The influence of sad mood on inhibitory control: the role of gender differences

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Abstract

Previous attempts to study the effect of sad mood on inhibitory control have not led to consistent results in clinical and non-clinical populations. We suggested that inconsistent results may have been caused by different task situations, different qualities of the experienced sad mood, and disregarding the possible effects of confounding factors such as gender and age differences. To fill in the gaps of previous studies, we recruited 30 male and 30 female participants aged between 20 to 27. They were randomly assigned to one of the sad or neutral mood groups. The music mood induction procedure was used to induce the sad mood state, while participants in the neutral mood group listened to some neutral audio materials. After mood manipulation, participants completed the color-word Stroop task. We observed that participants' inhibitory control performance was not influenced by any of the fleeting sad mood states or gender differences. We discussed possible reasons behind the findings.

Key words: Gender differences, Inhibitory control, Mood induction procedures, Sad mood, Stroop test

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Inhibitory control is one of the key components of executive functions. It consists of two inter-related cognitive processes: *cognitive interference* and *response inhibition*. Cognitive interference inhibition keeps distracting information away from occupying cognitive resources, and response inhibition prevents prepotent responses to interfere with the ongoing goal-related behavior (Tiego et al., 2018). As a result, successful inhibitory control leads to selecting the most goal-relevant stimuli and responses (Bessette et al., 2020; Dillon & Pizzagalli, 2007).

Due to the importance of inhibitory control in everyday life, the way it is affected by the internal states (e.g., the person's current mood) has been a topic of interest to researchers (Joormann et al., 2007; Pessoa, 2008; see Ottowitz et al., 2002 for a review). Among different mood states, studying the relationship between sad mood and inhibitory control is considered in clinical fields, and it is because persistent sad mood is assumed to be the "hallmark feature of depression" (Gotlib & Joormann, 2010; p. 286). The main questions were whether inhibitory control is compromised in depression (e.g., Gohier et al., 2009; Lemelin et al., 1997; Lockwood et al., 2002; Kertzman et al., 2010; Siegle et al., 2004), and whether inhibitory control deficits play any role in patients' road to recovery (e.g., Årdal & Hammar, 2011; Schmid et al., 2011). Despite extensive research, previous studies have not yielded consistent results in clinically depressed individuals: some studies did not report any significant difference between the performance of patients and their healthy peers (e.g. Markela-lerenc et al., 2006); while, some others observed impairments in inhibitory control (e.g.,; Gohier et al., 2009; Lemelin et al., 1997; Lockwood et al., 2002; Kertzman et al., 2010). Additionally, among those who found impairments in inhibitory control, there is not any agreement on the nature of the impartments: For example, in completing inhibitory control tasks, Lockwood and associates (2002) observed that depression increased the error rates, but, Lemelin et al. (1997) reported that depression delays the performance speed and does not affect the error rate.

To explain the inconsistent results, three reasons can be put forward: First, in different investigations, heterogeneous groups of patients have been recruited (Caldirola et al., 2017). For example, in some studies patients had histories of recurrent depression, while in some other studies participants had experienced only one episode of depression. Therefore, we cannot draw a single conclusion about the cognitive performance of these two groups (Hammar et al, 2003). Second, the task designs of different studies have different cognitive demands. For example, the Stroop (for a review, see Scarpina & Tagini, 2017) and the Eriksen-flanker (for a review, see Hubner & Tobel, 2019) tasks are among the most used tasks for studying inhibitory control (e.g., Dillon et al., 2015; Siegle et al., 2004). In both tasks participants are presented with conflicting situations and are asked to attend to a goal-relevant information and make a situation-appropriate response. Accurate performance requires inhibiting the irrelevant information as well as suppressing prepotent responses. In particular, in the color-word Stroop task, the names of different colors are presented in words. The color words are either written with matched ink colors (congruent trials) or with mismatched ink colors (incongruent trials). Participants are asked to ignore – inhibit- the word meaning and respond to the ink color. In the arrow flanker task, a target arrow is presented among the distracter arrows. The direction of the target arrow is either similar to that of the distracters (congruent trial) or is not (incongruent trials). Participants have to ignore –inhibit- the direction of the distracters and respond to the direction of the target arrow. In both tasks, individuals are more likely to show slower responses and higher error rates in incongruent trials than in congruent trials (Dillon et al., 2015; Lorist & Jolij, 2012; Scarpina & Tagini, 2017). Regardless of similarities between two tasks, the demand of the Stroop and the flanker tasks are completely different. That is, in the Stroop task the relevant (i.e., font color) and irrelevant (i.e., meaning) dimensions of the information are integrated together in one visual stimulus; but, in the flanker task the relevant (i.e., target arrow's direction) and irrelevant (i.e., distracter arrows' direction) information are presented in spatially different locations. This means, different inhibitory control mechanisms are activated to solve the conflicting situations in the Stroop and the flanker tasks (Chen et al., 2013; Cohen & Henik, 2012; Magen & Cohen, 2002; Keller et al., 2019). Therefore, the results are not comparable for different types of tasks. Third, in exploring the relationship between depressed mood and

