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Trait and state negative affect interactions moderate inhibitory control performance in emotionally loaded conditions

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ABSTRACT

Following the framework that controlled performance is dependent upon cognitive and emotional processes which are inherently inter-linked, effects of trait and state negative affect (NA) on inhibitory control (IC) were studied in two experiments using an emotional day-night task (EDNT) – an inhibition based decision-making task embedded with emotional content. It was hypothesized that the effects of processing negatively loaded stimuli would depend on trait levels of negative and positive affects, particularly in conditions that entail IC. In Experiment 1, EDNT performance was compared with performance of an emotionally loaded control task that required to perform a dominant response rather than to inhibit it. In Experiment 2, EDNT performance was compared with an emotionally loaded control task that required performing an alternative rule which did not involve inhibiting the dominant response. Results of both Experiments showed that participants high on NA trait reactivity showed improved performance while processing 'sad' content, only in the inhibitory task and not in either of the control tasks. Results point to an interaction of trait and state factors in IC, and highlight the notion that heightened NA may sub-serve inhibition in sad contexts, which require counter-intuitive operations.

1. Introduction

The role of affective processes in cognitive decision-making has yielded a significant body of research over the last two decades. Underlying this research are contemporary theoretical viewpoints suggesting that rather than multiple but independent systems for regulation and control, these systems represent the application of global control mechanisms where emotion and cognition are inherently linked (Corr, 2010a,b; Derryberry & Rothbart, 1997; Posner & Rothbart, 2007). This perspective postulates that emotional reactions to external and to internal stimuli guide controlled production of appropriate behavioral outputs (Corr, 2010a,b; Gasper, 2003).

One of the most important mechanisms underlying behavioral regulation is inhibitory control (IC) – the ability to inhibit a dominant response in order to activate an alternative response (Diamond, 2002). IC is crucial to selectively attend to a subset of a complex environment, activate appropriate meanings during language comprehension and appropriate memories at encoding and retrieval (Diamond, 2002; Posner & Rothbart, 2007). IC is essential for flexible adaptive responses in the face of changing contextual demands (Boucher, Palmeri, Logan, & Schall, 2007; Geva & Feldman, 2008; Geva, Gardner, & Karmel, 2010; Posner & Rothbart, 2007) and plays a critical role in learning, planning and decision-making (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006).

While these processes were shown with regard to positive affect (PA; Isen, 2008; Rowe, Hirsh, & Anderson, 2007), existing data regarding the relationship between negative affect (NA) and IC offers little insight into its nature in healthy adults.

Difficulties in understanding this relationship arise from contradicting findings. A significant body of research links trait NA, expressed as high levels of chronic negative arousal (Watson & Clark, 1994), with increased tendency to inhibit behavior (Biederman et al., 2001; Carver & White, 1994; Degnan & Fox, 2007; Gray, 1982; Leen-Feldner, Zvolensky, Feldner, & Lejuez, 2004). This association appears to be particularly relevant with regard to trait anxiety (Corr, 2011). At the same time, studies suggest a negative correlation between NA and IC (e.g. Evans & Rothbart, 2007; Joormann & Gotlib, 2010; Langenecker et al., 2007).

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These findings appear difficult to console without consideration of methodological differences. Some of these studies relied on self-report measures of IC (e.g. Evans & Rothbart, 2007; Leen- Feldner et al., 2004). While such methods produce significant results, integration of the findings is challenged since self-reports may reflect in part conscious moderation, rather than direct IC capacities.

Recent work reports significant associations between NA and experimental measures of IC in clinical populations (Joormann & Gotlib, 2010). Comparable work on the relationship between NA and IC in healthy adults is rather scant. Some suggested that NA is associated with improved IC performance (Constantinou et al., 2010; Lewis, Lamm, Segalowitz, Stieben, & Zelazo, 2006), while others found little evidence for this relationship (Chepenik, Cornew, & Farah, 2007; Santucci, 2003).

One possible explanation for the lack of findings in healthy populations may be due to the fact that studies typically focus either on trait, chronic personality related NA, or on state, transient stimuli related NA, but do not include both. So far, the interaction between trait and state factors in healthy participants was not studied directly. Findings suggest that trait emotional characteristics moderate responses to emotionally charged stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). Yet, state NA improved IC performance in anxious adolescents, but not in healthy controls (Constantinou et al., 2010; Hardin et al., 2009). These findings suggest that trait sensitivity plays a role in the effectiveness of mood manipulations in IC in the general population. The goal of the current study was to explore the effects of state NA on IC performance and examine how these effects are moderated by trait levels of NA.

