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The Influence of Positive and Negative Mood on Working Memory and Prepotent Inhibition

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The Influence of Positive and Negative Mood on Working Memory and Prepotent Inhibition

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF ARTS

in Social Ecology

by

Kamalakannan SO M Vijayakumar

Thesis Committee:
Associate Professor Elizabeth A. Martin, Chair
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2021

DEDICATION

To

my aunt who I lost too soon

and her unconditional love for me

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ABSTRACT OF THE THESIS

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by

Kamalakannan SO M Vijayakumar

Master of Arts in Social Ecology

University of California, Irvine, 2021

Associate Professor Elizabeth A. Martin, Chair

The effect of positive and negative mood on different cognitive processes remains largely unknown due to mixed findings. One reason for this is that the methods used in mood induction procedures are widely varied. This study therefore aimed to elucidate the effect of positive and negative mood on two cognitive processes used extensively in daily life: working memory capacity measured using the running memory span, and prepotent inhibition measured using the Flanker task. This study also utilized the three parameters (mu, sigma and tau) of ex-Gaussian distribution to analyze the reaction time data. Participants (N = 306) were predominantly young adults recruited from an undergraduate sample (M = 21.1 years old, SD = 4.2). They were randomly assigned to a positive, negative, or neutral mood group and underwent a mood induction by a watching 3-minute-long video clip. They then performed the running memory span or the Flanker task in a counter-balanced order. Analysis of variance indicate that there was no effect of condition on working memory capacity nor prepotent inhibition. Exploratory analyses indicated that positive mood showed a non-significant tendency to be associated with greater difficulty in prepotent response inhibition, whereas negative mood showed a non-significant tendency to be associated with slower responses (larger tau) in stimulus incompatible trials. These mixed findings suggest that positive and negative mood might influence response inhibition differentially and that there needs to be

further experimentation to clarify the differential effect of positive and negative mood on different cognitive processes.

INTRODUCTION

The effect of positive and negative moods – affective states that last from minutes to days (Lazarus, 1994; Mitchell & Phillips, 2007) – on different cognitive processes, including working memory and cognitive control, remain largely unknown (Mitchel & Philips, 2007; Pessoa, 2009; Pessoa et al., 2012; Storbeck, 2012). While some researchers have found that negative mood enhances working memory (e.g., Gray, 2001), others have found that it impairs working memory instead (e.g., Xie & Zhang, 2016). Similarly, evidence for the association of positive mood with working memory and cognitive control has been mixed.

One reason for the differential findings regarding the effects of mood on these two cognitive processes is that the methods used to investigate the effect of mood on cognition are greatly varied. While some studies have employed emotional cues and stimuli in tasks (Xue at al., 2013, Yegiyan & Yonelinas, 2011), others have used video clips in inducing the targeted moods (Gray, 2001, Martin & Kerns, 2011). This difference in methods could influence the strength of the induction, and in turn, differentially affect the cognitive processes in question. Furthermore, researchers have utilized different tasks aimed at probing similar cognitive processes. Even across studies in which the same tasks are employed, there are differences in task stimuli and stimulus-onset asynchrony as well as other variations in presentation of stimuli and recording of reaction (Chen et al., 2013; Servant & Logan, 2019; Paap et al., 2020). Researchers have relied on broader findings relating to associations between mood and cognition instead of focusing on the nuanced differences in methodology that might account for the varied findings.

The interaction between mood and cognition is an integral component of experiences in daily life; however, the varied findings make it difficult for researchers to further our understanding of this interaction. Therefore, it is important for us researchers to further this line of research to better understand the association between mood and cognitive processes such as working memory capacity and cognitive control. This line of research in turn would better help researchers delineate the differential findings in the body of research thus far. Furthermore, as the cognitive functioning of individuals with severe mood states, such as those with psychopathology, tends to be poorer, this line of research would aid researchers in understanding how working memory capacity and cognitive control may be impacted in these individuals.

In order to address these issues, the current study utilized video clips to elicit negative or positive mood. We also included a "neutral" mood as a control or referent condition to draw comparisons against. We then examined the effects of mood on cognitive processes – namely working memory capacity and cognitive control—using a within-subjects design. By doing so, not only do we hope to add to the current body of literature on the effects of mood on working memory capacity and cognitive control but also to delineate differences to help clarify the differential findings by the various researchers thus far.

BACKGROUND

Working Memory

Working memory involves the temporary storage and manipulation of information in preparation for further complex cognitive activities (Baddeley, 1996; Fletcher & Henson, 2001). Baddeley's model posits that working memory is comprised of three components-the phonological loop, the visuospatial sketchpad, and the central executive. The phonological loop processes verbal information (both words and digits). The visuospatial sketchpad tackles non-verbal information that can be represented in a 3-dimensional space. The central executive is involved in attentional control and manipulation of information (Baddeley, 1996). Baddeley posits that working memory is hierarchically organized such that the central executive is responsible for manipulating subservient systems (i.e., phonological loop and visuospatial sketchpad) to attend to relevant information, as well as holding and manipulating the incoming information (Baddeley, 1996). In the phonological loop, 5 to 9 pieces of information can be maintained and manipulated. However, strategy known as "chunking" is sometimes used to maintain and manipulate more than 5 to 9 items. By organizing numerous separate items into fewer meaningful chunks, more than 5 to 9 separate pieces of info can be maintained in working memory. One means of testing the phonological loop of the working memory in an experimental setting is the Running Memory Span (RMS). In the RMS task, participants hear a series of digits, and are asked to recall a set number of digits in either forward or reverse order. Experimenters can prevent the participants from employing chunking strategies by sufficiently overloading their working memory. This can be achieved by presenting long strings of numbers or at a rate that is too quick for them to utilize any strategy such as chunking or rehearsing, in turn allowing the experimenters to measure their working memory capacity more accurately (Bor & Seth, 2012; Klingberg, 2010).

