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THE INFLUENCE OF HAPPINESS AND ANXIETY ON EMOTIONAL STROOP EFFECT

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The main aim of this study was to examine how happiness and anxiety influence emotional Stroop effect. According to the principle of emotion congruence, information processing is facilitated if its emotional tone matches an individual's mood. The first hypothesis suggested that emotional Stroop effect would be greater with stimuli incongruent with a participant's emotional state. The second hypothesis was based on two theories; the broaden-and-build theory predicting that happiness makes attention broader, and Attentional Control Theory predicting that anxiety impairs inhibition. Hence, it was suggested that emotional Stroop effect would be smaller in the happy state compared to neutral and anxious states. We used an emotional Stroop task with neutral, happy, and threatening words, music for mood induction, and the EmoS-15 questionnaire to estimate the effectiveness of mood induction. The first hypothesis was partly confirmed. Emotional Stroop effect estimated in error rates was greater for stimuli incongruent with emotional states, although this effect did not reach the conventional level of statistical significance. The second hypothesis was not confirmed. The size of emotional Stroop effect did not depend on participants' emotional states.

JEL Classification: Z

Keywords: emotional Stroop effect, emotions, attention, mood induction, anxiety, happiness

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Introduction

This research aims to understand how different emotional states influence emotional Stroop effect (ESE) and whether its size depends on emotion congruence. Emotional Stroop effect is defined as a delay in reaction time (RT) while naming the colors of emotional words compared with neutral (Algom et al., 2004). ESE can be also estimated as a difference in the error rate (ER) for emotional and neutral stimuli. Emotion congruence suggests that the processing of information that has a similar emotional tone to a participant's emotional state will be facilitated (Rusting, 1998).

In the classical Stroop task, participants must name colors in which the words are printed, while the words are the names of colors. If the meaning of a word and the color in which it is printed is congruent, RT is faster than when they are not congruent (Stroop, 1935). The classical Stroop effect has a lot of theoretical explanations. The most popular explanation refers to the parallel distributed processing model (Cohen et al., 1990). The model is based on the idea that processing takes place in a system consisting of connected units through activation, which moves along pathways of varying strength. The automaticity of processing also depends on the strength of the path. When receiving a task, the model chooses a path that is activated in one or more modules. Interference occurs if two paths are activated simultaneously, and the activity at their intersection is contradictory, e.g., the word "red" is written in blue. If the activity at the intersection coincides, this leads to easier processing. Attention in this model performs a control function and regulates the operation of the modules. In the Stroop task, information about the color and word meaning goes in two pathways, divided into input units to response units. As a result, one of the modules receives activation exceeding the threshold value and sufficient to produce a response. The attention modules associated with the corresponding task adjust attention by strobing or skipping the flow of information.

Emotional and neutral words are used in the emotional Stroop task (EST) instead of color words. ESE has two main explanations. The first one refers to the mechanism explaining the classical Stroop effect. Emotional information, especially negative, automatically captures attention (Pratto & John, 1991). A participant focuses her attention on the meaning of the word. This induces interference and distracts a participant from performing the main task (recognize and name the color of the word). The time that a participant needs for inhibiting the irrelevant channel causes a delay in the answer.

Algom with co-authors (2004) suggested another explanation named Generic Slowdown. The authors claim that ESE cannot have the same explanation as classical Stroop effect because of the differences in their procedures. There are two matched dimensions in the classical Stroop task, the color, and the meaning (also, color) of a word. These dimensions can be congruent or incongruent. However, we do not have the same situation in EST. According to the Generic Slowdown account, in response to a threatening stimulus, all reactions irrelevant to the threat slow down. This is the reason for a delay in naming the color of a threatening word. The main disadvantage of this theory is that it can be applied only to cases with threatening stimuli and says nothing about ESE with stimuli of different emotional tones. This approach denies the role of selective attention in ESE.

Many researchers follow the explanation of ESE that involves the capture of attention. So, it is important to consider how emotional states influence attention to better understand how moods influence ESE.