A common method of exploring emotional processes effects on inhibition of a pre-potent response is the emotional Stroop paradigm (Williams, Mathews, & MacLeod, 1996) which requires naming the print color of an emotionally loaded word. Studies using this task indicate that participants high on trait NA respond more slowly when exposed to negatively loaded words. This finding was interpreted as supporting the notion that NA disrupts IC (e.g. Taake, Jaspers-Fayer, & Liotti, 2009). However, such findings may reflect a general emotion-driven slowdown of processing verbal stimuli, rather than inhibition difficulty (Algom, Chajut, & Lev, 2004; McKenna & Sharma, 2004; Phaf & Kan, 2007). In particular, it was suggested that color naming and reading emotional words do not share the same processing dimension as do color naming and reading color names in the classic Stroop task, thus eliminating the IC element of the task (Algom et al., 2004).

To circumvent this confound, we employed a non-verbal Stroop variant of the day-night task (Gerstadt, Hong, & Diamond, 1994). On the classic day-night task a subject is required to respond "night" when shown a picture of the sun, and "day" when presented the moon and stars. For purposes of this study, the task was modified to include emotionally positive and negative content (schematic emotional facial expressions) which were not directly pertinent to the IC element of the task. The emotional day-night task (EDNT) therefore allows the introduction of emotional components to the task, without verbal mediation, while retaining the inhibitory elements of the classic Stroop.

We hypothesized that trait NA would interact with exposure to negatively loaded stimuli and affect performance. More specifically, we hypothesized that exposure to negatively loaded content would influence performance only when two conditions are met: (i) the task requires the participants to apply IC and (ii) the participants report high trait sensitivity to such emotional content.

In view of partial dependence between PA and NA and based on findings associating PA and IC (e.g. Gasper, 2003), we hypothesized that exposure to positively loaded content would hamper performance only when the task is inhibitory and the participants report high trait PA.

2. Experiment 1

The goal of Experiment 1 was to explore the effects of the interaction of trait and state NA on performance in a task which requires inhibition a dominant response, the EDNT, compared to a similar task that does not require such inhibition. State affect was manipulated by embedding facial emotional signals within the task's stimuli.

2.1. Method

2.1.1. Participants

90 undergraduate psychology students from Bar-Ilan University (53 women and 37 men (age range 19 to 27 years, $M = 22.86$, SD = 2.74) participated in return for course credit. All were right handed, had no history of neurological or psychiatric disorders and reported no recent use of any drug or alcohol. Participants provided informed consent according to University's ethics committee' guidelines.

2.1.2. Materials

2.1.2.1. Trait negative and positive affect. Trait emotional characteristics were measured using a Hebrew version of the Positive and Negative Affective Schedule (PANAS; Watson & Clark, 1994), using the 'general' instructions format. This measure has been commonly used to explore individual differences in emotional states and traits across diverse descriptor sets, time frames, response formats, languages, and cultures (Watson & Clark, 1994).

2.1.2.2. The emotional day-night task (EDNT). In this task emotionally loaded schematic facial expressions (Fig. 1) were added to the neutral stimuli of the original Day-night task (Gerstadt et al., 1994). Affective facial expressions are a common source of emotional information, and are highly efficient for inducing emotional processing and affective responses, even when unrelated to one's goal-directed focus (Barrett & Niedenthal, 2004). As a control condition a stimulus containing scrambled facial features was included.

The task was adapted for computer presentation using e-prime (Psychology Software Tools, Inc.). It comprised of 5 blocks, one for each stimuli type (neutral/angry/happy/sad/scrambled), with each block consisting of 16 trials (8' day' and 8 'night' stimuli), presented in random order. The neutral block appeared first, followed by the loaded blocks, with presentation order counterbalanced between subjects. Stimuli were presented on a 17′color monitor with a 600×800 resolution at a 55 cm viewing distance. Stimuli were 8.38×10.52 cm. A stimulus was displayed at the center of the screen for 120 ms, followed by a blank screen, and 1000 ms were allotted to respond. If no response was recorded during this time frame, the next trial appeared automatically. Subjects responded by pressing the same neutral images of the day or night stimuli, which were attached to the computer mouse.

