. Recent studies have shown that emotion is one important such factor.

Emotional contents have been shown to decrease logicity in reasoning (Blanchette & Leese, 2011; Blanchette & Richards, 2004; Oaksford, Morris, Granger, & Williams, 1996; Radenhausen & Anker, 1988). In one study, Blanchette and Richards (2004) investigated the effect of emotions on logicity using

conditional syllogisms (of the form “if P then Q”). The contents of the syllogisms, which were semantically non-emotional, were conditioned to evoke either no emotion, in the neutral condition, or negative emotions, in the emotional condition, using evaluative conditioning (i.e. by pairing the reasoning stimuli with neutral or emotional images). Despite the fact that semantic content was exactly the same in the two conditions, and that the logical structure was identical, participants provided less normatively logical responses when reasoning about contents conditioned to be emotional. Similar findings were obtained using syllogisms with emotional/neutral words (e.g. comparing the word “torture” to the word “table”) (Blanchette & Leese, 2011).

Emotion is a state that involves several dimensions (e.g. Dolan, 2002), namely, a cognitive dimension (in the appraisals/evaluations that lead to the emotion and the conscious, subjective elements linked to the emotional response), a behavioural dimension (in the form of facial expressions of emotion or action tendencies) and a physiological dimension (that includes changes in autonomous nervous system activity related to arousal). A recent study suggests that the origins of the deleterious effect of emotional contents on reasoning may be mediated, at least partly, by the

physiological dimension of emotions. In this study, a larger increase in skin conductance in response to an emotional stimulus was associated with a lower level of logicity in a deductive-reasoning task (Blanchette & Leese, 2011). Because skin conductance is a good indicator of physiological arousal, defined as an increase in the activity of the sympathetic nervous system (Critchley, 2002), this suggests an important link between emotion-related physiological changes and reasoning. A potential mechanism for this comes from neuroimaging studies. Recent evidence shows that skin conductance responses are centrally represented in the ventromedial prefrontal cortex (Nagai, Critchley, Featherstone, Trimble, & Dolan, 2004), an area which also subserves heuristic processing in reasoning (e.g. Goel & Dolan, 2003). An increase in the activity of this region could lead to decreased logicity. Overall then, there are reasons to expect a negative link between peripheral bodily arousal and logicity in reasoning.

In the reasoning literature, the impact of emotions on logicity has often been studied experimentally by observing emotion inductions of low personal relevance (e.g. comparing the word "torture" to the word "table") (e.g. Blanchette & Leese, 2011). Such experimental manipulations of emotion afford good experimental control, but lack the dimension of personal relevance that is important not only for increased ecological validity, but for evoking potentially more intense emotions. There are a few studies suggesting that, in conditions where emotional contents are highly personally relevant, emotions improve rather than impair logicity (Blanchette & Campbell, 2012; Blanchette, Richards, Melnyk, & Lavda, 2007; Johnson-Laird, Mancini, & Gangemi, 2006). Blanchette and Campbell (2012) have shown that war veterans are more logical when reasoning about categorical syllogisms (e.g. "some As are Bs, all Bs are Cs, therefore, some As are Cs") containing emotional war-related content (e.g. "some chemical weapons are used in war") than when reasoning about categorical syllogisms containing neutral content (e.g. "some teas are natural substances"). Similarly, patients suffering from obsessive-compulsive disorder (OCD) or depression reason more logically about OCD- and depression-related contents, respectively (Johnson-Laird et al., 2006). Finally, participants closely affected by terrorist attacks are more logical when reasoning about some emotional terrorism-related content than controls (Blanchette et al., 2007).

The mechanism through which relevant emotional contents might improve reasoning – compared to irrelevant emotional contents – remains unknown. It is possible that the effect of emotional relevance is mediated not by the physiological dimension of emotions but by the cognitive one. Thus, relevant emotional contents have been proposed to activate task-relevant semantic concepts and mental representations in autobiographical or semantic memory (Blanchette, Caparos, & Trémolière, *in press*; Evans, Handley, & Harper, 2001). These concepts and/or mental representations would overlap with the concepts/representations necessary for the resolution of the reasoning problem, and this would improve, or at least not interfere with, participants' logical performance (Blanchette, Gavigan, & Johnston, 2014).