Fredrickson's broaden-and-build theory (Fredrickson, 1998) claims that positive emotions broaden the scope of attention, and negative emotions, in contrast, narrow it. Rowe with co-authors (2007) confirmed this prediction. They empirically demonstrated that positive affect makes attention filters broader and suggested that it happens because positive affect weakens inhibitory control. Extrapolating this theory on ESE, it can be expected that the expansion of attention help participant not concentrate on the meaning of the word, inhibit this information, and name the color of the word faster. Therefore, ESE would be smaller in a happy state. Conversely, if positive attention weakens inhibitory control, the results will be the opposite. It is harder to ignore the meaning of an emotional word and to go to the main task. Because of it, a delay in an answer, and ESE will be greater in happiness.

One of the critical theories connected with anxiety and attention is the attentional control theory (ACT; Eysenck et al., 2007). The authors claim that anxiety impedes the work of the goal-directed system of attention and weakens inhibitory control. As a result, attention focuses on the threatening information relative to the general threat (attention becomes narrower). Because of weak attentional control, participants cannot inhibit the meaning of words and "start" to make the main task. Therefore, ESE will be greater in anxiety. In addition, attention focuses on the congruent information, therefore, ESE will be even greater using threatening stimuli.

Studying the influence of mood on attention to emotional stimuli, it is impossible not to consider the phenomenon of emotion congruence. According to this phenomenon, it is easier to process a stimulus if its emotional tone is the same as a person's emotional state. In the opposite case, we can discuss incongruence, which will inhibit the processing. Does ESE depend on emotion congruence? Many studies showed the existence of emotion congruence for samples with affective disorders or stable emotional traits. ESE in depressed people was greater for congruent words (related to depression) compared to maniacal words (Gotlib & McCann, 1984). Mogg with colleagues (1990) induced stress in participants with high and low anxiety. Results showed no connections with anxiety traits, only with stressful states. Participants with higher stress selectively focused on processing threatening stimuli. The authors concluded that trait anxiety does not cause an attention shift to stress words. MacLeod and Rutherford (1992) observed the evidence of emotion congruence in ESE. They tested students with different levels of trait anxiety at the beginning of the semester and before exams. Participants demonstrated similar results when situational anxiety was lower (at the beginning of the semester), but the effect was greater in more anxious students before the exams. All these studies show that we can get the phenomenon of emotion congruence on the material of EST when participants have anxious or depressive disorders or traits.

Another field of research is dedicated to ESE and emotion congruence with induced temporary emotional states. Williams (1996) suggests three possible factors influencing the selective processing of emotional stimuli: emotionality, concern relevance, and mood congruence. Gilboa-Schechtman et al. (2000) tested the suggestion about concern relevance and mood congruence. Results showed that RTs were greater for stimuli with an emotional tone congruent to participants' emotional states. Recent research (Schwager & Rothermund, 2013) demonstrated the opposite results. ESE was greater for stimuli with emotional tones incongruent with participants' emotional states. The authors explain that referring to emotional counter-regulation. According to this theory, attention is automatically redirected to incongruent information to provide balanced processing of emotional information.

Detected controversies about changes in the size of ESE depending on mood and emotion congruence allow us to formulate two hypotheses. The *emotion congruence* hypothesis predicts that emotional Stroop effect will be greater for incongruent stimuli. This hypothesis is based on the suggestions about facilitating the processing of emotionally congruent information (Rusting, 1998). The facilitation leads to faster processing of the meaning of these words. If this process takes less time, the participant names the color of the word faster, and ESE becomes smaller. Conversely, the processing of incongruent stimuli requires more time; therefore, interference and ESE become greater.

The *emotional state* hypothesis predicts that emotional Stroop effect will be greater in anxiety than in happiness regardless of the emotional tone of stimuli. This hypothesis is based on the broaden-and-built theory (Fredrickson, 1998) and Attentional Control Theory (Eysenck et al., 2007). We expect that attention becomes broader in the happy state and will prevent focusing on the irrelevant dimension (word meaning), and color-naming will speed up. In anxiety, attention will focus on threatening stimuli (as predicted by ACT) that will interfere with the main task.

Method

Participants. Eighty-nine participants took part in the experiment aged from 18 to 31 (M = 20.25, SD = 2.69), 60 females, 29 males.