2.1.3. Procedure

Participants completed the PANAS first and then received instructions explaining the experimental task, directing them to keep focused on the center of the screen at all times and to perform the task as quickly and as accurately as possible. Subjects were also instructed to keep their index finger on the middle mouse key through the task to prevent possible distance effects on response. In a practice phase that followed, subjects were instructed to press the key with the image matching that of the stimuli (i.e.,' day' button for day picture) for 16 presentations. The results of these trials were not included in the statistical analyses.

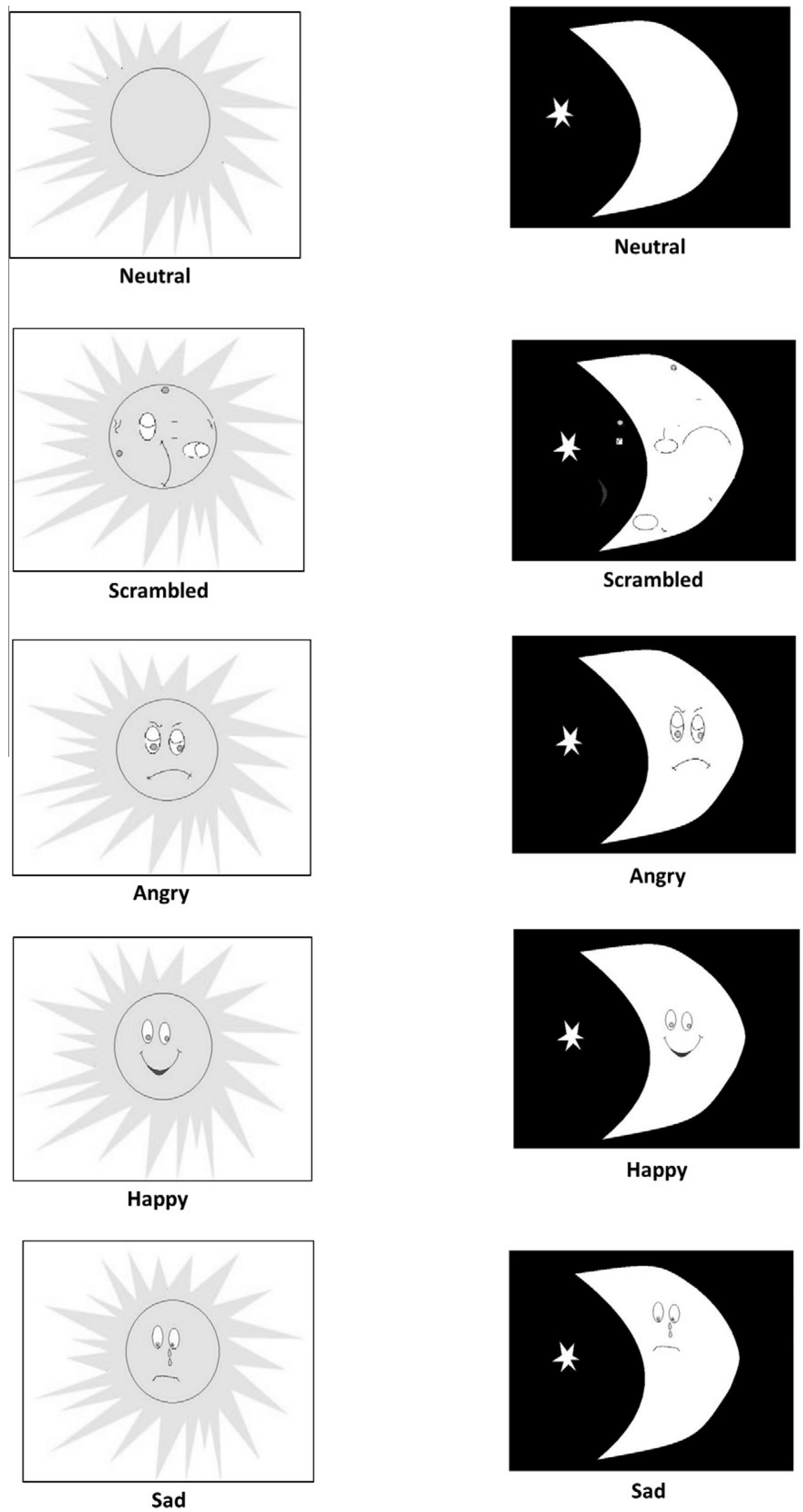

Fig. 1. EDNT – Stimuli set.