Working memory and mood

Studies on working memory and mood have mainly focused on the effect of mood on verbal and visuospatial working memory (Aoki et al., 2011; Storbeck & Maswood, 2016). According to the affect-as-information theory (Schwarz & Clore, 2003), the state of the environment is reflected by mood states. A negative mood state is associated with potential threats in the environment, resulting in a bottom-up processing that shifts focus to rapid detection of detailed changes in the environment that could signal danger (Gilet & Jallais, 2012). In turn, there is a shift in information processing in which the focus becomes the individual trees instead of the forest. This trading quantitative information processing for qualitative information processing, results in impaired working memory capacity (Xie & Zhang, 2016). This shift in information processing explains why some studies have found negative mood states improving visuospatial working memory but impairing working memory capacity (Storbeck, 2012). Conversely, according to affect-as-information hypothesis, positive mood is likely to improve working memory capacity. This improvement in attributed to positive emotions expanding one's attention (Fredrickson, 2004). This is because positive mood signals a favorable environment, which leads to reduced alertness to rapid changes, greater focusing on global information instead and thus, improving working memory capacity (Storbeck & Clore, 2005). In sum, theoretical evidence suggests that both positive mood state is likely to enhance working memory capacity, whereas negative mood state is likely to impair working memory capacity. To date however, the effects of both these two mood states on working memory capacity have been studied in only a few studies (Baddeley et al., 2012; Huntsinger, 2012).

Prepotent inhibition

While working memory is involved in temporary storage and manipulation of information for further complex cognitive activities (Storbeck & Maswood, 2016), cognitive control is involved in adapting to situational demands (van Steenberg at al., 2010). In other words, prepotent inhibition is related to coordination among multiple task-demands, facilitating maintenance of goal-relevant representations and preventing interference from goal-irrelevant representations (Banich, 2009; Braver, 2012) as well as adjusting the degree of selectivity in information processing (Schuch & Kock 2015). The degree to which task-relevant aspects are attended and task-irrelevant aspects are filtered out (Schuch & Koch, 2015) is called prepotent inhibition. A common way prepotent inhibition is measured in experimental setting is through tasks in which distraction or conflict is introduced to detract the participant from their goal. One prepotent inhibition paradigm, the Flanker task (Eriksen & Eriksen, 1974), has participants respond to a target stimulus that is flanked by distractors. These distractors can be either mapped onto the same response key (congruent) or different response key (incongruent) from the target letter. In doing so, participants need exercise prepotent inhibition in order to respond correctly and not be distracted by task-irrelevant information.

Prepotent inhibition and mood

Researchers argue that for cognitive control to exist, there first must be conflict (Hoffman, 2012; Inzlicht et al., 2015). This conflict is usually accompanied by negative affect, (Hirsh et al., 2012) that tends to be transient (Fritz & Dreisbach, 2014), similar to a negative mood. According to conflict monitoring theory (Botvinick et al., 2001; Botvinick et al., 2004), conflict leads to an increase in processing selectivity, known as conflict adaptation, adjusting to goal-directed behavior (Kerns at al., 2004), while filtering out irrelevant information. This is done to deal with threats or potential dangers in the environment. Furthermore, negative mood states, which are congruent with the context when in a conflict, result in facilitation of cognitive control. On the other hand, positive mood states are typically induced based on approach and enjoyable contexts, and thus would likely lead to a more diffused and less controlled processing. The conflict adaptation also leads to incongruency with positive mood states, resulting in impaired cognitive control. However, while some studies that have found positive mood states to have impaired performance in tasks involving prepotent inhibition (Dreisbach, 2006; Frober & Dreisbach, 2012; Phillips et al., 2002), other studies have found positive mood states do not significantly influence performance (Martin & Kerns, 2011; van Wouwe et al., 2011). In sum, based on the aforementioned theories, negative mood states are likely to improve prepotent inhibition whereas the effects of positive mood states on prepotent inhibition is less clear.

Current Study

In the current study, we aimed to examine the effect of positive, negative, and neutral mood states on working memory capacity and prepotent inhibition. Participants were randomly assigned to one of three group and underwent either a positive, negative, or “neutral” mood induction. They then performed an RMS and a Flanker task to examine the effects of mood on working memory and prepotent inhibition respectively. We hypothesized that the positive mood group would have enhanced performance in the RMS task compared to neutral group, but the negative mood group would have impaired performance compared to the neutral mood group. We also hypothesized that positive mood group would have had impaired performance on the Flanker task, but the negative mood group would have had enhanced performance compared to the neutral mood group.