inhibitory control, the potentially confounding factors (e.g., gender and age differences) have been ignored in many studies; while these factors are assumed to play a crucial role in manifestation of the cognitive impairments in depression (Caldirola et al., 2017; Goldberg et al., 2003).

The development of different Mood Induction Procedures (MIPs) open new doors to manipulate participants' mood in the laboratory, under a more controlled environment (Gilet, 2008; Marston et al., 1984), and study its effect on different cognitive performance. The benefits of using MIPs to explore the effect of sad mood on inhibitory control were twofold: (1) researchers could manipulate healthy individuals' mood and study how everyday sad mood influences inhibitory control in healthy populations; (2) they could generalize their findings and propose how the affective component of depression (i.e., sad mood) influences inhibition (Nixon et al., 2013). This methodology has been justifiable because the neurobiological findings have shown that identical regions are involved in experiencing fleeting sad mood and clinical depressed mood (Mayberg et al., 1999). Despite advantages, very few studies used laboratory-based MIPs to research the effect of sad mood on inhibitory control (Mitchell & Phillips, 2007). Additionally, the few available studies could not explain the nature of this effect clearly. For example, using the color-word Stroop task, Brand et al. (1997) reported that, in comparison to the neutral mood, induced sad mood results in lower error rates; but it does not affect the reaction time. These findings were not in-line with Chepenik et al.'s findings (2007) showing that induced sad mood did not have any effect on the color-word Stroop task performance.

In sum, the relation of sad mood and inhibitory control is complex, and to understand this relationship, the characteristics of the experienced mood, the task situation, and possible confounding factors have to be taken into the account (van der Elst et al., 2006). In the current research, we aimed to address the shortcomings of previous investigations: We induced sad mood in healthy participants using music MIP. This manipulation technique has been shown to be one of the most effective MIPs (Westermann et al., 1996). To study inhibitory control performance, we utilized the color-word Stroop task. This task belongs to the Stimulus-Response Compatibility (SRC) category which measures both cognitive

interference and response inhibition (Tiego et al., 2018). Because some studies proposed in healthy individuals, gender differences have a general influence on the interaction of mood and cognition (Koch et al., 2007), we intended to compare the effect of sad mood on the Stroop task performance between male and female participants. It is surprising that the influence of gender on the relation of sad mood and inhibitory control has not been addressed in healthy individuals or in clinically depressed populations. To control for the potential confounding effects of age and education level (van der Elst et al., 2006), we recruited participants with similar educational level, within a narrow age range (20 to 27 years). These three variables (sad mood, inhibitory control & gender differences) were not investigated together before, so we explored possible relations among them.

Methods

Participants

Sixty undergraduate students from Amir-Kkabir University of Technology, ranging in age from 20 to 27 and without any history of mental disorders volunteered to complete the experiment. Thirty participants (15 females) were randomly assigned to the sad mood induction state and the thirty participants (15 females) were assigned in control (neutral) mood state. Participants had a normal or corrected-to-normal vision.

Materials

MIP: In order to induce a sad mood state in the experimental setting, a sad piece of classical music (i.e., Adagio for Strings by Samuel Barber) was played for participants. This piece was played for 4 minutes and 27 seconds. Previous studies showed this piece of music is effective in inducing sad mood (Chepenik et al., 2007; Mokhtari & Buttle, 2015). In order to induce the neutral mood, an audio file about the geographical and historical facts was used. This audio file lasted for 3 minutes and 57 seconds. The music and the audio files were played through headphones.

To define the participants' current mood score, a 7-point scale was used, in which 1 referred to very sad and 7 refereed to very happy.