If the deleterious effect of emotional contents is mediated by emotions' physiological dimension and the beneficial effect by their cognitive dimension, these two effects may be independent. This question has never been addressed in previous research. In this paper, we tested whether arousal and relevance exert independent or interacting effects by comparing the relationship between arousal and reasoning in low- and high-relevant emotional contents. Because arousal has already been shown to be negatively related to logicity with low-relevant emotional contents (Blanchette & Leese, 2011), the key issue concerns the relationship between arousal and logical errors with high-relevant emotional contents; a positive relationship would support an independence account.

To investigate these questions, in the present study, we employed a quasi-experimental design (Blanchette & Campbell, 2012; Blanchette et al., 2007; Johnson-Laird et al., 2006). Participants reasoned about emotional stimuli associated with intense emotions: sexual abuse or car accident. We operationalised personal relevance in the following way. We compared participants who had personally experienced an emotional event, sexual abuse or car accident, and participants who had not experienced it, instantiating higher personal relevance in the first case and lower personal relevance in the second. Consequently, personal relevance was treated as a categorical variable in the analyses.

The impact of emotional content on reasoning was indexed by subtracting logical errors when reasoning about neutral content (which provided a baseline) from logical errors when reasoning about high-relevant or low-relevant emotional content. Previous

work has indeed illustrated the importance of contrasting the effect of emotional content against a neutral baseline (Blanchette et al., 2007; Blanchette & Leese, 2011), among other reasons because trauma can be linked more generally with impairments in higher level cognitive functions (El-Hage, Gaillard, Isingrini, & Belzung, 2006; Klein & Boals, 2001) and affect reasoning performance on neutral problems. Emotional content with high relevance (i.e. sexual-abuse contents for sexual abuse victims, and car accident contents for car accident victims) was expected to have a positive impact on reasoning while emotional content with low personal relevance (e.g. car accident contents for sexual-abuse victims) was expected to have a negative impact on logicity.

Arousal was indexed using measures of skin conductance reactions to the presentation of the reasoning stimuli. Because the measure of skin conductance was a continuous variable and personal relevance a categorical one, we used a general linear model with both categorical and continuous independent variables to analyse their effect.

## Method

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

### Participants

Eighty-five participants were recruited from the Université du Québec à Trois-Rivières, Canada, and from the general population of Trois-Rivières, using advertisements on campus and in local newspapers.<sup>1</sup> Based on the results of previous quasi-experimental studies on reasoning and emotion (Blanchette & Campbell, 2012; Blanchette et al., 2007), we expected that a strict minimum of 20 participants was necessary in each group to observe effects of our independent variables.<sup>2</sup> Although larger groups would be desirable to reach stronger statistical power, we stopped collecting data when we had achieved this target due to the challenges inherent in recruiting trauma-exposed populations.

The advertisement mentioned that the study was about the effect of sexual abuse and car accident on cognitive processing. Both victims and non-victims were invited to contact us. Only women were included since sexual abuse is more relevant to this group (e.g. in 2008, more than 80% of sexual-abuse victims were

women in Canada; see [www.statcan.gc.ca](http://www.statcan.gc.ca)). The occurrence of a sexual-abuse experience and/or a car accident was assessed using a semi-structured interview. Only participants who did not experience head trauma during the accident were included in the study. In addition, only those for whom the experience was impactful (i.e. participants who had a score higher than zero at the Impact of Event Scale (IES); see below) were included in the victim groups. Forty-seven participants had experienced neither abuse nor accident (Mean age 29.3 years, SEM = 2.2; 14.8 years of education in average, SEM = 0.2), we refer to them as the control group. Thirteen participants had experienced an accident (Mean age 27.5 years, SEM = 3.9; 13.9 years of education in average, SEM = 0.6), 17 participants had experienced sexual abuse (Mean age 34.3 years, SEM = 3.9; 13.6 years of education in average, SEM = 0.6), and 8 participants had experienced both abuse and accident (Mean age 28.1 years, SEM = 4.2; 14.0 years of education in average, SEM = 0.8). All participants had normal or corrected-to-normal vision and spoke French as their first language. Participants received \$30 as a compensation for their time at the end of the experiment.