MATERIALS AND METHODS

Participants

A total of 306 participants were recruited from a Southern California university. Some participants were excluded from the final analyses due to technical issues that resulted in loss of data, poor performance in the cognitive tasks, for failing to meet inclusion criteria, and data points that were exerting high influence on the models for analyses (see section on Cleaning Data for further details). Of the 270 retained for the study, approximately 85.2% of the participants were female with a mean age of 21.1 years (SD = 4.2, range from 18-56 years). Approximately 40.4% of the participants were Asian, 31.1% Hispanic, 14.1% Euro-American, 4.1% South Asian, 3.0% Black and 7.4% other ethnicity.

Procedure

Following informed consent, participants were randomly assigned to one of the three mood induction groups. Participants completed an initial mood measure and then viewed a 3-minute clip before completing a post-induction mood measure. The participants then completed the RMS task and the Flanker task with task order counterbalanced across participants. Upon completion of both tasks, participants answered one final mood questionnaire along with other questionnaires and a memory task not related to this study.

Power analysis

An *a priori* statistical power analysis was conducted using G*Power (Faul et al., 2009) for sample size estimation based on data from previous studies comparing mood to cognitive control

(Schuch & Koch, 2015; Martin & Kerns, 2011; Yang & Pourtois; 2018; Miller et al., 2018). With an alpha = .05, power = .8, and 3 groups, the projected sample size needed with a similar effect size of .253 was approximately N = 246 (82 per group). Thus, the sample size of 270 in the current study (87 in positive mood group, 93 in negative mood group and 90 in neutral mood group) was adequately powered to test the hypotheses.

Materials

Mood-induction

Participants each watched a 3-minute video clip, involving an interaction between two men, to induce positive, negative, and neutral mood. The clip varied depending on the condition they were assigned to. The clip for the positive mood induction group was a scene from "Monty Python and The Holy Grail", (Jones & Gilliam; 1975) in which King Arthur and the Black Knight engage in a comical duel set in a forest. Participants in the negative induction group watched a scene from the movie "My Bodyguard" (Bill, 1980) in which a man bullies another. Finally, the clip for the neutral group was a clip from the Youtube channel "This Old House" in which one man teaches another to hang a mirror in a workshop (This Old House, 2014).

Task 1: Running Memory Span

Task 1 was a running memory span forward recall task identical to an earlier study by Martin and Kerns (2011). For a total of 18 trials, 12-20 single-digit numbers were randomly presented at a rate of 4 numbers per second, to participants through a headset. They were then instructed to recall the last six digits they heard, in forward order, by entering as many digits as they could recall into respective numbered slots (slots numbered 1-6 for the last 6 digits that were presented). The participants were informed that they could guess or leave slots empty. They were awarded a point so long as they correctly guessed the digit one slot before or after the correct position in the span of digits (e.g., If "6" was the second to last digit presented, participants would be awarded a point if they entered “6” in the #4, #5 or #6 slot). Their score was tallied up by adding the points they received per trial, and then averaged across the 18 trials.

Task 2: Flanker Task

The Flanker task was similar to the one utilized by Martin and Kerns (2011). A row of 5 letters were presented in the center of the computer screen. The center letter (position #3) was the target letter, flanked on either side by compatible or incompatible letters. Participants were instructed to press “1” if the target letter was a “H” or “K” but press “0” if the target letter was “C” or “S”. A trial was compatible if the letters flanking the target letter were the same as the target (e.g., “HHHHH”; “SSSSS”). A trial was stimulus-incompatible if the letters flanking the target letter were associated with the same response key (e.g., “HHKHH”; “CCSCC”) and response-incompatible if the letters flanking the target letter were associated with a different response key (e.g., “SSKSS”; “HHCHH”). The participants completed a total of 3 blocks of 48 trials for a total of 144 trials, with an inter-trail interval of 500ms. A third of the trials were congruent, a third stimulus incompatible and another third response incompatible.

Mood questionnaire

Participants reported how much of seven positive and 11 negative emotions they felt using items from Rottenberg et al. (2007) that validated how effective the video clips used in the mood induction were at eliciting the target mood state. The items were scored on a 9-point scale (1 = not at all/none to 9 = extremely/a great deal) and were averaged for each valence to reflect an overall positive affect and an overall negative affect score. The questionnaires were administered before and after the mood-induction, as well as after the participants completed both the running memory span and the Flanker task.

Cleaning Data

Data from nine participants were removed due to technical errors (software failure and researcher error), 16 were removed for poor performance on the tasks, and one participant was removed for failing to meet inclusion criteria. Following convention in identifying influential sources in data (Belsley et al., 1980; Bollen & Jackman, 1985; Walker & Birch, 1988), regression diagnostics were run, and eight participants were removed for exerting high influence in our models of analysis as their covratios were much greater or lesser than 1. Regression diagnostics were run again and there were no further participants exerting high influence.

