Title
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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 33(33)

ISSN
1069-7977

Authors
Wichary, Szymon
Rieskamp, Jorg

Publication Date
2011

Peer reviewed

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Szymon Wichary (swichary@swps.edu.pl)
Interdisciplinary Center for Applied Cognitive Studies
Warsaw School of Social Sciences and Humanities
Ul. Chodakowska 19/31, 03-815 Warsaw, Poland
University of Basel, Department of Psychology
Missionsstrasse 62a, 4055, Basel, Switzerland

Jörg Rieskamp (joerg.rieskamp@unibas.ch)
University of Basel, Department of Psychology
Missionsstrasse 62a, 4055, Basel, Switzerland

Abstract

Many models of cognition neglect emotional states that could affect individuals' cognitive processes. The present study explores the effect of emotional stress on people's cognitive processes when making probabilistic inferences. It was hypothesized that emotional stress reduces cognitive capacity, leading to the selection of simple inference strategies. Emotional stress was induced with highly arousing negative pictures briefly presented to participants before they made an inference. Emotional stress influenced the selectivity of participants' information search. Emotionally stressed individuals relied on the importance of the cues to a greater extent than the nonstressed participants. They also spent less time on the least important information. Moreover, the proportion of participants' choices consistent with a simple lexicographic heuristic was higher for the emotionally stressed participants than for the nonstressed participants. The results suggest that people respond adaptively to emotional stress by selecting heuristics that require less information and fewer cognitive operations.

Keywords: emotional stress; information search; inference strategies.

Affect and strategy use

Many theories of cognition treat the human mind as a cold information processor that always performs under the same conditions. In contrast, humans make decisions in varying emotional states (e.g., Schwarz, 2000). Do the cognitive processes underlying people's inferences change when they are emotionally aroused? This is the central question of the present article.

Decision making is influenced by affective states. Isen and Means (1983) showed that people in a mildly positive mood made decisions more quickly, analyzed less information, and therefore seemed to select simpler strategies for making decisions than people in neutral affective states. Luce, Bettman, and Payne (1997) showed that task-related negative emotions, induced by conflict among attributes, led to more extensive information search, but the search was at the same time more selective and more attribute based.

The above studies employed rather mild manipulation of affect. A few other studies looked at more extreme affective states. Mano (1992) showed that participants under social stress (anticipated in-class presentation) employed simpler decision strategies and were more polarized in their decisions. Lewinsohn and Mano (1993) showed that more highly aroused participants, when performing multi-attribute choice tasks, acquired less information and acquired it in a more selective manner, ignoring more attributes than less aroused participants and focusing on the subjectively important attributes. They concluded that "under conditions of extremely high arousal, the decision maker may shift to a very 'thin' processing strategy and could be forced to oversimplify the decision process" (Lewinsohn & Mano, 1993).

The above studies provide evidence that affect influences the selection of decision strategies. However, these studies did not examine directly which strategy was best in predicting participants' choices; instead, strategy selection was inferred from participants' information search behavior. The analysis of information search often does not allow an unequivocal identification of decision strategies, a problem that has been pointed out repeatedly (Luce et al., 1997; Rieskamp & Hoffrage, 2008). Therefore, we think it is important to extend the research on affect and strategy selection by studying participants' information search *and* their actual choices.

Probabilistic inference

In a probabilistic inference task, individuals make an inference about a criterion on the basis of several cues (e.g., Gigerenzer & Goldstein, 1996). For instance, one could infer which of two patients requires more urgent treatment on the basis of several cues such as respiration or heart rate. The cues are only probabilistically related to the criterion, so that a positive cue value makes a positive criterion (e.g., a more precarious physical status) only more likely. Probabilistic inferences require a relatively long sequence of cognitive operations that usually result from the application of cognitive strategies.