### Stimuli

The reasoning problems were categorical syllogisms containing two premises and a conclusion (i.e. "no B is an A, some Cs are Bs, then, all Cs are As"; "no A is a B, some Cs are Bs, then, all Cs are As"; "No A is a B, some Cs are Bs, then, some Cs are not As"; or "No B is an A, some Cs are Bs, then, some Cs are not As"). Eight of the problems used abstract content (e.g. "no P is a Q, some Ks are Ps, then, all Ks are Qs"; example of invalid problem), 12 problems used neutral content (e.g. "no woman is a teacher, some researchers are women, then, some researchers are not teachers"; example of valid problem), 12 problems used generally emotional content (e.g. "no physician is a psychopath, some killers are psychopaths, then, some killers are not physicians"; example of valid problem), twelve problems used content related to sexual abuse (e.g. "no sexual-abuse victim is a paedophile, some rapists are sexual-abuse victims, then, all rapists are paedophiles"; example of invalid problem), and eight problems used content related to car accidents (e.g. "no criminal is a driver, some recidivists are drivers, then, all recidivists are criminals"; example of invalid problem). In each semantic-content category, the conclusions of half the problems

were valid and the other half were invalid. The same logical structures were used for all content types. Syllogisms were presented in French. Their English translation is presented in the Appendix.

Abuse-related content was expected to present high personal relevance for abuse victims and low personal relevance for controls and car accident victims. Accident-related content was expected to present high personal relevance for accident victims and low personal relevance for controls and victims of sexual abuse. We predicted that abuse- and accident-related contents should have a beneficial impact in participants for whom abuse or accident was personally relevant.

### **Procedure**

This study was also part of a larger investigation looking into the effect of emotional experiences on cognitive functions, including attention, short-term memory and long-term memory. Participants performed the reasoning task along with a battery of other cognitive tasks measuring these functions.

Participants were interviewed one week before they performed the cognitive tasks to screen for the occurrence of two types of potentially traumatic events: sexual abuse and car accident. Participants who had experienced abuse and/or an accident filled a French translation of the Impact of Event Scale questionnaire (Horowitz, Wilner, & Alvarez, 1979), for each emotional event that they had experienced (i.e. participants who had experienced both abuse and accident filled one questionnaire for the abuse event and one for the accident event). This 22-item questionnaire indexes the incidence of life difficulties experienced during the seven days preceding testing related to the sexual-abuse/accident event(s). Participants gave an answer from zero (not at all) to four (extremely) to each item. Items addressed a range of difficulties that may result from trauma, such as sleep disturbance, nervousness or the intrusion of disturbing thoughts related to the event. Answers were added to produce a score from 0 (no impact) to 85 (extremely high impact) which was used as a measure of the psychological consequence of the sexual-abuse/accident experience. Only participants for whom the emotional event was impactful (i.e. participants who had a score higher than zero at the IES) were included in the victim groups. The average abuse-related IES score ( $M = 25.5$ ,  $SEM = 3.7$ ) was marginally larger than the average

accident-related IES score ( $M = 17.0$ ,  $SEM = 3.2$ ),  $t(44) = 1.69$ ,  $p = .099$ .

There was no reason to expect that abuse and accident experiences were influencing each other, and therefore abuse and accident experiences were treated as separate independent variables (each of them with two levels: not experienced/experienced) in the analyses.

Cognitive testing took place one week after the interview, in a dimly lit and quiet testing room. Stimuli were presented on an LCD 22-in monitor, operating at a resolution of  $1280 \times 1024$  pixels. Viewing distance was 60 cm. The stimuli were generated and the experiment was run using EPrime 2 (Schneider, Eschman, & Zuccolotto, 2002).

Participants were told that they would reason about a number of problems and that they would have to determine whether the conclusion of the problem could be drawn based on logic or not. Participants were told to reason as if the premises were true, even when they were not true in real life. Participants pressed the "yes" key (i.e. the "1" key covered with a "yes" sticker) if they thought that the conclusion was valid or the "no" key (i.e. the "2" key covered with a "no" sticker) if they thought that it was not. An example was given to illustrate the instructions. Problems were presented in black on a white screen. The different problems were presented in a randomised order.

During the first six seconds of each syllogism presentation, participants' skin conductance was measured using a constant voltage approach, with the LabChart 6 software (AD-Instrument) and the Powerlab 26T hardware (model ML116; one gel-free MLT116F electrode plate was placed on the second phalange of the ring finger and one on the second phalange of the forefinger). During each stimulus presentation, we measured the average electrodermal deviation from the participant's reference level (which was established using a one-minute baseline recording at the start of the experiment).