Reaction time data

As is convention, only correct trials were considered when computing reaction time data (Paap et al., 2020; Chen et al., 2013; Friedman & Miyake, 2004). Participants who scored less than 50% (n = 18) on any of the three trial types were excluded as they scored less than chance. Also following convention, trials with reaction times less than 200ms were considered too quick to have tracked an actual response from the participants. Trials with reaction times longer than 2000ms (~3sd from the mean) were considered aberrant and removed as well (Paap et al., 2020; Chen et al., 2013; Friedman & Miyake, 2004). This however, still resulted in only a loss of 8.4% of the original reaction time data. The remaining reaction time data was used to calculate the "exponential-Gaussian" parameters (see portion below on Exponential-Gaussian distribution). The data was then further trimmed around 3 standard deviations to obtain the trimmed means of each participant for each trial type. Using the trimmed means, the Flanker effect indicators were calculated as the difference between stimulus incompatible and response incompatible trials reflecting prepotent response inhibition, and difference between the compatible and response incompatible trials as the visual focus effect of attention.

Exponential-Gaussian distribution

In addition to calculating the Flanker effect indicators (prepotent response inhibition and visual focus effect of attention) using trimmed means, reaction time for each trial type was broken into three exponential-Gaussian (ex-Gauss) parameters; mu (the mean of the gaussian portion), sigma (the variance of the gaussian portion) and tau (the exponential tail). This is because reaction time data is not represented by a normal or Gaussian distribution but looks much closer to a heavily (positively) skewed distribution, that reflects a combination of a Gaussian distribution and an exponential tail. As such, using trimmed means results in removing much of the exponential tail in order to force the data into a more Gaussian shape for more convenient data analyses. Although, in doing so, instances where the main effects of manipulations are represented by differences in the exponential tail are lost. Therefore, the ex-Gaussian parameters of mu, sigma and tau were included in the analyses as advocated by Ratcliff (1993) and Whelan (2008) to capture nuances in the reaction time between groups otherwise missed in analyses using only the trimmed means. Studies that have included the "ex-gaussian" parameters of mu, sigma and tau in their analyses have found nuances in the reaction time data between groups, otherwise missed in conventional methods of analyzing reaction time using only trimmed means (Hervey et al., 2006; Lin et al., 2015; Galloway-Long & Huang-Pollock, 2018; Adamo et al., 2018).

Software used for cleaning data

R (R Core Team, 2020) was used primarily for data cleaning and analyses, with data manipulation performed using the packages *tidyverse* (Wichkam et al., 2019) and *qdapRegex* (Rinker, 2017). The *trimr* package (Grange, 2015) was used to clean reaction time data and *retimes* package (Massidda, 2012) was used to obtain the ex-Gaussian parameters mu, sigma and tau. The package *psych* (Revelle, 2020) was used to derive descriptive statistics while *car* (Fox & Weisber, 2019) was used to evaluate participants with extreme scores that were exerting high influence on our models.

RESULTS

Mood-induction

Two separate mixed-model ANOVAs were conducted to assess the effects of the mood induction on positive and negative mood ratings. The between-subjects factor was condition (positive, negative and neutral) and the within-subjects factor was time (before the mood induction, immediately after the induction, and at the end of the experiment). Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated for both models [χ^2 positive (2) = .47, p < .001; χ^2 negative (2) = .52, p < .001]. Greenhouse-Geisser correction was therefore used in examining the main and interaction effects of the mood induction. Planned pair-wise comparisons were performed to clarify the simple effects in the interaction between time and condition (i.e., comparisons within mood group by time and comparisons between mood groups at each time point) and Games-Howell multiple comparison procedure correction was used to correct for Type 1 due to the violation of assumption of sphericity.

Positive mood ratings

The effect of time on positive mood rating [$F(2.62, 349.91) = 23.90$, $p < 0.001$, $\eta 2 = .15$] as well as on negative mood rating [$F(2.69, 359.61) = 94.68$, $p < 0.001$, $\eta 2 = .42$] varied as a function of condition. As seen in Figure 1, although all three groups reported similar positive mood rating pre-induction [$F(2, 267) = 1.22$, $p = .30$], those in the positive mood group reported no decrease post-induction (p = 1.00), whereas the neutral and negative mood groups reported significant decreases (ps < .001) in positive mood ratings. However, the positive mood group (M = 4.21) reported significantly higher levels of positive mood compared to the negative (M = 2.36) and neutral (M = 2.84) mood groups after the induction, ps < .001. The neutral mood group reported a significantly higher positive mood than the negative mood group, p = .01. Despite all three groups reporting a significant decrease in positive mood rating (p < .001) from post-induction to the end of the experiment, the pattern remained the same in which the positive mood group reported the highest ratings, followed by neutral and then negative mood groups.

At the end of the experiment, the positive mood group (M = 3.71) reported significantly higher positive mood rating than the negative (M = 2.14) and neutral mood groups (M = 2.55), ps <

.001. Neutral mood group maintained significantly higher positive mood ratings compared to the negative mood group, $p = .03$.

Negative mood ratings

For negative mood ratings, the mood ratings pre-induction were similar to one another ($F(2, 267) = 1.44$, $p = .24$) and those in the negative mood group ($p < .001$) reported a significant increase in negative mood post-induction. While the neutral ($M = 1.40$, $p < .001$) mood group reported a significant decrease in negative mood rating, the positive mood group ($M = 2.26$, $p = .15$) reported no significant change in negative mood rating. That is, the negative mood group ($M = 4.41$) reported significantly higher levels of negative mood compared to the neutral ($M = 1.40$) and positive ($M = 2.26$) mood groups after the induction, ps < .001. The positive mood group reported a significantly higher negative mood than the neutral mood group, $p < .001$.