Participants were randomly assigned to either the inhibition or control groups. In the inhibition condition instructions were to press the key with the image *opposite* to the one appearing on screen ('night' button for day picture and vice versa). Control participants were instructed to continue responding by pressing the key with the image matching that of the stimuli. Participants performed four training trials. Following the training phase, subjects completed the full EDNT. Two participants in the control group did not complete the experiment due to personal requests and were excluded from the analysis.

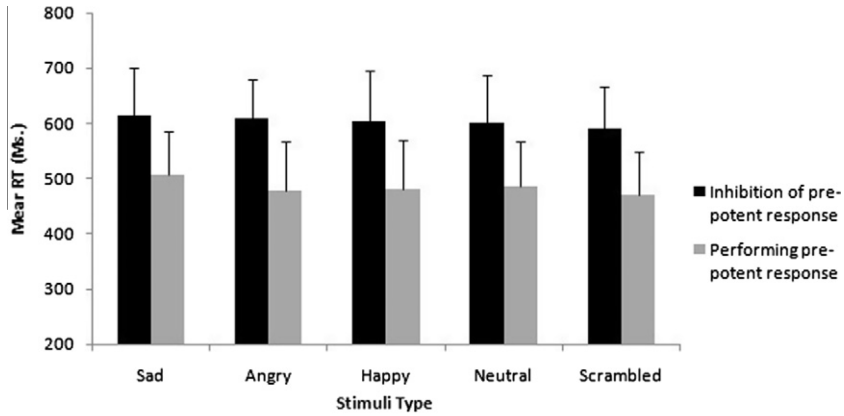

Fig. 2. Reaction time (msec.) as a function of rule type and facial expression type.

2.2. Results

Overall, there were no gender or age or PANAS scores differences between groups (all *ps* > .05). As expected, participants reported higher levels of PA on the PANAS ($M = 3.48$, SD = .42) than NA ($M = 2.31$ SD = .51), t (87) = 16.08, $p < .001$, consistent with comparable cohorts in Israel (Ben-Zur, 2002). Accuracy rates were similar and high in both conditions (i.e., average in EDNT $M = 90.56\%$, SD = 7.66 and in control $M = 92.08\%$, SD = 5.47). Accuracy did not dependent on PANAS, or on emotion effects. We thus limit the report to reaction times (RT) analyses.

To explore differences in RTs to the different emotional stimuli between the experimental conditions, three statistical analyses were conducted: (1) an omnibus repeated measures analysis, with stimuli type as a within subjects' variable, condition (inhibition/control) as a between subjects' variable and both PANAS scales (NA and PA) as continuous predictors; (2) contrast analysis to identify which stimuli type (if any) was related to the Condition X PANAS interaction; and finally (3) a regression analysis to explore the nature of the Condition X PANAS X Stimuli type interaction.

Analysis of mean RT (correct responses only) revealed a significant main effect for condition, such that RT in the inhibition condition ($M = 603.69$, SD = 66.26) was significantly slower than in the control condition, ($M = 498.81$, SD = 90.37), F(1, 84) = 31.24, p < .001 $\eta^2 = .27$. There were no significant effects of Stimuli type ($p > .2$) or Group × Stimuli interaction ($p > .09$) (Fig. 2).

The interaction between NA – PANAS scores and stimuli type was significant, F(4, 79) = 2.51, $p < .05$, $\eta^2 = .11$. This effect was significantly moderated by experimental condition, F(4328) = 2.35, $p = 0.05$, $\eta^2 = .09$. To explore which stimuli type were related to the condition∗PANAS interaction, post hoc contrast analysis was conducted, using the neutral stimuli as reference point, similar to the procedure used to analyze the emotional Stroop task (Williams et al., 1996). The NA scale moderated the differences between the inhibitory and control conditions only on sad stimuli, F(1,82) = 8.12, $p < .01$, $\eta^2 = .09$. No effects were found on any other stimuli type (all p values adjusted for multiple comparisons). Therefore subsequent analysis was conducted on RT to sad content only.