## **Results**

### **General reasoning skills**

First, we compared participants' general reasoning abilities, that is, their performance with neutral and abstract contents (see Table 1). The effect of sexual-abuse group (no-abuse control or sexual-abuse victim), accident group (no-accident control or

**Table 1.** Error percentages at the reasoning task as a function of problem content and group.

Group	Problem content				
	Abuse-related <i>M</i> (SD)	Accident related <i>M</i> (SD)	Generally emotional <i>M</i> (SD)	Neutral <i>M</i> (SD)	Abstract <i>M</i> (SD)
Abuse victims	17.6% (11.2)	19.4% (20.7)	20.9% (17.4)	15.9% (13.0)	14.8% (15.6)
No-abuse controls	18.0% (10.8)	15.8% (15.9)	14.1% (12.2)	11.2% (10.4)	14.4% (14.2)
Accident victims	19.4% (12.4)	11.8% (18.2)	17.8% (17.2)	14.7% (13.7)	12.9% (13.8)
No-accident controls	17.4% (10.3)	18.5% (16.9)	15.5% (13.1)	11.9% (10.5)	15.1% (14.8)

accident victim) and content (abstract or neutral) on error percentages was tested using a mixed-design analysis of variance (ANOVA). The analysis showed no significant main effect or interaction. Error percentages ( $M = 14.4\%$ ,  $SEM = 2.4$ ) were equivalent across groups (no-abuse controls vs. sexual-abuse victims, and no-accident controls vs. accident victims) and across contents (abstract vs. neutral contents).

### Effect of personal relevance

We subtracted error percentages for neutral content from error percentages for generally emotional, abuse-related and accident-related contents. In doing so, neutral content was used as a baseline against which to measure the effect of each type of emotional content in each participant.

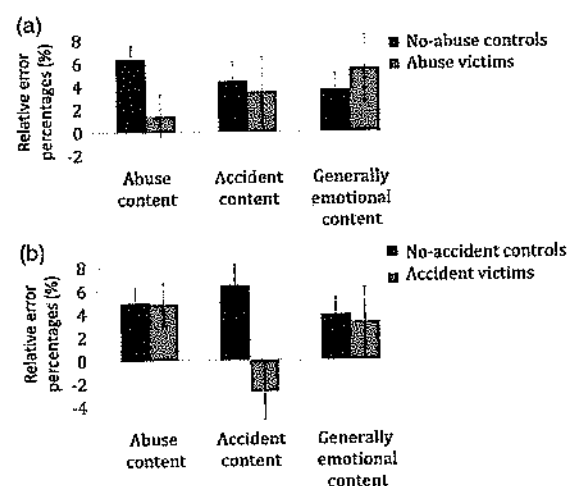
We used a mixed-design ANOVA to test for effects of personal relevance on relative error percentages. Emotional content (generally emotional, abuse-related or accident-related) was entered as a within-subject variable. Abuse group (sexual-abuse victims or no-abuse controls) and accident group (accident victims or no-accident controls) were entered as between-subject variables.

First, the intercept effect was significant,  $F(1,81) = 9.16$ ,  $p = .003$ ,  $\eta_p^2 = .102$ ,  $\eta_p^2 = .102$  (observed power = .85), showing that relative error percentages were significantly different from zero, in other words, error percentages were higher with emotional contents (pooled across generally emotional, abuse-related or accident-related contents) than with neutral contents.

We expected selective effects of groups (i.e. abuse group and accident group) on relevant emotional contents (i.e. respectively, abuse-related and accident-related contents). The results confirmed this prediction. There was a significant two-way interaction between accident group and type of emotional content,  $F(2,162) = 4.60$ ,  $p = .011$ ,  $\eta_p^2 = .054$  (observed power = .77), and there was a marginal two-way interaction between abuse group and type of emotional content,  $F(2,162) = 2.99$ ,  $p = .053$ ,  $\eta_p^2 = .036$  (observed power = .57).<sup>3,4</sup>

The origin of these interactions was examined using pairwise comparisons. While abuse victims had lower error percentages than controls for abuse-related contents,  $t(83) = 2.27$ ,  $p = .026$ ,  $d = 0.556$  (observed power = .64), this was not the case for accident-related contents and generally emotional contents ( $ps > .400$ ; see Figure 1(a)). In addition, while accident victims had lower error percentages than controls when reasoning about accident-related contents,  $t(83) = 2.88$ ,  $p = .005$ ,  $d = 0.793$  (observed power = .88), this was not the case when reasoning about abuse-related and generally emotional contents ( $ps > .700$ ; see Figure 1(b)).