Compared to post-induction, at the end of the experiment, although there was a decrease in negative mood rating for the negative mood group that was trending towards significance (p = .057) the decrease was not significant for the neutral ($p = .15$) and positive ($p = .44$) mood groups. At the end of the experiment, the negative mood group ($M = 4.22$, ps < .001) reported significantly higher mood rating than the positive ($M = 2.15$) and neutral ($M = 1.34$) mood groups. Positive mood group maintained significantly higher negative mood ratings than the neutral mood group, $p < .001$.

To summarize, after the mood induction, compared to each other the mood groups showed the expected pattern of mood ratings. That is, the positive mood group reported higher levels of positive mood compared to the other groups (positive group > neutral group and negative group), and the negative mood group reported higher levels of negative mood compared to the other groups (negative group > positive group and neutral group). Similarly, at the end of the experiment, the positive mood group reported higher levels of positive mood than the other two groups, and the negative mood group reported higher levels of negative mood compared to the other groups.

Effect of mood induction on RMS and Flanker

Analysis of variance was conducted to examine the effect of condition on the running memory span task. The categorical covariate of task order (RMS vs Flanker) was included. There was no significant effect of mood induction on running memory span, [$F_{RMS}(2,266) = .345$, p = .71] across task order. However, there was a significant effect of task order on RMS score [$F_{task\ order}(1,266) = 4.66$, $p = .03$] collapsed across mood conditions with participants performing the RMS later ($M = 3.97$) scoring higher on the running memory span than those who performed the RMS first ($M = 3.81$). This means that task order affected performance on RMS such that those who performed the RMS later, had a higher score on average than those who performed the RMS first. Both ANCOVA and two-way ANOVA were conducted as sensitivity analyses, and the results were consistent in both analyses.

There was also no significant effect of mood on accuracy on the Flanker task, nor on the Flanker effect indicators. In addition, analyses of covariance on the ex-Gaussian parameters did not yield any significant findings neither (refer to Table 1).

Exploratory analyses

As indicated in the analyses of mood ratings over time in the participants (Figure 1), and in our analyses of covariance, task order was significantly related to performance on the tasks. One possibility is that the Flanker task had a facilitative effect, improving performance on the RMS. Another possibility is that the mood induction did not have the same effect on every participant's mood in each of the mood groups. Thus, using categorical mood groups in statistical analyses, rather than considering mood ratings dimensionally, might have obscured the effect of mood on the cognitive tasks. Therefore, we explored the effect of mood ratings (positive and negative rating) as continuous predictors on the performance on the cognitive tasks splitting the dataset based on task order (Table 2 report these results).

Running memory span score regressed on mood

Two separate linear regression analyses were conducted for positive and negative mood ratings serving as the continuous predictors. Score on running memory span served as the continuous outcome in each model. Only participants who performed the running memory span as their first task were included in this portion of analyses. Neither positive mood rating nor negative mood rating were significant predictors of performance on the running memory span (see Table 2).

Flanker indices regressed on mood

As with the analyses for running memory span, separate regressions were conducted with positive and negative mood rating serving as continuous predictors, and the indices of Flanker (accuracy, Flanker effect and ex-Gaussian parameters) serving as outcome variables. As each Flanker task had three trial types (compatible, stimulus-incompatible, response-incompatible), the number of analyses had increased, and therefore the alpha level was adjusted to control for Type 1 error.

Flanker accuracy and Flanker effect. We found that positive and negative mood ratings were not significant predictors of accuracy on any of the three trial types. There was however, a trend for positive mood ratings to be a significant predictor of prepotent inhibition [b_{PPRI} = 4.91, 95% CI_{boot} (.260, 9.60), $t(133) = 1.96$, $p = .052$]. This indicated that every one unit increase in positive mood rating predicted a 4.9ms increase in prepotent response inhibition and explained about 2.1% proportion of variance in prepotent response inhibition [R_{multiple}= .028, Adj. R_{multiple} = .021, $F(1,133) = 3.85$, $p = .052$]. This indicates that participants with a higher positive mood rating had more difficulty in prepotent response inhibition. However, positive mood rating was not a significant predictor of visual focus effect of attention. At the same time, negative mood rating was not a significant predictor of prepotent response inhibition nor visual focus effect of attention.

Exponential-Gaussian Parameters. In general, for all three trial types, neither positive nor negative mood were significant predictors of the ex-gaussian parameters with one exception. There was a trend for negative mood rating to be a significant predictor of tau on stimulus incompatible trials [$b_{\text{stim\_tau}}$ = 7.96, 95% CI_{boot} (-1.08, 17.2) $t(133) = 1.96$, $p = .052$]. Specifically, every one unit increase in negative mood rating predicted a 7.96ms increase in reaction time in tau for the stimulus incompatible trials. Negative mood rating also explained about 2.1% of proportion of variance in the longer reaction times in stimulus incompatible trials [$R_{\text{multiple}} = .028$, Adj. $R_{\text{multiple}} = .021$, $F(1,133) = 3.84$, $p = .052$]. This finding indicates that the higher the negative mood rating, the more likely participants were in taking longer to respond in stimulus incompatible trials.