Emotional Stroop Task. The task included 21 neutral, 21 threatening, and 21 happy words. Words were taken from the base ENRuN (Lyusin & Sysoeva, 2017). Threatening words had the highest ratings for the scale "Fear" (Страх), happy words had the highest ratings on the scale "Happiness" (Радость), and neutral words had the lowest ratings on all scales. A fixation cross appeared before each trial for 400 ms. Then a word was presented in the center of the black screen, printed in one of three colors: blue, green, or yellow. Participants responded in which color the word is printed using three different keys on a keyboard. Words of the same valence were presented in one block. These blocks were given three times, so every word was presented in each color. The sequence inside blocks was pseudorandom with one restriction: one color could not be repeated more than twice in a row. PsychoPy v.2020.2.10 was used to present stimuli and response recording (ER and RT) (Peirce et al., 2019).

Mood induction. Three types of music were used for mood induction: «A Man Named Fred Krueger – Steve Jablonsky – A Nightmare on Elm Street – 2010» for anxiety, the backing track of the song «Safe and Sound – Capital Cities – In a Tidal Wave of Mystery – 2013» for happiness. White noise was used for the neutral state. Participants were listening to the music while making the EST. The design was within-subject, every participant took part in all three parts of the experiment with every type of music. The sequence of music types varied across participants.

Mood manipulation check. We used the EmoS-15 questionnaire (Lyusin, 2019) to check the effectiveness of the induction of target emotional states. The questionnaire includes three scales: "Positive affect", "Negative affect" and "Tension". The scales "Tension" and "Positive affect" were mainly used for mood manipulation checks.

Procedure. At the beginning of the experiment, participants estimated their emotional state using EmoS-15. After that, participants were presented with a practice session to learn target buttons. At the end of the practice session, they got feedback on the number of correct responses. If this number was bigger than 29, the experiment continued. If not, a participant took a practice session once again. In the first part, we induced one of the emotional states, happy or anxious, with the help of relevant music. During listening to the music, a participant performed the EST. After that, a participant filled out the EmoS-15 questionnaire. A participant did the same tasks in a neutral state while listening to the white noise in the second part. We induced another emotional state in the third part, anxious or happy. Every experimental part included 189 trials. Participants filled out the EmoS-15 after every part of the experiment. The schema of the experiment is presented in Figure 1.

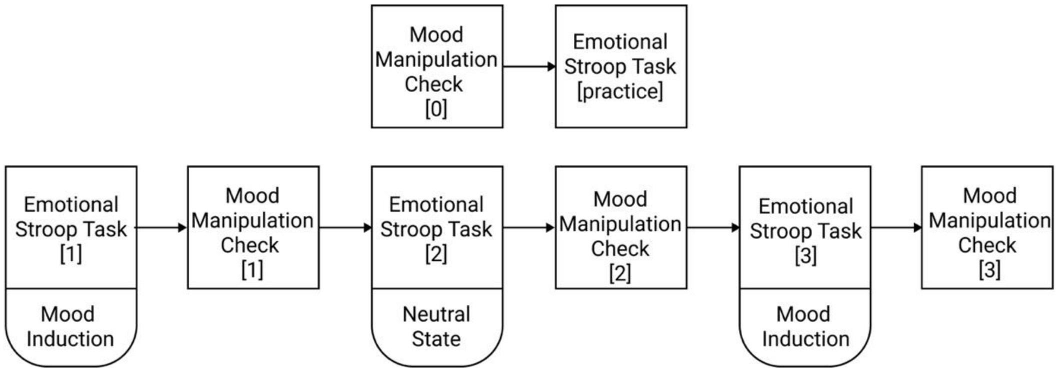

Figure 1. The procedure of the experiment.

Results

Mood manipulation check

We used average scores of the scales "Positive affect" and "Tension" of EmoS-15 to estimate how effective the mood induction procedure was. These scores are shown in Table 1.