Relative error percentages with emotional contents were never in the negative range, showing that participants never reasoned better with emotional content than with neutral content. While relative error percentage for accident-related content appeared to be negative in accident victims (see Figure 1(b)), it was not significantly different from zero,  $t(20) = 1.21$ ,  $p = .239$ ,  $d = 0.278$  (observed power = .22). A power analysis (using G\*Power; Faul,



**Figure 1.** Reasoning task. Relative error percentages (a) in no-abuse controls and abuse victims and (b) in no-accident controls and accident victims, for abuse-related, accident-related and generally emotional content (error bars represent standard error of the mean).

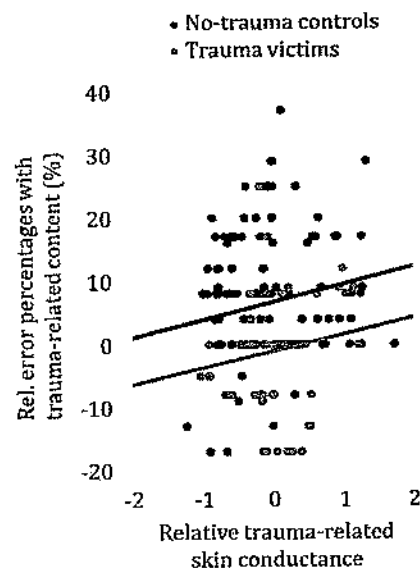
Erdfelder, Lang, & Buchner, 2007) revealed that in order for an effect of this size to be detected as significant (with 80% chance) at the 5%  $p$  level, a sample of 104 participants would be required, suggesting that, because of the modest sample size in the present study ( $N = 21$ ), insufficient statistical power may have played a role in limiting the significance of this finding.

### Reasoning and arousal

We subtracted skin conductance for neutral content from skin conductance for generally emotional, abuse-related and accident-related contents. In doing so, neutral content was used as a baseline against which to measure the effect of each type of emotional content in each participant.

We tested whether generally emotional, abuse-related and accident-related error percentages were linked, respectively, to generally emotional skin conductance, abuse-related skin conductance and accident-related skin conductance, and whether these relationships varied across abuse and accident groups. For these analyses, we used three ANOVAs, respectively on generally emotional, abuse- and accident-related error percentages, with skin conductance entered as a continuous covariable and abuse and accident groups entered as two categorical variables. Main effects of skin conductance and interactions between skin conductance and groups were not significant.

On the basis that abuse-related and accident-related data produced comparable trends, however, they were collapsed into one single "trauma" dataset in order to increase power, and the same ANOVA was performed again. The main effect of skin conductance approached significance,  $F(1,162) = 3.43$ ,  $p = .066$ ,  $\eta_p^2 = .021$  (observed power = .45), thus replicating previous findings in the literature showing a positive relationship between skin conductance and error percentages (Blanchette & Leese, 2011). Importantly, this effect did not interact with group,  $F(1,162) = 0.03$ ,  $p = .960$ ,  $\eta_p^2 = .001$  (observed power = .05). A power analysis (using G\*Power) revealed that in order for an effect of this size to be detected as significant (with 80% chance) at the 5% level, a sample of 7800 participants would be required, indicating that the small sample size was unlikely to be the cause of the absence of interaction. This finding suggested that,



**Figure 2.** Relative error percentages on trauma-related contents (pooled across abuse- and accident-related contents) as a function of trauma-related skin conductance responses: each light-grey dot represents the average for one abuse/accident victim with trauma-specific content, and each dark-grey dot represents the average for one no-abuse or no-accident control participant with respectively, abuse or accident content.

both in trauma victims and no-trauma controls, an increase in skin conductance was associated with an increase in error percentages for trauma-related contents (see Figure 2).

### General discussion

This study tested whether two factors, arousal and personal relevance of emotional content, exert independent effects on deductive reasoning. The impact of personal relevance was measured by contrasting performance on contents with high personal relevance and contents with low personal relevance. Skin conductance measures were used to test the relationship between arousal and reasoning performance. This work generated the following important findings.