*The inhibitory control task***:** The Persian version of the color-word Stroop task was used in this study. This task had three sections: (1) presenting patches on red, green and blue colors, (2) presenting three color words - "RED", "GREEN", and "BLUE"- in black ink (3) presenting color names in either matched ink color (e.g., "GREEN" word which was written with green ink) or presenting color names in mismatched color inks (e.g., "GREEN" which was written in red ink). When the color word and the ink color were matched, the trial was called congruent and when they were mismatched, the trials were called incongruent. The first two sections consisted of six trials. The third section consisted of 48 trials (24 congruent & 24 incongruent) which were presented randomly. Similar number of trials were used in Shao et al.'s (2015) and Phillips et al.'s (2002) studies

Data collection procedure

Participants were informed about the task and their rights upon arrival and verbal consent was obtained. Participants were seated before an ASUS lap top with 15/6-inch screen size. The distance between the participant and the screen was approximately 60 centimeters. Each participant was randomly assigned to the sad or the neutral mood induction group. The task instructions were presented on the screen, but a brief verbal explanation was also given to each person. All participants rated their current moods on a 7-point Likert scale. Then, they wore the headphones and listened to the audio which was played for them. Participants of the sad mood induction group were instructed to feel the emotion of the music. The participants of the neutral mood state were asked to listen carefully to the presented geographical and historical information. After listening to the audios, all participants rated their current mood for the second time on the same scale. Finally, the Stroop task was presented to the participants: In the first part of the task, participants were required to specify the color of the patches by pressing the relevant key on the keyboard (a red, green, and blue labels were placed on three keys of the lap top keyboard). In the second part of the task, the participants were asked to press the key which was related to the presented

color word. In the last part of the task, the participants were instructed to ignore the color words and respond to the words' ink color. Written feedback was given after each trial. If the participant made no answer to a trail, it was terminated after 5 seconds and was considered as a wrong answer. The experiment had a 2 (Trial type: congruent, incongruent; within-subject factor) × 2 (Mood state: sad, neutral; between-subjects factor) × 2 (Gender: female, male; between-subjects factor) design.

Ethical procedure

The experimental design and procedure of this study were approved by the board of the biomedical engineering department at Amir-Kabir University of Technology. The participant of this study were volunteers who responded to advertisements located at different faculties of the university. Volunteers were provided further details about the study and were informed about their rights. Oral informed-consent was obtained from all participants.

Results

Data preparation

Data of two participants were excluded due to error rates exceeding 25% (both had 29.2% error responses). For the remaining participants, trials with reaction times slower than 3000 milliseconds were eliminated from further analysis. Similar procedure was used in previous studies (Keng et al., 2017). After that, five more participants were removed from further analysis because more than 65% of their responses were slower than 3000 milliseconds. The final number of participants were 13 male and 14 female participants in the sad mood group, and 12 male and 14 female participants in the neutral mood group.

Mood Manipulation Check

In order to measure the success of the MIP, a t-test was conducted on before and after mood scores using SPSS v.26. Data showed that, after sad mood induction, mood scores were decreased significantly

(*M* = 3.9, *SD* = 1.4) compared to before mood induction (*M* = 4.4, *SD* = 1.3), *t* (26) = 1.89, *p* = 0.03 (one-tailed). For the neutral mood induction group, the mood score after induction (*M* = 4.3, *SD* = 1.0) was slightly changed *t* (25) = -1.98, *p* = .03 (one-tailed) towards a positive mood state compared to before mood manipulation (*M* = 4, *SD* = .9). Similar strategy for evaluating the mood manipulation success was used in previous studies (e.g., Huntsinger, 2012).

Reaction Time Analysis

Reaction time analysis, using a repeated measure ANOVA, revealed that the main effect of the trial type was significant [$F(1,49) = 42.43$, $p < .001$, $\eta 2 = .46$]. That is, participants performed significantly slower in incongruent trials (*M* = 2037ms, *SD* = 161) compared to congruent trials (*M* = 2124ms, *SD* = 162). The main effects of mood state and gender were not significant, $F(1,49) = .50$, $p = .48$ and $F(1,49) = .32$, $p = .58$, respectively.

The interaction between trial type and mood state was significant, [$F(1,49) = 4.15$, $p = .05$, $\eta 2 = .08$]. That is, the difference between the reaction time to congruent and incongruent trials was significant in sad (61ms, $p = .002$) and neutral (116ms, $p < .001$) mood states. Data showed the interaction between trial type and gender [$F(1,49) = .06$], the interaction between mood an gender [$F(1,49) = .22$], and the interaction between trail type, gender and mood [$F(1,49) = .03$] were not significant $p = .81$, .64, and .87, respectively.

Figure 1 shows the mean reaction time for the sad and neutral mood states.

Response accuracy analysis

The Response accuracy analysis, using a repeated measure ANOVA, showed that the main effect of trial type [$F(1,49) = 2.95$, $p = .09$] and the main effect of mood state was not significant [$F(1,49) = .02$, $p = .9$]. However, the main effect of gender was significant [$F(1,49) = 7.98$, $p = .007$, $\eta 2 = .14$]. That is, female had more accurate response (*M* = 98.07, *SD* = 3.37) relative to males (*M* = 95.42, *SD* = 4.85). Data revealed that the interaction between trial type and gender [$F(1,49) = 2.47$], trial type and mood [$F(1,49) = .55$], and gender and mood [$F(1,49) = 1.19$] were not significant $p = .12$, .46, and .28, respectively.