Table 1. Mean scores and standard deviations of positive affect and tension after induction of an anxious, happy, and neutral states

Emotional state	**Scale**	
	Positive affect ***M (SD)***	**Tension** ***M (SD)***
Anxious	11.33 (5.03)	13.02 (5.01)
Happy	13.35 (5.21)	10.47 (4.52)
Neutral	11.28 (5.30)	11.57 (4.94)

Repeated measures ANOVA (3 x 2) was used. There were two factors: *emotional state* (anxious, happy, and neutral) and *scale* (Positive affect, Tension). Results for the interaction of the factors ($F(2, 87) = 55.36$, $p < .01$, $\eta_p{}^2 = .05$) show higher scores for the scale "Tension" after anxiety induction and higher scores for the scale "Positive Affect" after happiness induction (Figure 2). Further analysis was implemented using Tukey's HSD. Mean scores for scale "Positive affect" during happiness are greater than during anxiety ($t = 6.16$, $p < .01$) and neutral state ($t = 6.29$, $p < .01$), and mean scores for scale "Tension" during anxiety are greater than during happiness ($t = -7.76$, $p < .01$) and neutral state ($t = 4.41$, $p < .01$). Therefore, the target moods were induced successfully.

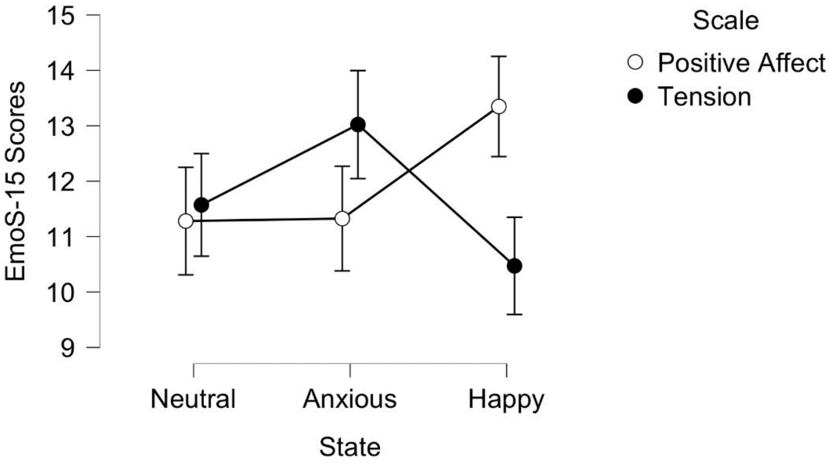

Figure 2. Scores of EmoS-15 scales “Positive Affect” and “Tension” in neutral, anxious, and happy states.

Emotional Stroop Effect

Trials with incorrect responses (3.70%) or RTs with more than three interquartile ranges above the third quartile or more than three interquartile ranges below the first quartile of the response time distribution were excluded from the analysis. Error rates (ERs) were analyzed separately.

Mean RTs and ERs were calculated for each participant in each emotional state (neutral, anxious, and happy) for all types of stimuli (neutral, threatening, and happy). The size of ESE was calculated in two ways: as a difference between mean RTs for emotional (threatening and happy) and neutral stimuli and as a difference between mean ERs for the same types of stimuli. We used paired t-test to evaluate the significance of ESE (Table 2).

Table 2. Size and significance of emotional Stroop effect for RTs (in ms.) and ERs

Emotional state	**Stimuli**					
	Threatening			**Happy**		
	ESE (sd)	Paired t-test	p	ESE (sd)	Paired t-test	p
Reaction Time						
Neutral	24.60* (56.63)	4.09	<.001	22.80 (50.72)	4.24	<.001
Anxious	33.99* (63.45)	5.05	<.001	20.67 (53.40)	3.60	<.001
Happy	35.84* (53.37)	6.33	<.001	26.05 (49.14)	4.99	<.001
Error Rate						
Neutral	0.33 (1.89)	1.64	.10	0.20 (1.17)	0.88	.38
Anxious	0.16 (2.07)	0.72	.48	0.28 (2.02)	1.31	.19
Happy	0.38 (1.94)	1.86	.07	-0.26 (2.25)	0.53	.60

Testing the hypotheses

We used Repeated-Measures ANOVA (2 x2), where the *emotional state* (anxiety and happiness) was the first factor, and the *type of stimuli* (threatening and happy) was the second factor. The size of ESE was a dependent variable.

For RT, the interactions between the factors and the effect of *emotional state* were not significant (*F*s < 1). The effect of *type of stimuli* was significant with ESE greater for threatening stimuli compared to happy ones ($F(1, 88) = 6.14$, $p = .02$, $\eta_p^2 = .07$) (Figure 3).