DISCUSSION

Although there have been many studies examining the effect of positive and negative mood states on cognitive processes, such as working memory and cognitive control, much of the findings have been mixed. The aim of this study was to examine the effect of both positive and negative mood on working memory capacity and prepotent inhibition within the same sample in order to clarify some of the differential findings.

Working Memory Capacity

We hypothesized that working memory capacity as measured by the forward recall running memory digit span for both the positive and negative mood groups would be lower than the neutral group. However, we found no significant differences in performance between the three mood groups. Although we found no significant differences between the groups, our means were consistent with other studies that look at the association between mood and working memory capacity. Most studies have found that positive mood predicts greater working memory capacity than neutral (Martin & Kerns, 2011; Carpenter et al., 2013; Yang et al., 2013) and negative mood (Storbeck & Maswood, 2016), while negative mood predicted an impairment in working memory capacity (Curci et al., 2013; Moran 2016). Of these studies, Martin and Kerns (2011) were the only others to employ both a mood-induction procedure using films, and measure of working memory capacity using a digit recall. Although we found no significant differences between the groups, our means were consistent with other studies, in which the working memory capacity for those in the positive mood groups was higher than neutral mood group and working memory capacity was poorest in the negative mood group.

Flanker Effect

We hypothesized that the positive mood group would have had impaired performance compared to the neutral mood group, whereas the negative mood group would have had enhanced performance on the Flanker task. Although we found no significant differences in accuracy scores, we found that there was a trend for positive mood to be a significant negative predictor of prepotent response inhibition. Therefore, greater positive mood predicted poorer prepotent response inhibition and in turn, greater susceptibility to distractors. While this finding corroborated that of some earlier studies (Biss et al., 2011; Rowe et al., 2017), it was divergent from several others in that they either found positive mood to not have an influence on susceptibility to distractors (Bruyneel et al., 2013; Martin & Kerns 2011). Of these studies, Martin and Kerns (2011) was the only one to that employ both a mood-induction procedure using films and using the Flanker task as a measure of prepotent response inhibition. One reason for divergent findings could be that the researchers have used a variety of means to elicit emotions when examining associations between mood and cognitive control. With cognitive paradigms such as the Flanker task, there is an added option of using emotional stimuli in the task itself to assess the influence of mood instead of relying on a separate mood-induction. Furthermore, stimuli used (e.g., arrows and lines vs alphabets), response collection and procedure vary between the studies. These differences in eliciting emotions then could affect the strength of the induction, in turn affecting prepotent response inhibition.

Ex-Gaussian parameters

To our knowledge, this was one of the few studies to examine the nuances in reaction time relating to mood by including the ex-Gaussian parameters. The ex-Gaussian parameters are important because often, the longer reaction time trials are trimmed to make the reaction time data fit into a more Gaussian shape for analyses and in the process of doing so, lose some of the data points that might provide nuanced information. A finding that is unique to this study through the examination of the ex-Gaussian parameters is the tau parameter which captures longer reaction times. We found that there was a trend for participants in the negative mood group to be more likely to take longer to respond in stimulus incompatible trials in which the flankers and target are different but map on to the same response. Although non-significant, this is a novel finding suggesting that the more one is susceptible to distractors and has trouble with response inhibition, the more likely the effect is going to be found on the trials with longer reaction time. The conventional method of reaction time data analyses in which trimmed means are used would have resulted in the loss of this nuanced finding.

Limitations and future directions

Mood induction

One reason for our lack of significant findings relating to mood and working memory capacity could be that our mood induction procedure did not result in clean induction of moods. As seen in Figure 1, post-induction and at the end of the experiment, our positive mood group had a higher negative mood rating than the neutral mood group. The mood induction could have led to smaller group differences than would have been in an ideal mood induction. While we did attempt exploratory analyses by only including the participants that performed the respective task first since task order was a significant predictor of performance, the sample size was reduced by half and that also affected the power of our analyses. Although the pattern of mood ratings at the end of the experiment was similar to the pattern of mood ratings post-induction, having a mood booster before the second task would ensure that participants were in the desired mood state for the task. Furthermore, including a mood rating after the booster would also allow us to detect any changes in the pattern of mood ratings that might have influenced performance in the second task.

Although the video clips we used were previously reported to elicit negative affect (Rottenberg et al., 2007), multiple discrete emotions were likely evoked. For example, while the video from "The Bodyguard" (Bill, 1980) that we used to elicit negative affect mostly induced anger, it was also found to have elicited disgust, interest, and sadness. Many theories of the effects of negative affect on working memory and cognitive processing focus on the effects of fear, but many mood induction procedures elicit a range of negative emotions, and this may account for the differential findings as well. Furthermore, we computed a composite score each for positive and negative mood from the responses of participants on discrete emotions (e.g., average of score on joy, love, amusement, interest, pride, surprise, and happiness for positive mood score), which could have conflated some of the responses. An alternative would have been to create latent class variables for the positive and negative moods instead, allowing them to freely vary, which might have more accurately captured their mood states.