First, participants made fewer reasoning errors when contents were emotional and relevant to them (e.g. accident-related contents for participants who had experienced an accident) than when they were emotional but not as personally relevant (e.g. accident-related contents for participants who had not experienced an accident). This finding is consistent

with the view that personal relevance tempers the negative effect of emotional contents (Blanchette et al., 2007). Note that, in the present study, the relevance-driven advantage remained relative however. A deleterious effect of emotional content was always observed; indeed, participants never reasoned better with emotional content than with neutral content, even when content was relevant to them. Nevertheless when this emotional content was personally relevant, the negative effect was mitigated.

One of the novelties of this work was to study the impact of a new type of trauma, namely car accidents. This type of trauma is frequent; it represents one of the principal causes of posttraumatic stress disorder (PTSD) in western populations (Blanchard & Hickling, 1997). Examining two types of traumas allowed us to ensure that the observed effects were driven by relevance (the same contents were high-relevant to one group and low-relevant to the other) and not by confounding factors (such as the stimuli themselves or group differences).

The (relative) beneficial effect of personally relevant emotional contents may rely on several factors. When contents are relevant to the participant, emotion-driven competing thoughts are more likely to be closely related to the reasoning material; this might help participants find counterexamples and/or validating examples relevant to the reasoning problem (Evans et al., 2001), thus increasing logicity. It is also possible that personally relevant emotional contents increase motivation to solve reasoning problems (Mercier & Sperber, 2011), thus reducing the emotion-driven rerouting of attentional resources away from the task. More generally, the beneficial impact of personally relevant emotional content could be accounted for by recently proposed utility theories (Blanchette & Caparos, 2013). Personally relevant emotional contents may carry high utility, in terms of a person's progress towards his/her goals, and thus promote an increase in the allocation of resources towards problem solving (Bonnefon, 2009).

Our results concur with prior literature in that the effect of emotional content was generally to decrease logicity in reasoning. The deleterious effect of emotional content appeared to be positively related to physiological arousal. Importantly, an increase in arousal had similar effects across relevant and non-relevant emotional contents. Previous work had shown a negative link between arousal and logicity only for

generic, personally irrelevant emotional contents (Blanchette & Leese, 2011). Here, the results suggested that this relationship can also be observed when participants reason about personally relevant contents. Our findings are generally consistent with the idea that the effects of arousal and personal relevance are independent (although note that the strength of the effect or arousal was low in this study). This might explain inconsistent findings in the literature, if the involvement of arousal and relevance varied across studies, with the effect of arousal taking over that of relevance in some studies, and the other way around in other studies.

Our findings are consistent with other findings showing a detrimental effect of physiological arousal on higher level cognitive functioning (e.g. Burbridge, Larsen, & Barch, 2005). The precise mechanisms through which arousal is related to central reasoning processes remain to be isolated however. It is possible that emotional contents, through an effect on physiological arousal via the ventromedial prefrontal cortex (e.g. Nagai et al., 2004), promote heuristic reasoning (e.g. Goel & Dolan, 2003) at the expense of logicity. In any case, more work will be necessary to directly test the mechanisms through which arousal affects reasoning.

In conclusion, this study shed important new light on the processes that underlie the impact of emotions on deductive reasoning. While emotions generally have a deleterious effect on reasoning, the strength of this effect is determined by a fine balance between two factors, personal relevance and physiological arousal, which seem to act independently of each other. Consistent with new utility theories (Blanchette & Caparos, 2013; Bonnefon, 2009; Mercier & Sperber, 2011), this work showed that emotions play a major role in human rationality.

## Notes

1. Nine participants suffering from clinical PTSD and 15 male participants were also tested because we initially intended to form PTSD and male comparison groups. We excluded these participants from the analyses reported in this paper due to the difficulty in completing these comparison groups.
2. Cohen's *d* measure of effect size varied between 0.40 and 1.40 across five studies on the effect of emotional contents on logical reasoning (Blanchette & Campbell, 2012; Blanchette et al., 2007, 2014; Blanchette & Leese, 2011; Blanchette & Richards, 2004), with an average effect size of 0.77. With such effect size, groups of 20 participants yield a statistical power of 77%.
3. We ran the same analyses using the  $d'_{\text{logic}}$  index  $[=z(P(\text{"yes it's valid"} | \text{answer} | \text{Valid Problem})) - z(P(\text{"yes it's valid"} | \text{answer} | \text{Invalid Problem}))]$ .



answer[Invalid Problem]] reported by Heit and Rotello (2014) which are more robust against strategic effects than the traditional accuracy index used in this study. This analysis helps us determine whether differences are related to changes in reasoning process, rather than changes in response bias. With the  $d'_{\text{logic}}$  index, both the interaction between content and abuse group, and that between content and accident group, were significant, respectively,  $F(2,162) = 3.58, p = .030$ , and  $F(2,162) = 3.57, p = .031$ . In addition, a Receiver Operating Characteristic (ROC) representation of the data (Fawcett, 2006) suggested that differences in performance between emotional contents were not due to trade-offs between 'true positives' ('yes it's valid' answers to valid problems) and 'false alarms' ('yes it's valid' answers to invalid problems). The latter ROC representation thus suggests that the interaction effects reported in this study are not the result of strategic differences in response bias between victims and controls. The data are available as supplemental material for additional analyses.