However, the interaction between trial type, gender, and mood was significant [F (1,49) = 4.61, p = .04, η2 = .09]. The results showed that the difference between the percentage of accurate responses to the congruent (M = 99.11) and incongruent (M = 96.13) trials was only significantly different in females with a neutral mood (p = .02). The correlation analysis revealed that there was not any trade-off between reaction time and accuracy data in congruent and incongruent trials.

Figure 2 shows mean response accuracy for sad and neutral mood conditions in both genders.

Discussion

In this study, we intended to investigate the effect of induced sad mood on inhibitory control of female and male participants. We assumed that manipulating the mood in the laboratory would help to understand how everyday fleeting sad mood influence the inhibitory control. It could also facilitate understanding the relation of depressed mood – as the hallmark feature of depression (Gotlib & Joormann, 2010; p. 286)- and inhibitory control.

Our reaction time data showed that regardless of mood states, participants had a slower reaction in the incongruent compared to the congruent trials of the Stroop task. This means that sad mood does not have any effect on the typical pattern of response to conflicting and non-conflicting situations. This finding was consistent with the results of Chepenik et al. (2007), and Mitchell and Phillips (2007), but is not in line with Brand et al.'s (1997) findings. Chepenik et al. (2007) showed that the laboratory induced mood has very little effect on the executive functions, particularly on inhibitory control. Mitchell and Phillips (2007) concluded that sad mood could influence inhibitory control only if the task includes emotional materials. However, in a recent study, King (2020) claimed that MIPs arouse emotional thoughts which would occupy cognitive resources and distract the person from the ongoing inhibitory task. This means, a sad mood state per se does not influence the inhibitory control, but, the mood manipulation technique used in a study might affect inhibitory control (King, 2020). For example, when a MIP includes self-referencing materials (e.g.,

writing about sad events of a person's life), it engages a person with her/his past emotional experiences; as a result, the stimulated emotional thoughts and memories may occupy cognitive resources, and impede inhibitory control performance (Seibert & Ellis, 1991). However, when a MIP include general sad materials (e.g., listening to a sad piece of music), the stimulated thoughts are not intense and may only occupy limited cognitive resources; and thus, they don't distract the person from the task in hand. Similarly, we think that the inconsistency between our findings and Brand et al.'s (1997) results is rooted in different MIPs used in the studies. Brand and associates observed that in a sad mood, participants showed fewer error rates, in comparison to neutral mood condition. To induce a sad mood state, they used a video MIP depicting the procedure of electrocution of a criminal using the electric chair. The researchers have reported that more than one-third of their participants could not watch the video clip to the end. With regard to the content of the Brand et al.' s (1997) MIP, we postulate that inhibitory control performance, observed in Brand et al.'s study, was not the effect of sad mood but was the result of distress. Therefore, we suggest that in drawing conclusions regarding the effect of laboratory-induced sad mood states and inhibitory control, the characteristics of the utilized MIP should also be considered (Mokhtari and Buttle, 2015).

Our data also showed that the overall effect of gender on the relation of laboratory-induced sad mood and inhibitory control is not significant. The relation of these three factors has not been investigated before, but we could think of one reason behind our finding: Deng and colleagues (2016) reported that, in healthy populations, males and females do not differ in emotional experience of sad contents. Therefore, it is not surprising that gender differences do not play a role in the relation of sad mood and inhibitory control of healthy individuals.

The only significant gender effect we observed was that females outperformed males in the overall accurate responses. We suggest that von Kluge's (1992) findings could explain this result: She observed that under the mild experience of anxiety, created by the experimental situation, the overall accuracy level of men's performance decreased in the Stroop task, but it was not observed among women.

The last part of our result showed that although the trend of typical Stroop effect (higher accurate responses to the congruent Vs. incongruent trials) existed in all conditions, it only reached the significant level in female participants with a neutral mood. We think that our experimental design might be the reason behind this finding: in comparison with some of previous studies (e.g., Chepenik et al., 2007), we had fewer trials for congruent and incongruent conditions in our Stroop task. Although the number of trials in the current study was similar to the number of trials in Shao et al.'s (2015) and Phillips et al.'s (2002) studies, we suggest that because Stroop task is not very mentally challenging, the error rate is generally low. Thus, detecting the significant difference in accuracy level requires a higher number of trials.