Affect as cognitive feedback

One explanation for our lack of significant findings relating to mood and the cognitive processes assessed could be that positive and negative affect do not specifically enhance or impair performance in any cognitive process. Our hypotheses were based on the theory that affective reactions modify attentional scope between global and local processing. However, according to the "affective as cognitive feedback" approach (Huntsinger et al., 2014), positive and negative affect instead reinforce or inhibit responses related to them. Affective reactions have the effect that they do by conferring positive and negative value on the dominant attentional orientation (of local or global processing) in each situation. If one has a global dominant attentional orientation, then a positive mood would result in broadening of attention while a negative mood would result in narrowing of attention. In contrast, if one had a local dominant attentional orientation, then a positive mood would result in narrowing of attention, and a negative mood would result in broadening of attention. A narrowing of attention would result in a smaller flanker effect and would likely enhance working memory capacity, whereas a broadening of attention would result in a greater flanker effect but impaired working memory capacity. Since affect operates on whichever attentional orientation is dominant, then when global and local orientations are equally accessible, no association between mood and attentional scope would be evident. In a similar vein, if neither global nor local orientation was dominant, affect would have failed to influence the scope of attention at all.

In our study, as we do not have a measure of attentional orientation dominance, it is difficult to conclude if our findings were due to lack of a dominant attentional orientation, or if there was a mix of participants with varying attentional orientations in each mood group that ended up being conflated. Therefore, a future direction would be to examine the interaction between mood states and attention orientation, and how that interaction affects cognitive processes such as prepotent inhibition and working memory capacity as explored in this study. An effective way would be to include the Navon task that examines attentional orientation so that the association with mood states can be probed.

Conclusion

Overall, in our current study, although the scores for running memory span performance were in the hypothesized direction, we found no statistically significant association between neither positive nor negative mood and working memory capacity. However, we found that positive mood showed a non-significant tendency to be associated with greater difficulty in prepotent response inhibition and negative mood showed a non-significant tendency to be associated with slower responses in stimulus incompatible trials. These mixed findings then suggest that positive and negative mood might influence response inhibition differentially.

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Figures

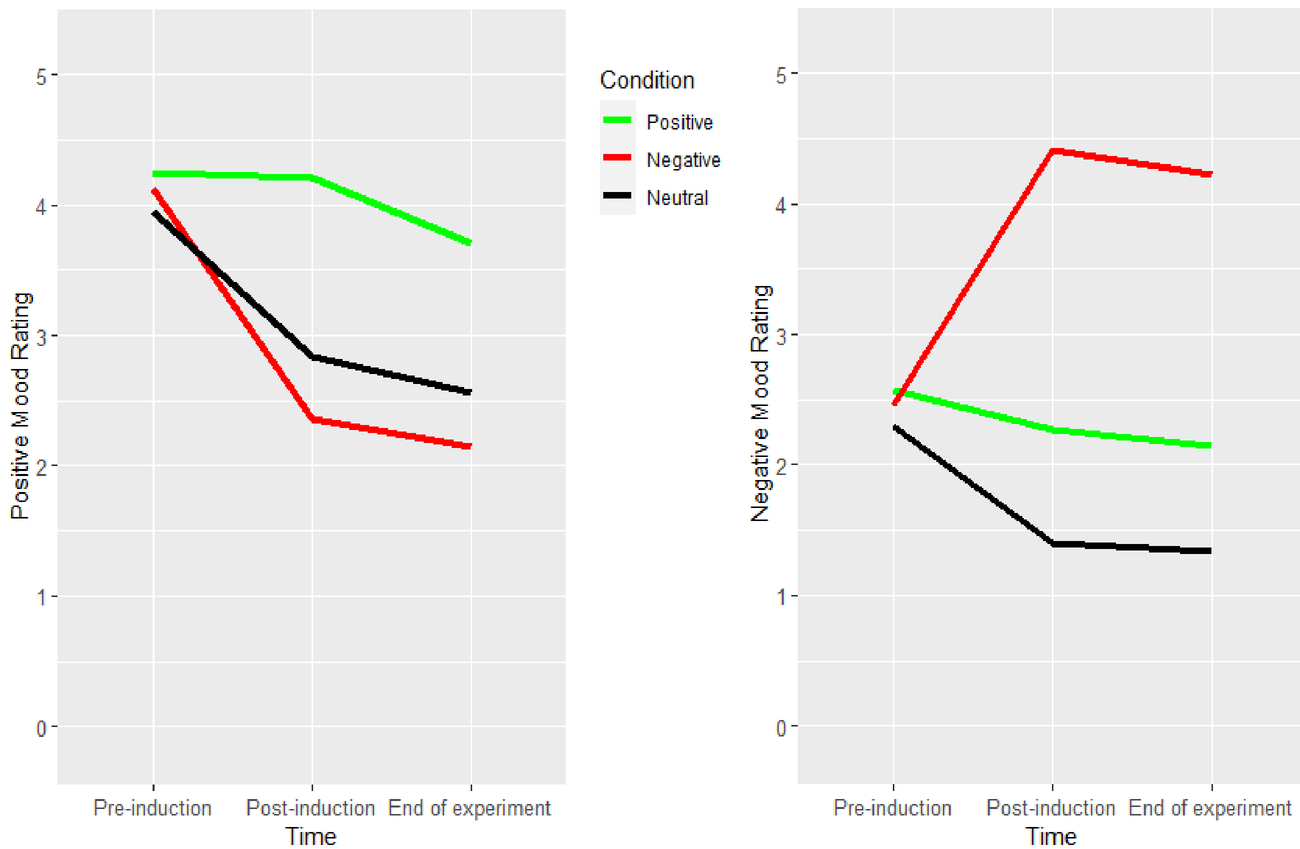

Figure 1: Graphs of change in mood ratings for the different mood conditions over time