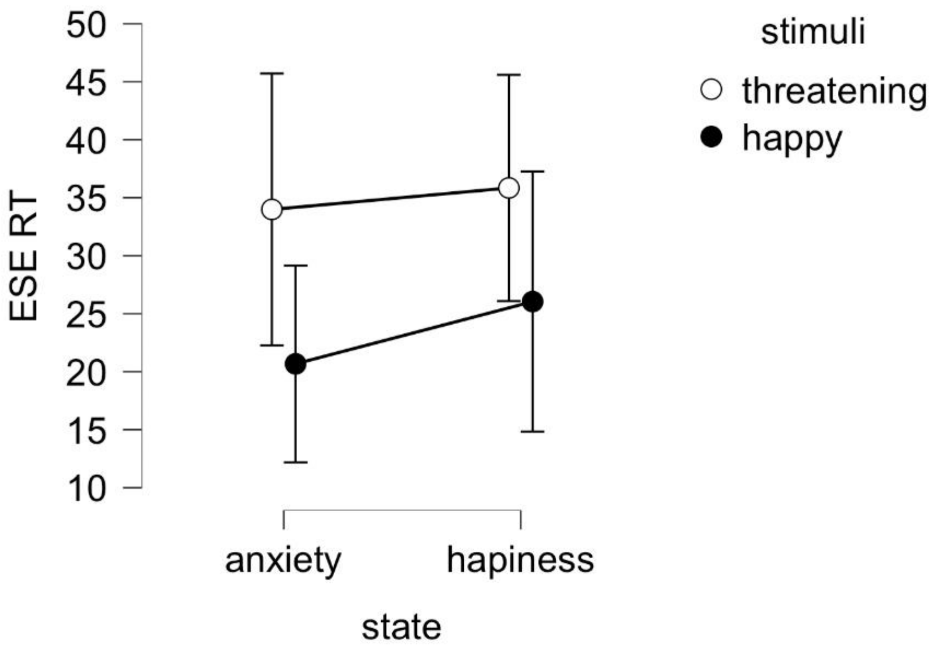

Figure 3. ESE as RTs (ms) in happiness and anxiety

For ERs, the effects of *emotional state* and *type of stimuli* were not significant ($p > 0.1$). The interaction of the factors was not significant ($F(1, 87) = 3.11$, $p = .08$, $\eta_p^2 = .03$) either. Still, we observed that ESE was greater for stimuli whose emotional tone was not congruent to an emotional state.

We assume that the effect did not reach the conventionally significant level because not all subjects were inducted into the target emotional states. For this reason, we selected the subsample (N = 70) with more effective mood induction to test this suggestion. This subsample included participants whose scores on the scale "Positive affect" in happiness were greater than on the scale "Tension" in happiness and whose scores on the scale "Tension" in anxiety were greater than on the scale "Positive affect" in anxiety. Before the comparison, all scores were standardized to make different scales comparable.

The analysis was similar to that conducted on the full sample. Repeated Measures ANOVA (3 x 2) with factors *state* and *scale* of EmoS-15 was conducted for estimation of emotion conduction effectiveness. Results for the interaction of factors (*state* * *scale*) (F (2, 68) = 51.38, *p*

< .01, $\eta_p{}^2$ = .43) show higher scores for the scale "Tension" after anxiety induction and higher scores for the scale "Positive Affect" after happiness induction.

We used Repeated Measures ANOVA (2 x 2) with factors *state* and *type of stimuli* for testing the emotional state hypothesis. The interaction of factors (*state* * *type of stimuli*) (Figure. 4) were not significant neither ($F(1, 68) = 3.47$, $p = .07$, $\eta_p{}^2 = .05$)