In order to explore the nature of the Condition∗PANAS NA scale interaction for sad content, a regression model was used, with PANAS NA scale and their interaction as continuous predictors, the difference between RT to neutral and sad stimuli as the dependent variable, and condition. The regression model was significant, F(3,84) = 3.95, $p < .01$, $R^2 = .12$. Similarly, the interaction between condition and the NA scale was significant, $\beta = .29$, $p < .05$. Simple slope analysis revealed that in the inhibition condition NA was negatively related to RT to sad stimuli, so that participants high in NA had faster responses in the presence of sad, compared to neutral, stimuli, $\beta = .47$, $p < .01$. No such relationship was found in the control condition, $\beta = .01$, N.S. Figure 3 presents the interaction with participants split into two groups based on median score on the PANAS-NA (MD = 2.30). There were no effects of trait PA, state NA, or their interaction (all p values >.1).

Control analysis: Given the speed of habituation to repeated presentation of the same facial expression (Ishai, Pessoa, Bikle, & Ungerleider, 2004), we calculated mean RT for early exposure stage (first 8 presentations) and later exposure (final 8 presentations) in each block. Stage of presentation was then entered into the repeated measures analysis as a second within-participants' variable. Presentation stage was not significant ($p > .1$) and did not alter the results of the original analysis. Similarly, an additional analysis controlling for gender and age showed that neither variable contributed to the model (all p values >.1).

2.3. Discussion

As expected, results of Experiment 1 revealed that performance was influenced by the nature of the task (inhibitory vs. control), but not by any emotional content processed while performing

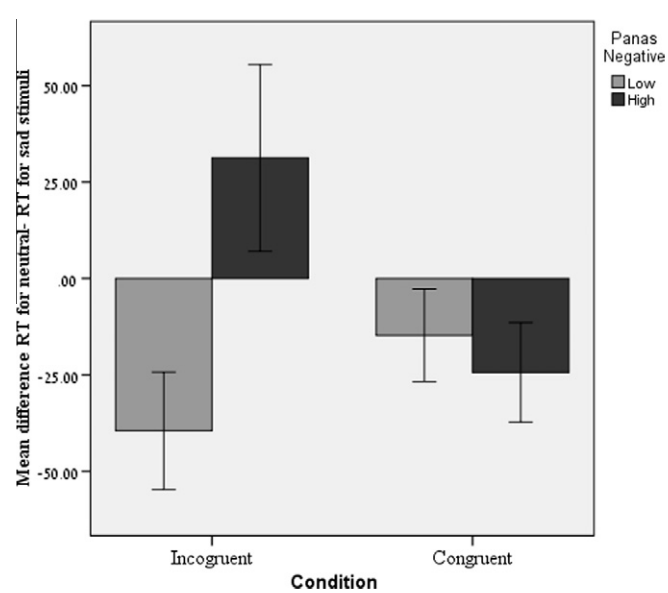

Fig. 3. Median Reaction time for sad (compared to neutral) stimuli as a function of rule type and PANAS-NA level.

the task. Moreover, exposure to negatively loaded (sad) stimuli in the EDNT facilitated IC performance in participants high on trait NA. No effects for either stimuli type or trait characteristics on performance in the non-inhibitory congruent condition of the task, suggest the interaction of trait and state NA was specifically related to IC performance. Contrary to our hypothesis no effects were found for either state or trait positive affect.

3. Experiment 2

The results of Experiment 1 support the hypothesis that the interaction of trait and state NA facilitate changes in IC performance. To advance our understanding of the mechanism involved in the expression of this interaction on IC, it is important to consider whether the interaction facilitates implementation of an inhibitory response or moderates the ability to comply with a rule, albeit one that does not include an inhibitory component. This is particularly important because there is evidence that suggests that state NA may help participants to focus on external cues rather than on their own internal response proprieties (Gasper, 2003). As the EDNT involves both inhibiting a pre-potent response and a rule maintenance capacity, it is important to test it directly.

For that purpose, in Experiment 2 we compared the effects of exposure to emotionally loaded stimuli between the EDNT and a control task that required participants to follow a rule that does not necessitate inhibiting a pre-potent response. If the effect of emotional factors is primarily to divert attention to external information, performance in any type of rule maintenance condition should be influenced by emotional factors. However, if NA has a particular contribution to inhibiting a pre-potent response, the effect of the manipulation should be apparent only in the inhibition condition.

3.1. Method

3.1.1. Participants

90 undergraduate psychology students from Bar-Ilan University and Ashkelon Academic College (58 women and 32 men ranging in age from 21 to 31, $M = 22.65$, SD = 2.05) participated in return for course credit. None took part in Experiment 1. Comparable inclusion and exclusion criteria as in Experiment 1 were exercised.