Tables

Table 1: Descriptive Statistics of Mood Rating and Main Effect of Condition on Running Memory Span and Flanker

	Condition			Main Effect of Condition	
	Positive mood	Negative mood	Neutral mood	F	η^2
Task 1: Running memory span	3.93 (.57)	3.840 (.57)	3.890 (.60)	.35	.004
Task 2: Flanker					
Flanker accuracies (%)					
Compatible	97.53 (2.59)	97.20 (3.16)	97.35 (3.34)	.15	.002
Stimulus incompatible	98.13 (2.40)	98.44 (2.59)	98.17 (2.27)	.49	.003
Response incompatible	94.42 (5.064)	94.99 (5.34)	93.96 (6.37)	1.02	.006
Trimmed means (ms)					
Compatible	613.67 (125.03)	642.66 (135.47)	616.04 (112.83)	1.7	.011
Stimulus incompatible	627.39 (119.17)	657.99 (126.17)	630.67 (116.34)	2.00	.013
Response incompatible	683.11 (124.10)	711.37 (139.70)	691.97 (131.85)	1.26	.008
Ex-Gaussian (ms)					
Compatible					
mu	431.87 (110.75)	452.67 (122.92)	435.49 (115.33)	1.05	.006
sigma	91.82 (49.68)	108.45 (66.19)	102.61 (50.49)	2.06	.015
tau	199.06 (70.61)	206.49 (71.97)	199.13 (86.88)	.22	.002
Stimulus Incompatible					
mu	456.88 (110.56)	475.22 (110.49)	464.50 (107.15)	.92	.005
sigma	94.08 (50.99)	102.88 (59.20)	89.94 (48.35)	1.25	.011
tau	186.90 (88.87)	199.51 (77.48)	181.88 (71.13)	1.00	.009
Response Incompatible					
mu	508.39 (116.13)	536.26 (117.49)	517.77 (122.37)	1.63	.010
sigma	95.03 (53.56)	104.90 (64.65)	96.39 (56.23)	.81	.006
tau	191.76 (74.51)	187.63 (71.61)	189.73 (74.94)	.13	.001
Flanker effect (ms)					
Prepotent response inhibition	55.72 (43.25)	53.38 (49.27)	61.30 (49.16)	.65	.005
Visual focus effect of attention	69.44 (42.06)	68.70 (54.22)	75.93 (53.60)	.53	.004

Note: Running memory span (RMS) is reflected as a score out of a maximum of 6 and Flanker accuracy is reflected as % of correct trials. Prepotent response inhibition is the difference between stimulus and response incompatible trials, while visual focus effect of attention is difference between the compatible and response incompatible trials.

Table 2: Summary of Linear Regression Analyses

	Positive Mood Rating			Negative Mood Rating		
	b	95% CI [LL, UL]	*b**	*b*	95% CI [LL, UL]	*b**
Task1: Running memory span	-.022	[-.097, .052]	-.05	-.02	[-.08, .03]	-.07
Task 2: Flanker						
Flanker accuracies						
Compatible	-.002	[-.31, .30]	-.001	.07	[-.23, .37]	.04
Stimulus incompatible	-.03	[-.25, .18]	-.03	.09	[-.19, .35]	.06
Response incompatible	-.25	[-.97, .47]	-.07	.17	[-.55, .88]	.04
Ex-Gaussian						
Compatible						
mu	-.69	[-14.79, 13.41]	-.009	2.62	[-12.21, 16.94]	.03
sigma	-3.67	[-8.92, 1.60]	-.11	.49	[-5.52, 6.45]	.01
tau	-1.73	[-9.87, 6.75]	-.03	.13	[-8.87, 8.95]	.003
Stimulus Incompatible						
mu	-2.85	[-17.53, 11.97]	-.04	.46	[-12.48, 13.19]	.006
sigma	-1.06	[-6.58, 4.59]	-.03	5.2	[-.69, 10.90]	.16
tau	-5.21	[-12.92, 2.63]	-.11	7.96	[-1.08, 17.24]	**.17**$^{+}$
Response Incompatible						
mu	-2.98	[-18.57, 12.94]	-.04	1.23	[-11.85, 14.12]	.01
sigma	.94	[-4.98, 6.93]	.03	1.34	[-5.20, 7.77]	.04
tau	1.59	[-5.90, 8.93]	.04	1.87	[-6.06, 9.73]	.04
Flanker effect						
Prepotent response inhibition	4.91	[.26, 9.60]	**.17**$^{+}$	-4.28	[-9.59, 1.17]	-.14
Visual focus effect of attention	-.86	[-5.91, 4.30]	-.03	.07	[-5.22, 5.61]	.002

Note: While none of the variables were significantly related to mood, there was a trend toward significance for prepotent response inhibition and tau of stimulus incompatible trials as indicated by $^{+}$. *b*s represent unstandardized regression coefficients whereas *b** represent standardized regression coefficients.