Cognitive strategies

The inference task described above can be solved with various inference strategies, like the lexicographic strategy,

elimination by aspects or an additive model (for an overview, see Rieskamp & Hoffrage, 2008). The strategies differ in the amount of information they require to make an inference and the way information is processed. One very simple lexicographic strategy called take-the-best (Gigerenzer & Goldstein, 1996) infers that the alternative with the highest cue value on the cue with the highest validity also has the highest criterion value. If the cue with the highest validity does not discriminate between alternatives, then take-the-best considers the cue with the second highest validity, and so on. An alternative strategy called weighted additive (WADD) integrates the available information; it computes the sum of all cue values multiplied by their cue validity for each alternative. WADD finally selects the alternative with the largest sum. The first strategy, take-the-best, is a strategy that does not integrate any information. It is noncompensatory since the information of cues with high validity cannot be compensated for by cues with lower validity. In contrast, WADD is a compensatory strategy that integrates all information.

Although there are many other strategies that people could apply to make inferences, taken together, take-the-best and WADD often appropriately describe people's inferences (Bröder, 2000; Rieskamp & Otto, 2006). People seem to select WADD more often when they make inferences in a new environment with which they have no experience and where the costs of applying the strategy are low. In contrast, in cases with increased application costs, for instance, due to high monetary costs associated with information search or due to time pressure, take-the-best more suitably predicts people's inferences (Rieskamp & Hoffrage, 2008; Rieskamp & Otto, 2006). Following the approach taken by Rieskamp and Otto (2006), we will concentrate on take-the-best and WADD as two prototypical inference strategies, while being aware that people might use variants of these strategies or even other strategies. It is important to stress that when considering the operations that are necessary to process the strategies and the required amount of information, take-the-best is much simpler than WADD to apply (see also Payne, Bettman, & Johnson, 1993).

Current study

Predictions

The application of inference strategies implies performing elementary cognitive operations (Huber, 1980; Payne et al., 1993). In general, strategy application requires the search for information and the short-term storage and retrieval of information. The application of WADD additionally requires information integration. In contrast, the application of take-the-best does not require the integration of information but rather, only comparison processes. According to the *reduction of the range of cue utilization* hypothesis proposed by Easterbrook (1959), emotional arousal elicited by stressors limits the number of cues used to solve a particular task. Under high emotional stress only the central, or highly relevant cues are retained for use, whereas peripheral, or irrelevant cues are ignored. If high emotional arousal restricts cue utilization, it can be predicted that under emotional stress people will prefer simpler strategies that require less information and do not have to integrate information. Thus, under emotional stress, when compared with no emotional stress, a larger proportion of people's choices should be predictable with the simple lexicographic strategy take-the-best. If people select take-the-best more frequently under emotional stress to make inferences, this will also affect their information search. The application of take-the-best when compared to WADD implies that people will search in general for fewer cues, search for cues in the order of their validity, spend more time on the cues with very high validity, and ignore the less relevant information. Thus, it can be predicted that people under emotional stress, when compared to nonstressed people, should exhibit a more selective information search that focuses on the important cues and ignores the less important cues.

Method

Participants Forty-one participants (33 women) took part in the experiment; they were recruited from first-year students of psychology at Jagiellonian University in Krakow, Poland and took part in the experiment for partial course credit.

Inference task The task was implemented as a computerized information board (Payne, Bettman & Johnson, 1988). The participants' task was to choose the most productive worker from among four job candidates. The participants could acquire information about the candidates by uncovering the cells of a table with six rows and four columns that was presented on a computer screen. This computerized information board was used to allow us to assess information-processing characteristics. The experiment commenced with a training phase of 10 tables and continued with a test phase of 56 tables; each table in the test phase was preceded by a 2-s presentation of a photograph (see *Manipulation of emotional arousal*). The candidates were described with the following cues: conscientiousness, intelligence, initiative, creativity, communication skills, and agreeableness. Cue values were presented as numbers ranging from 1 to 5, 1 indicating a low evaluation of the cue and 5 indicating a high evaluation of the cue. The corresponding cue validities were: 0.82, 0.80, 0.76, 0.69, 0.57, and 0.44. Cue validities are defined as the conditional probabilities of making a correct decision based on the cue, under the condition that the cue discriminates, that is, only one alternative has the highest cue value. The item set (the cue values and validities used as input in the task) used in the test phase was created to allow discrimination between take-the-best and WADD; that is, it included 33 items where take-the-best and WADD made different predictions. The item set additionally allowed

discrimination among other strategies not examined here (see Rieskamp & Hoffrage, 1999).