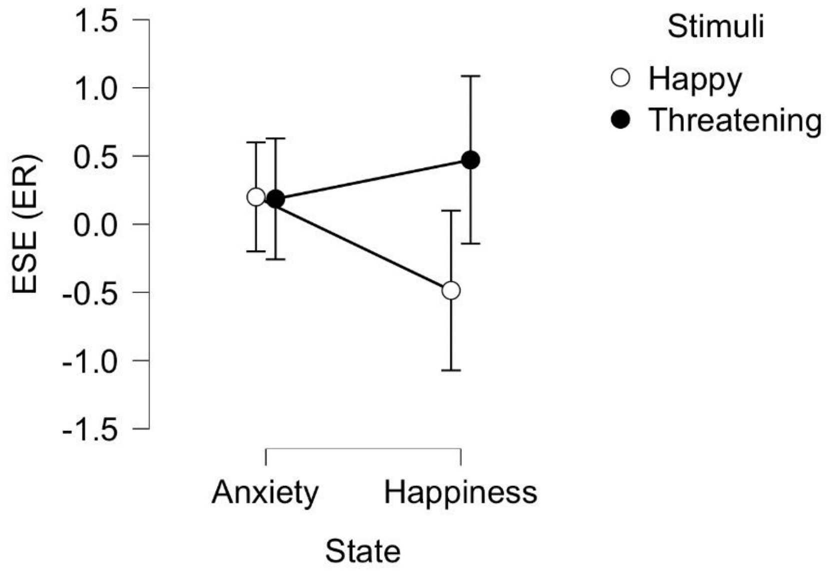

Figure 4. ESE as ERs in happiness and anxiety

Discussion

Target emotional states (happiness and anxiety) were induced successfully. This allowed us to test hypotheses about the influence of emotional states on ESE. Two ways of calculating ESE were used, one based on RTs, and another on ERs.

According to the emotion congruence hypothesis, ESE is greater for stimuli incongruent with participants' emotional states than for congruent stimuli. The interaction of factors *emotional state* and *type of stimuli* was insignificant for ESE assessed by RTs and ERs. ESE assessed by ERs for happy stimuli in anxiety was greater than in happiness, whereas ESE assessed by ERs for threatening stimuli in happiness was greater than in anxiety (Figure 4). These results are similar to recent research (Schwager & Rothermund, 2013), but the authors compared the exact number of mistakes, not the ESE. Unfortunately, the similar analysis of our data did not replicate their results ($F(1, 88) = 1.58$, $p = .21$, $\eta_p{}^2 = .02$).

The subsample with more effective mood induction (the subsample with the highest scores on target scales "Positive affect" and "Tension") showed a greater effect of emotion congruence. Still, it did not reach the conventional level of statistical significance either. Noteworthy, the effect size increased in the subsample with effective mood induction although the subsample was smaller than the complete sample, so the effect size was greater with a smaller sample (.05 vs. .03).

This result suggested that the interaction between the automatic processing of the emotional word meaning, and a person's mood can change the size of ESE. Unfortunately, we did not get direct confirmation of this idea. This can be explained by the low intensity of induced moods.

According to the emotional state hypothesis, ESE is greater in anxiety than in happiness. The absence of differences demonstrates that moods did not influence the size of ESE. One of the possible explanations is that the emotional state cannot influence attention directly as in classical attention tasks (e. g. flanker task, see Finucane, 2011) because stimuli are also emotional and influence the participant's perception (Dresler et al., 2009; Ben-Haim et al., 2014). This hypothesis was based on Fredrikson's broaden-and-built theory and Eysenck's Attentional Control Theory, which predict the influence of happiness and anxiety on attention. These theories may not apply to ESE because of the EST procedure. As we said, there are two dimensions (color and meaning) in EST, and it is unclear how exactly attention is distributed when processing these two dimensions. First, we can assume that if attention is broadened, it is easier to ignore the meaning of the word, because more objects are included in a participant's field of attention, so the delay in completing the task will be less due to the lesser influence of the emotional significance of the word. Or vice versa, due to the broadening of the focus of attention, a person has more cognitive resources to process the word meaning including its emotional component, which will lead to an additional delay in response. Secondly, if anxiety contributes to the direction of attention to threatening stimuli, this will lead to the fact that the subject will be more focused on the meaning of the word and will not be able to distract from it to proceed to the main task, or this may lead to faster processing of the meaning and the ability to distract from it faster and name the color of the word.

In sum, these results show the absence of emotional state influence on ESE. Nevertheless, the effect of emotion congruence was detected, although it was weak and manifested in ER, not RT. The results suggest that the influence of mood on ESE is specific rather than general. This influence depends on the interactions between a perceiver's mood and specific types of emotional stimuli.

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