To conclude, we did not observe any effect of fleeting sad mood and gender differences on inhibitory control. We recommend that future studies should focus on the effect of different MIPs on the relation of mood and inhibitory control. Additionally, this effect should be tested in females and males of other age groups.

Reference

Årdal, G., & Hammar, Å. (2011). Is impairment in cognitive inhibition in the acute phase of major depression irreversible? Results from a 10-year follow-up study. *Psychology and Psychotherapy: Theory, Research and Practice, 84(2),* 141-150. https://doi.org/10.1348/147608310X502328

Bessette, K., Karstens, A. J., Crane, N. A., Peters, A. T., Stange, J. P., Elverman, K. H.,… Langenecker, S. A. (2020). A lifespan model of interference resolution and inhibitory control: Risk for depression and changes with illness progression. *Neuropsychology Review.* Advanced online publication. https://doi.org/10.1007/s11065-019-09424-5.

Brand, N., Verspui, L., & Oving, A. (1997). Induced mood and selective attention. *Perceptual and motor skills, 84(2),* 455-463. https://doi.org/ 10.2466/pms.1997.84.2.455

Caldirola, D., Sangiorgio, E., Riva, A., Grassi, M., Alciati, A., Scialò, C., & Perna, G. (2017). Does gender influence cognitive function in non-psychotic depression? *Personalized Medicine in Psychiatry, 4,* 25-31. https://doi.org/10.1016/j.pmip.2017.10.002

Chen, A., Tang, D., & Chen, X. (2013). Training reveals the sources of stroop and flanker interference effects. *PloS One, 8(10*), e76580. https://doi.org/10.1371/journal.pone.0076580

Chepenik, L. G., Cornew, L. A., & Farah, M. J. (2007). The influence of sad mood on cognition. *Emotion, 7,* 802-811. https://doi.org/10.1037/1528-3542.7.4.802

Cohen, N., & Henik, A. (2012). Do irrelevant emotional stimuli impair or improve executive control? *Frontiers in Integrative Neuroscience, 6*:33. https://doi.org/10.3389/fnint.2012.00033

Deng, Y., Chang, L., Yang, M., Huo, M., & Zhou, R. (2016). Gender differences in emotional response: Inconsistency between experience and expressivity. *PLoS One,* 11(6): e0158666. https://doi.org/10.1371/journal.pone.0158666

Dillon, D. G., & Pizzagalli, D. A. (2007). Inhibition of action, thought, and emotion: a selective neurobiological review. *Applied and Preventive Psychology, 12(3),* 99-114. https://doi.org/10.1016/j.appsy.2007.09.004

Dillon, D. G., Wiecki, T., Pechtel, P., Webb, C., Goer, F., Murray, L., ... & Parsey, R. (2015). A computational analysis of flanker interference in depression. *Psychological medicine, 45(11*), 2333-2344. https://doi.org/10.1017/S0033291715000276

Gilet, A. L. (2008). Procédures d'induction d'humeurs en laboratoire: une revue critique [Mood induction procedures: A critical review]. *L'encéphale, 34*, 233-239. https://doi.org/10.1016/j.encep.2006.08.003

Gohier, B., Ferracci, L., Surguladze, S. A., Lawrence, E., El Hage, W., Kefi, M. Z., ... & Le Gall, D. (2009). Cognitive inhibition and working memory in unipolar depression. *Journal of Affective Disorders, 116*, 100-105. https://doi.org/10.1016/j.jad.2008.10.028

Goldberg, J. H., Breckenridge, J. N., & Sheikh, J. I. (2003). Age differences in symptoms of depression and anxiety: examining behavioral medicine outpatients. *Journal of Behavioral Medicine, 26(2),* 119-132. https://doi.org/10.1023/A:1023030605390

Gotlib, I. H., & Joormann, J. (2010). Cognition and depression: current status and future directions. *Annual review of clinical psychology, 6*, 285-312. https://doi.org/10.1146/annurev.clinpsy.121208.131305

Hammar, Å., Lund, A., & Hugdahl, K. (2003). Long-lasting cognitive impairment in unipolar major depression: a 6-month follow-up study. *Psychiatry research, 118(2),* 189-196. https://doi.org/10.1016/S0165-1781(03)00075-1

Hubner, R., & Tobel, L. (2019). Conflict resolution in the Eriksen Flanker task: Similarities and differences to the Simon task. *PloS One, 14*(3): e0214203. https://doi.org/10.1371/journal.

pone.0214203

Huntsinger, J. R. (2012). Does positive affect broaden and negative affect narrow attentional scope? A new answer to an old question. *Journal of Experimental Psychology: General, 141(4),* 595. https://doi.org/10.1037/a0027709