4. In an additional analysis, we excluded the 'both abuse and accident' participants and used Group as one independent variable with three levels (control, abuse, accident). This analysis included 77 participants, compared to 85 participants for the main analysis. The important interaction between Group and Content remained marginally significant,  $F(4,148) = 2.15, p = .078$ . This suggests that the interactions between groups and content were not solely driven by the 'both abuse and accident' participants.
5. Note that the syllogisms presented in Tables A1–A5 are English translations of the French syllogisms used in the study.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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## Appendix

**Table A1.** Percentage of yes responses to abuse-related syllogisms.<sup>5</sup>

Syllogism	Logically valid	Percentage of "yes" answers			
		Abuse victims	No-abuse controls	Accident victims	No-acc. controls
No woman is traumatised. Some rape victims are traumatised. Then, all rape victims are women	No	0.04	0.05	0.10	0.03
No sexual-abuse victim is a paedophile. Some rapists are sexual-abuse victims. Then, all rapists are paedophiles	No	0.08	0.03	0.10	0.03
No woman is human being. Some rape victims are women. Then, all rape victims are human beings	No	0.24	0.17	0.14	0.20
No man benefits from rape. Some animals benefit from rape. Then, all animals are men	No	0.00	0.07	0.05	0.05
No child is abused. Some victims are abused. Then, all victims are children	No	0.00	0.02	0.00	0.02
No rapist is punished. Some policemen are rapists. Then, all policemen are unpunished	No	0.52	0.63	0.57	0.61
No policeman has been raped. Some sexual-abuse victims are policemen. Then, some sexual-abuse victims have not been raped	Yes	0.48	0.68	0.52	0.66
No hairdresser is a rapist. Some women are rapists. Then, some women are not hairdressers	Yes	0.76	0.90	0.90	0.84
No animal is a rapist. Some males are rapists. Then, some males are not animals	Yes	0.80	0.85	0.86	0.83
No new-born is a potential rapist. Some boys are new-borns. Then, some boys are not potential rapists	Yes	0.88	0.87	0.86	0.88
No woman is a rapist. Some professors are women. Then, some professors are not rapists	Yes	0.92	0.73	0.76	0.80
No caress is harmful. Some fondling is harmful. Then, some fondling is not caresses	Yes	0.92	0.77	0.71	0.84

**Table A2.** Percentage of yes responses to accident-related syllogisms.

Syllogism	Logically valid	Percentage of "yes" answers			
		Abuse victims	No-abuse controls	Accident victims	No-acc. controls
No passenger is traumatised. Some women are traumatised. Then, all women are passengers	No	0.00	0.03	0.00	0.03
No accident is terrifying. Some traumas are accidents. Then, all traumas are terrifying	No	0.24	0.15	0.19	0.17
No criminal is a driver. Some recidivists are drivers. Then, all recidivists are criminals	No	0.16	0.15	0.14	0.16
No speed excess is dangerous. Some infractions are speed excesses. Then, all infractions are dangerous	No	0.16	0.15	0.19	0.14
No victim is injured. Some drivers are victims. Then, some drivers are not injured	Yes	0.92	0.80	0.90	0.81
No man is an accident survivor. Some handicapped people are accident survivors. Then, some handicapped people are not men	Yes	0.76	0.77	0.86	0.73
No car impact is a loss of control. Some complete losses are car impacts. Then, some complete losses are not losses of control	Yes	0.64	0.72	0.95	0.61
No collision is deadly. Some accidents are deadly. Then, some accidents are not collisions	Yes	0.68	0.92	0.86	0.84