3.1.2. Materials and procedures

As in Experiment 1, upon completion of the PANAS participants completed the EDNT-practice stage, and were then randomly assigned to two groups ($N = 45$ in each). The inhibitory task was performed as detailed in Experiment 1. In the new-rule-maintenance condition participants were instructed to press on a picture of a dog when presented with the day stimuli and press on a picture of a cat when presented with the night stimuli. No other changes were made to the task from Experiment 1.

3.2. Results

There were no differences between groups in gender, age or PANAS scores. Overall participants reported higher levels of PA ($M = 3.46$, SD = 0.40) than NA ($M = 2.49$ SD = .51), $t(89) = 11.75$, $p < .001$. Levels were comparable to those obtained in Study 1. Accuracy rates were similar and high in both conditions (i.e., average in EDNT $M = 91.84\%$, SD = 6.73 and in control $M = 90.87\%$, SD = 6.37). Accuracy did not depend on PANAS, or on emotion effects.

The same statistical procedures used in Experiment 1 were applied to the current data set. The analysis revealed a significant main effect for condition: RTs in the inhibition condition ($M = 580.78$, SD = 50.96) was significantly slower than RT in the control condition, ($M = 460.09$, SD = 75.48), $F(1,86) = 57.11$, $p < .001$, $\eta^2 = .39$. The analysis revealed no effect of stimuli type ($p > .1$) or a Group × Stimuli interaction ($p > .01$) (Fig. 4).

As in Experiment 1, group differences in RT to the different stimuli varied as a function of NA, $F(4,81) = 2.50$, $p < .05$ $\eta^2 = .11$. Post-hoc contrast analysis, using the neutral stimuli as a reference point, showed that the NA moderated the differences between the inhibitory and control conditions with regard to sad stimuli only, $F(1,84) = 9.34$, $p < .01$, $\eta^2 = .10$. There were no other stimuli type effects (all p values adjusted for multiple comparisons), therefore subsequent analysis was conducted on RT to sad content only.

The regression analysis with condition, NA scores, and their interaction significantly contributed to explaining the difference between neutral and sad stimuli, $F(3,81) = 4.67$, $p < .01$, $R^2 = .14$. The interaction between condition and NA scores was also significant, $\beta = .47$, $p < .01$. Simple slope analysis revealed that the NA scores were negatively related to RT for sad stimuli, $\beta = .52$, $p < .01$ in the inhibition condition, but not in the rule condition, $\beta = -.07$, N.S. Figure 5 presents the interaction with participants split into two groups based on median score on the PANAS negative scale (MD = 2.30).

Effects with trait PA, state NA, or their interaction were not significant (all p values >.1).

Control analysis: as in Experiment 1, stage of presentation (initial vs. later) was entered into the repeated measures analysis as a second within-participants variable. It was not significant ($p > .1$) and it did not alter the results. Similarly, the repeated analysis

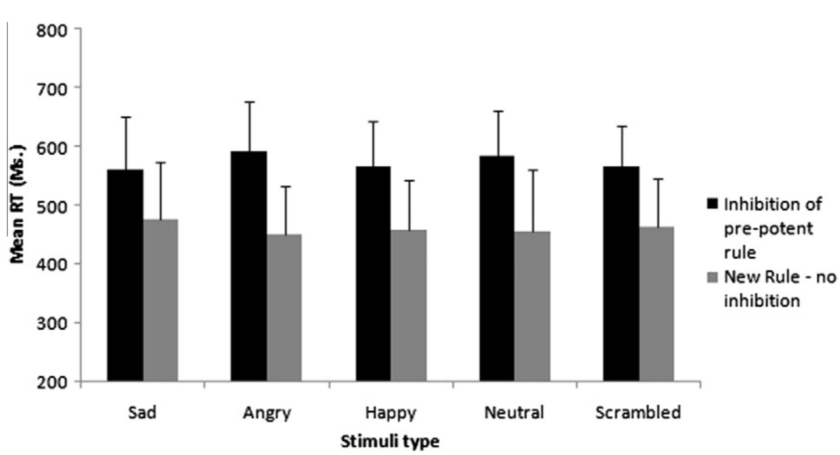

Fig. 4. Reaction time (msec.) as a function of rule type and facial expression type.