Joormann, J., Yoon, K. L., & Zetsche, U. (2007). Cognitive inhibition in depression. *Applied and preventive psychology, 12(3),* 128-139. https://doi.org/10.1177/0963721410370293

Keller, A. S., Leikauf, J. E., Holt-Gosselin, B., Staveland, B. R., & Williams, L. M. (2019). Paying attention to attention in depression. *Translational Psychiatry, 9*:279. https://doi.org/10.1038/s41398-019-0616-1

Keng, S. L., Tan, E. L. Y., Eisenlohr-Moul, T. A., & Smoski, M. J. (2017). Effects of mindfulness, reappraisal, and suppression on sad mood and cognitive resources. *Behaviour research and therapy, 91*, 33-42. https://doi.org/10.1016/j.brat.2017.01.006

Kertzman, S., Reznik, I., Hornik-Lurie., Weizman, A., Kotler., M., & Amital, D. (2010). Stroop performance in major depression: Selective attention impairment or psychomotor slowness. *Journal of Affective Disorders, 122 (2010),* 167-173. https://doi.org/10.1016/j.jad.2009.08.009

King, J. S. (2020). Sad mood, emotion regulation, and response inhibition. *Journal of Cognitive Psychology.* Advance online publication. https://doi.org/10.1080/20445911.2020.1777418

Koch, K., Pauly, k., Kellermann, T., Seiferth, N. Y., Reske, M., Backes, V., … Habel, V. (2007). Gender differences in the cognitive control of emotion: An fMRI study. *Neuropsychologia*. *45*, 2744-2754. https://doi.org/10.1016/j.neuropsychologia.2007.04.012

Lemelin, S., Baruch, P., Vincent, A., Everett, J., & Vincent, P. (1997). Distractibility and processing resource deficit in major depression. Evidence for two deficient attentional processing models. *The Journal of nervous and mental disease, 185(9*), 542-548. https://doi.org/ 10.1097/00005053-199709000-00002.

Lockwood, K. A., Alexopoulos, G. S., & van Gorp, W. G. (2002). Executive dysfunction in geriatric depression. *American Journal of Psychiatry, 159*, 1119-1126. https://doi.org/10.1176/appi.ajp.159.7.1119

Lorist, M. M., & Jolij, J. (2012). Trial history effects in Stroop task performance are independent of top-down control. *PloS One, 7*, e39802. https://doi.org/10.1371/journal.pone.0039802

Magen, H., & Cohen, A. (2002). Action-based and vision-based selection of input: Two sources of control. *Psychological Research, 66(4),* 247-259. https://doi.org/10.1007/s00426-002-0099-0

Markela-Lerenc, J., Kaiser, S., Fiedler, P., Weisbrod, M., & Mundt, C. (2006). Stroop performance in depressive patients: a preliminary report. *Journal of Affective Disorders, 94*, 261-267. https://doi.org/10.1037/0033-2909.109.2.163

Marston, A., Hart, J., Hileman, C., & Faunce, W. (1984). Toward the laboratory study of sadness and crying. *The American journal of psychology, 97(1),* 127-131. https://doi.org/10.2307/1422552

Mayberg, H. S., Liotti, M., Brannan, S. K., McGinnis, S., Mahurin, R. K., Jerabek, P. A., ... & Fox, P. T. (1999). Reciprocal limbic-cortical function and negative mood: converging PET findings in depression and normal sadness. *American journal of psychiatry, 156(5*), 675-682. https://doi.org/10.1176/ajp.156.5.675.

Mitchell, R. L., & Phillips, L. H. (2007). The psychological, neurochemical and functional neuroanatomical mediators of the effects of positive and negative mood on executive functions. *Neuropsychologia, 45*, 617-629. https://doi.org/10.1016/j.neuropsychologia.2006.06.030

Mokhtari, S., & Buttle, H. (2015). The effect of observers' mood on the local processing of emotional faces: evidence from short-lived and prolonged mood States. *Advances in cognitive psychology, 11*, 14-21. https://doi.org/10.5709/acp-0167-5

Nixon, E., Liddle, P. F., Nixon, N. L., & Liotti, M. (2013). On the interaction between sad mood and cognitive control: The effect of induced sadness on electrophysiological modulations underlying Stroop conflict processing. *International journal of psychophysiology, 87(3),* 313-326. https://doi.org/10.1016/j.ijpsycho.2012.11.014

Ottowitz, W. E., Dougherty, D. D., & Savage, C. R. (2002). The neural network basis for abnormalities of attention and executive function in major depressive disorder: implications for application of the medical disease model to psychiatric disorders. *Harvard review of Psychiatry, 10(2),* 86-99. https://doi.org/10.1080/10673220216210