Manipulation of emotional stress Emotional stress was manipulated between subjects with slides from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1990, 1998) — a slide was presented before each of the 56 tables in the test phase. The content of the pictures was chosen to match the two conditions: 'neutral' (or low arousal) and 'emotional stress' (or high negative arousal). In the neutral condition, the photographs showed different nonarousing objects and scenes. In the emotional stress condition the pictures showed drastic scenes, such as car accidents, victims of these accidents, mutilated bodies and body parts. The content of the pictures in the experimental condition was extreme in order to elicit high arousal as well as to make sure that the effect of the manipulation was present from the beginning of the task. The State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushenne, 1970; Polish adaptation: Sosnowski & Wrześniewski, 1983) was used as a manipulation check to assess anxiety (associated with emotional stress) before and after the experiment.

Procedure The study took place in a cognitive psychology laboratory at Jagiellonian University. Participants were told that the study concerned the effects of affect on decision making and were assigned to the experimental and control conditions by a quasirandom procedure. Participants assigned to the experimental condition were told that they would see unpleasant pictures and that they could quit the experiment at any time. After entering the laboratory, participants completed the state and trait anxiety inventory. Following that, they read the instructions for the inference task and completed the task. Afterward, participants filled out the state and trait anxiety inventory for a second time. At the end, a debriefing session followed, aimed at explaining the purpose of the study and the experimental manipulations. In addition, some weeks after the completion of the study, the participants were again invited to attend an additional information session, in which the purpose of the study was described again and the results of the study were explained.

Results

Manipulation check Overall, the manipulation of emotional stress with IAPS slides was effective, as indicated by the scores on the state anxiety scale administered before and after the inference task. Participants who saw the negative emotionally arousing pictures had an average anxiety scores of 34.1 (SD = 5.89) before the experiment, which increased to an average score of 48.1 (SD = 9.87) after the experiment. Participants in the neutral condition experienced on average a similar state anxiety before (with a score of 35, SD = 10.02) and after (with a score of 36.4, SD = 6.91) the experiment. A repeated-measures analysis of variance (ANOVA) revealed a significant interaction effect of the between-subjects stress manipulation and the time of measurement of state anxiety (pretest vs. posttest), $F(1,39) = 15.1$, $p < .001$. Although the manipulation was on average successful, there was a large variance, so that some participants did not have higher or had only slightly increased anxiety scores after the experiment. For this reason, we decided to exclude the five participants in the emotional stress condition for whom the posttest–pretest difference in anxiety score was smaller than 8 points. This guaranteed that for all participants left in the emotional stress condition, the emotion manipulation had a large effect, according to Cohen's classification (Cohen, 1988). We also checked that the experimental and control groups were not significantly different in terms of gender composition, to rule out the possibility that the difference in anxiety scores between the two groups was due to different emotional reactivity of males and females.

Information search analysis The predecisional information search was characterized by (1) variables describing the general amount of search: the average time a participant spent on a decision, the average number of information boxes opened, the average time these boxes remained open, and (2) variables describing the selectivity of search, that is, the focus on particular pieces of information: the proportion of time spent on the most important cue and on the least important cue out of the total time spent on all cues, and the correlation between the time spent on cues and their validities. The results for the search variables were aggregated across four blocks of 14 items each, to enable the analysis of change in strategy selection across trials. A series of repeated-measures ANOVAs was conducted with trial block as a within-subject factor, emotional stress as a between-subjects factor, and the search characteristics as dependent variables.

Emotional stress influenced the behavior on the inference task. The differences between the emotional and neutral condition were in how the information search was organized. In the emotional stress condition, the information search was strongly influenced by the information about the cue validities. In this condition, the correlation of time spent on cues and their validities was relatively high for the whole task, right from the beginning (r ranging from .57 in the first block to .6 in the last block). This contrasted with the behavior of the participants in the neutral condition, for whom this correlation was much lower in the beginning of the task (r = .35 in the first block) but steadily rose toward the end of the task (r = .56 in the last block). Figure 1 illustrates the Block × Emotional Stress interaction, $F(3,102) = 4.51$, $p = .005$. For the analyses, the original Pearson correlation was transformed with Fisher's Z-transformation; for presentation in the paper the original correlations are used.