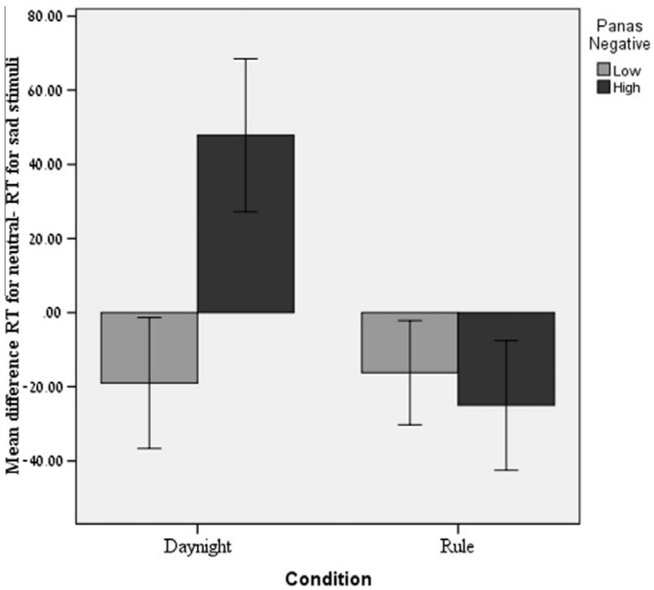

Fig. 5. Median Reaction time for sad (compared to neutral) stimuli as a function of rule type and PANAS NA level.

controlling for gender and age did not modify the results (all *p* values >.1).

3.3. Discussion

Experiment 2 offers further support for the hypothesis that trait and state NA may have a unique role in the inhibition of a pre-potent response, but not in similar tasks without the inhibitory component. This result suggests that the beneficiary effects of NA on IC performance is not general in operating according to rules, but rather is specific to executing IC.

4. General discussion

The results supported the hypothesis that state and trait factors of NA may moderate IC in healthy adults. In both experiments, participants with high trait NA showed improved performance in the IC task in the presence of negatively loaded content, compared to participants low on this trait. No such effect was observed in the control conditions that require execution of a pre-potent response in the presence of emotional stimuli (Experiment 1), or to follow a rule that does not entail inhibiting a pre-potent response (Experiment 2). Together these results suggest that the interaction between trait and state NA serves a particular role in inhibiting a pre-potent response.

These findings may add a missing theoretical piece on the relationship between NA and IC and resolve inconsistencies in experimental tasks with healthy participants. First, as hypothesized, the effects of exposure to negatively loaded stimuli were moderated by trait sensitivity to such content. Furthermore, no simple main effects were found for either trait or for state factors, suggesting the importance of integrating both, rather than focusing on either one.

Second, the interaction of trait and state was fairly subtle, and highlighted individual differences in IC depending on participants' sensitivity to sad stimuli. Individuals high on trait NA showed improved IC in the presence of negative content, while participants low on this trait showed no such heightened inhibition in this condition.

The finding that exposure to negatively charged content facilitated IC in participants high on trait NA may offer an interesting addition to the view that behavioral inhibition is inherently linked to NA and anxiety, as detailed by the reinforcement sensitivity theory (Corr, 2010a,b, 2011; Gray & McNaughton, 2000). According to this theoretical view, the behavioral inhibition system (BIS) serves as mediator of conflict between approach tendencies and risk aversion (fight, flight or freeze system). Since conflict resolution is achieved by increasing state NA (Corr, 2010a), the current findings suggest exposure to negatively charged content may alert those who are sensitive to such content to the presence of a conflict, resulting in increased activation of the BIS, expressed as facilitation of IC.

This study did not replicate findings that state or trait PA may impede IC. The present design may have been better suited for the study of NA, rather than PA, for two reasons: First, schematic positive expressions are identified faster than negative ones and tend to produce faster habituation, making this manipulation less effective (Breiter et al., 1996; Leppänen & Hietanen, 2004). Second, recent evidence suggests that the PANAS-PA scale reflects general approach tendencies, rather than exclusively positive affect (Harmon-Jones & Harmon-Jones, 2010), suggesting a more complex relationship between the PA and the state manipulations.

In conclusion, our results indicate that subtle sad content may facilitate IC in individuals with high trait NA, which may translate to efficient reactivity to negatively charge content when inhibition of a pre-potent response is required. People with heightened NA may employ this adaptive emotional-cognitive process to subserve inhibition in sad contexts, which require counter-intuitive operations.

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