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature reviews neuroscience, 9(2),* 148-158. https://doi.org/10.1038/nrn2317

Phillips, L. H., Bull, R., Adams, E., & Fraser, L. (2002). Positive mood and executive function: Evidence from Stroop and fluency tasks. *Emotion, 2(1),* 12. https://doi.org/10.1037/1528-3542.2.1.12

Scarpina, F., & Tagini, S. (2017). The Stroop color and word test. *Frontiers in psychology, 8*: 557. https://doi.org/10.3389/fpsyg.2017.00557

Schmid, M., Strand, M., Årdal, G., Lund, A., & Hammar, Å. (2011). Prolonged impairment in inhibition and semantic fluency in a follow-up study of recurrent major depression. *Archives of Clinical Neuropsychology, 26(7)*, 677-686. https://doi.org/10.1093/arclin/acr048

Seibert, P. S., & Ellis, H. C. (1991). A convenient mood induction procedure. *Bulletin of Psychonomic Society, 29 (2*), 121-124. https://doi.org/10.3758/BF03335211

Shao, Z., Roelofs, A., Martin, R. C., & Meyer, A. S. (2015). Selective inhibition and naming performance in semantic blocking, picture-word interference, and color–word Stroop tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41(6)*, 1806. https://doi.org/10.1037/a0039363

Siegle, G. J., Steinhauer, S. R., & Thase, M. E. (2004). Pupillary assessment and computational modeling of the Stroop task in depression. *International Journal of Psychophysiology, 52(1*), 63-76. https://doi.org/10.1016/j.ijpsycho.2003.12.010

Tiego, J., Testa, R., Bellgrove, M. A., Pantelis, C., & Whittle, S. (2018). A hierarchical model of inhibitory control. *Frontiers in psychology, 9*: 1339. https://doi.org/10.3389/fpsyg.2018.01339

van der Elst, W., Van Boxtel, M. P., Van Breukelen, G. J., & Jolles, J. (2006). The Stroop color-word test: influence of age, sex, and education; and normative data for a large sample across the adult age range. *Assessment, 13(1*), 62-79. https://doi:10.1177/1073191105283427

von Kluge, S. (1992). Trading accuracy for speed: gender differences on a Stroop task under mild performance anxiety. *Perceptual and motor skills, 75(2)*, 651-657. https://doi.org/ 10.2466/PMS.75.5.651-657

Westermann, R., Spies, K., Stahl, G., & Hesse, F. W. (1996). Relative effectiveness and validity of mood induction procedures: A meta-analysis. *European Journal of social psychology, 26(4)*, 557-580. https://doi.org/10.1002/(SICI)1099-0992(199607)26:4<557::AID-EJSP769>3.0.CO;2-4