**Table A3.** Percentage of yes responses to generally emotional syllogisms.

Syllogism	Logically valid	Percentage of "yes" answers			
		Abuse victims	No-abuse controls	Accident victims	No-acc. controls
No compulsion is a bad habit. Some addictions are compulsions. Then, all addictions are not habits	No	0.24	0.08	0.14	0.13
No Canadian resident can be executed. Some extremists are executed. Then, all extremists are Canadian residents	No	0.00	0.00	0.00	0.00
No prescribed substances are dangerous. Some drugs are prescribed substances. Then, all drugs are dangerous	No	0.24	0.12	0.19	0.14
No cancer is curable. Some illnesses are curable. Then, all illnesses are cancers	No	0.04	0.02	0.05	0.02
No disease is deadly. Some cancers are deadly. Then, all cancers are diseases	No	0.36	0.15	0.19	0.22
No dog is worth loving. Some loyal friends are dogs. Then, all loyal friends are worth loving	No	0.44	0.47	0.48	0.45
No child has heart disease. Some smokers are children. Then, some smokers do not have heart disease	Yes	0.80	0.80	0.76	0.81
No person can steal. Some humans can steal. Then, some humans are not persons	Yes	0.80	0.82	0.81	0.81
No physician is a psychopath. Some killers are psychopaths. Then, some killers are not physicians	Yes	0.68	0.80	0.76	0.77
No mother is depressed. Some humans are mothers. Then, some humans are not depressed	Yes	0.92	0.92	0.90	0.92
No father is violent. Some men are fathers. Then, some men are not violent	Yes	0.88	0.98	0.90	0.97
No child has aids. Some drug addicts have aids. Then, some drug addicts are not children	Yes	0.72	0.82	0.76	0.80

**Table A4.** Percentage of yes responses to neutral syllogisms.

Syllogism	Logically valid	Percentage of "yes" answers			
		Abuse victims	No-abuse controls	Accident victims	No-acc. controls
No expensive good is white. Some cars are white. Then, all cars are expensive goods	No	0.24	0.08	0.14	0.13
No reptilian is a big animal. Some dinosaurs are reptilians. Then, all dinosaurs are big animals	No	0.00	0.00	0.00	0.00
No woman is colour blind. Some blind people are women. Then, all blind people are colour blind	No	0.24	0.12	0.19	0.14
No blind person is a helicopter pilot. Some adults are helicopter pilots. Then, all adults are blind persons	No	0.04	0.02	0.05	0.02
No tropical plant is dangerous. Some cactus are dangerous. Then, all cactus are tropical plants	No	0.36	0.15	0.19	0.22
No feeling is positive. Some emotions are feelings. Then, all emotions are positive	No	0.44	0.47	0.48	0.45
No woman is a teacher. Some researchers are women. Then, some researchers are not teachers	Yes	0.80	0.80	0.76	0.81
No squirrel is a pet. Some animals are pets. Then, some animals are not squirrels	Yes	0.80	0.82	0.81	0.81
No fragile creature is a wild animal. Some rats are wild animals. Then, some rats are not fragile creatures	Yes	0.68	0.80	0.76	0.77
No light clothe is warm. Some coats are light clothes. Then, some coats are not warm	Yes	0.92	0.92	0.90	0.92
No peace of meat is spoiled. Some foods are peaces of meat. Then, some foods are not spoiled	Yes	0.88	0.98	0.90	0.97
No mushroom is poisonous. Some amanitas are poisonous. Then, some amanitas are not mushrooms	Yes	0.72	0.82	0.76	0.80

**Table A5.** Percentage of yes responses to abstract syllogisms.

Syllogism	Logically valid	Percentage of "yes" answers			
		Abuse victims	No-abuse controls	Accident victims	No-acc. controls
No ! is a ". Some / are !. Then, all / are "	No	0.12	0.05	0.05	0.08
No \$ is a %. Someare %. Then, allare \$	No	0.08	0.08	0.05	0.09
No alpha is beta. Some omegas are betas. Then, all omegas are alphas	No	0.08	0.07	0.14	0.05
No P is Q. Some K are P. Then, all K are Q	No	0.12	0.02	0.05	0.05
No - is a *. Some (are *. Then, some (are not -	Yes	0.76	0.77	0.86	0.73
No + is a =. Some # are +. Then, some # are not =	Yes	0.88	0.78	0.90	0.78
No X is a Y. Some W are X. Then, some W are not Y	Yes	0.80	0.70	0.67	0.75
No red is blue. Some yellows are blues. Then, some yellows are not reds	Yes	0.76	0.80	0.81	0.78