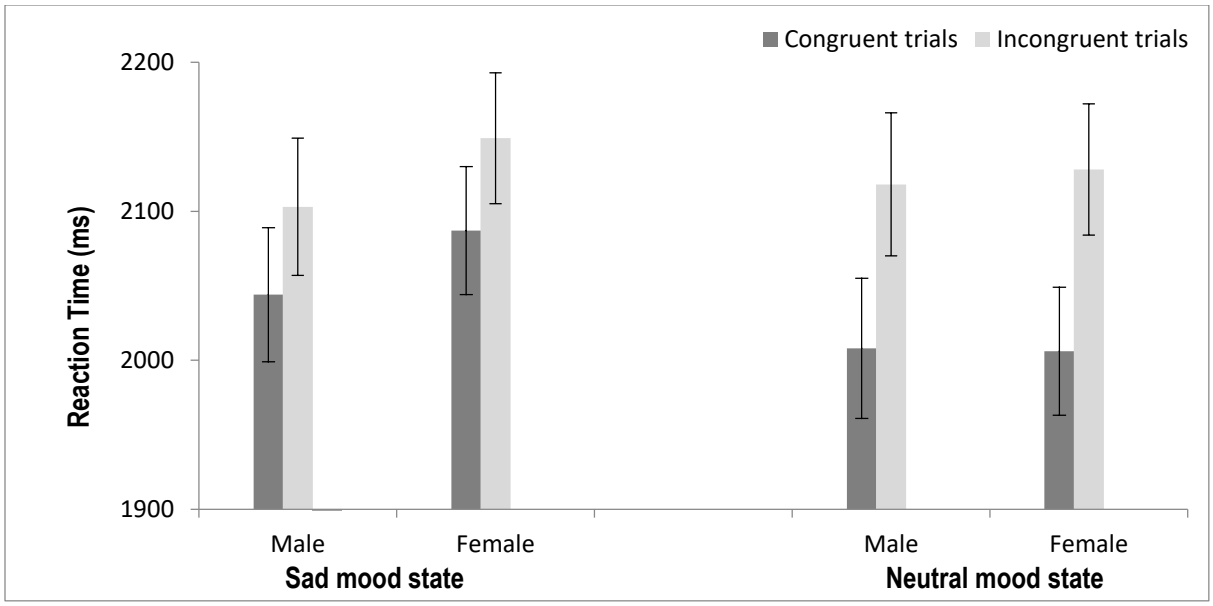

Fig. 1 Mean reaction time values (ms) in females, males in depressed and neutral mood states. Reaction time was slower in incongruent trials regardless of the mood state. The reaction time difference in depressed and neutral mood states was not significant. Mean reaction time in female participants was marginally faster than male participants. Error bars represent ±1 standard error of the mean

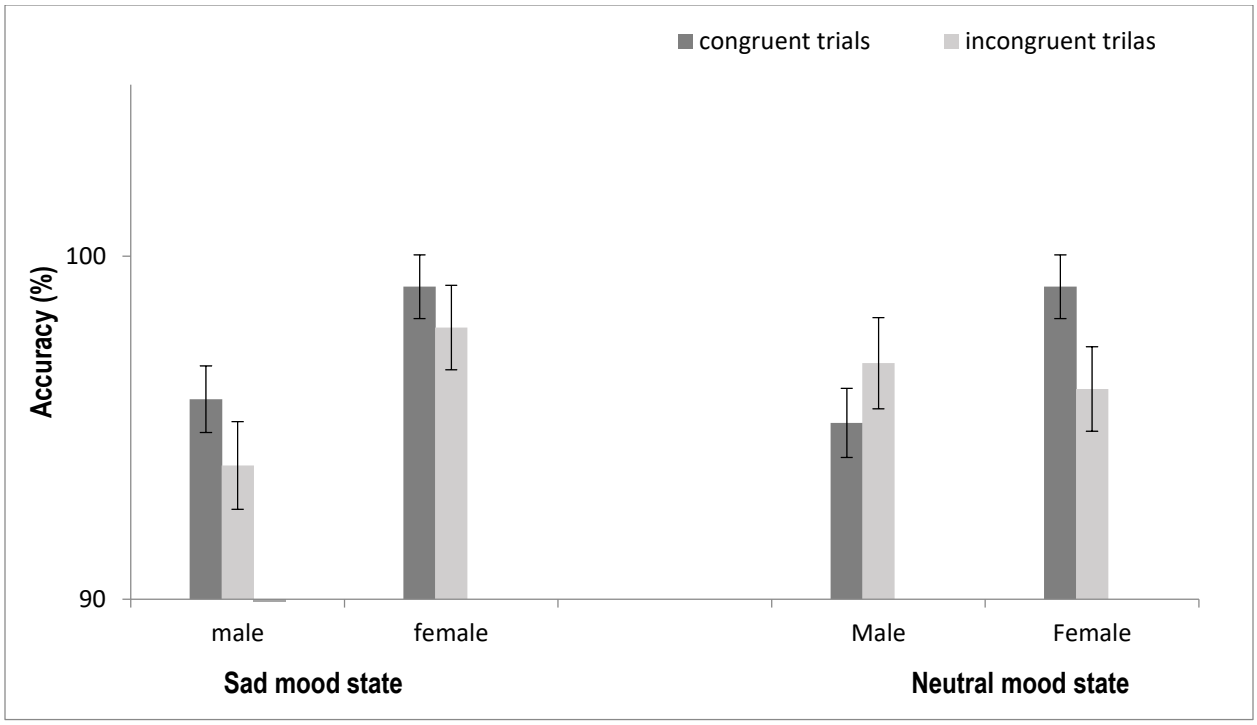

Fig. 2 Mean response accuracy (%) in female and male participants in two different mood states. The percentage of the accurate responses was higher in congruent trials relative to incongruent trials regardless of the mood state. Females had more accurate responses than males. The response accuracy difference in two mood states was not significant. Error bars represent ±1 standard error of the mean

Declarations

Conflict of Interest: The authors declare that they have no conflict of interest.

Authors contribution: S.M and F.B conceived the idea. S.M designed the experiment. R.H.M and F.B programmed the computerized task. R.H.M collected the data. S.M and L.E analyzed the data and wrote the manuscript with inputs from all authors. All authors read and accepted the final version of the manuscript.

Consent to Participate: Participants were informed about their rights and informed verbal consent were obtained from all of them.

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