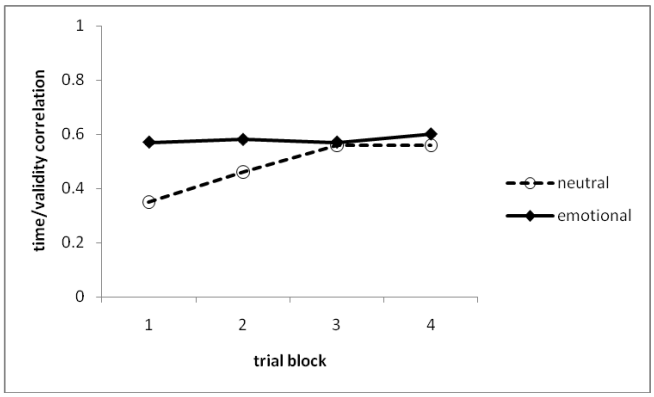

Figure 1: The correlation between time spent on cues and cue validities across the four blocks and the two experimental conditions.

The above effect can be further understood by analyzing the time devoted to the analysis of particular cues. In the emotional stress condition, the time devoted to the least important cue was consistently low from the beginning to the end of the task (from 5.2% in the first block to 5.8% in the last block). This contrasted with participants' behavior in the neutral condition, where they initially devoted relatively much time to the analysis of the least important cue (11.6% in the first block) and steadily decreased this time across the task (7.4% in the last block). Figure 2 illustrates the Block × Emotional Stress interaction, $F(3,102) = 3.45$, $p = .017$.

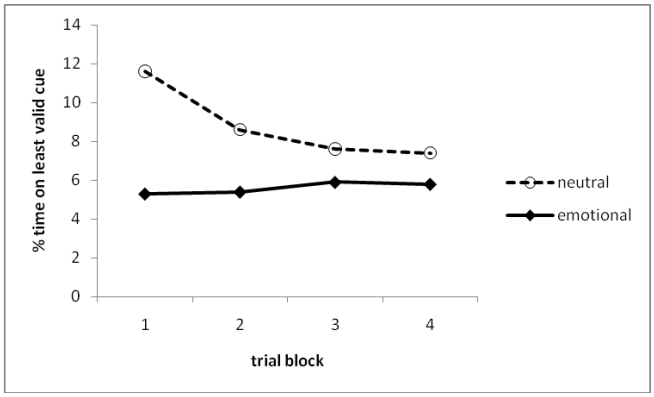

Figure 2: Proportion of time spent on the least valid cue across the four blocks and the two experimental conditions.

The proportion of time devoted to the most valid cue was high across the whole task, in both conditions. In the neutral condition, this proportion was slightly lower in the beginning and rose from about 22.5% in the first block to 25.5% in the last block, but this effect was not statistically significant. In the emotional stress condition, the proportion of time spent on the best cue remained consistently high across the task (about 30%).

In contrast to variables describing the selectivity of search, the variables characterizing the general amount of search were not affected by emotional stress. The only result concerning these variables was the effect of block. The total decision time and the average time of looking at the cues decreased across the four trial blocks, $F(3,102) = 10.85$, $p < .001$ and $F(3,102) = 43.68$, $p < .001$, respectively. The number of acquisitions differed across the four blocks, $F(3,102) = 7.32$, $p < .001$, with the highest value in the second block of trials.

Outcome analysis In addition to the information search analysis, we analyzed participants' actual choices. First, we determined the percentages of predicted inferences using the two strategies WADD and take-the-best across all participants and across all four trial blocks. Across all trials, WADD predicted 57% of all choices compared to take-the-best, which predicted 49% of all choices. Thus, both strategies did better than chance (i.e., 25%) in predicting participants' choices, and on average WADD was better than take-the-best at predicting the inferences. However, the success of the strategies in predicting participants' choices depended on the experimental condition.

To analyze this, we first conducted two repeated-measures ANOVAs, with the proportion of choices predicted by WADD and take-the-best as the dependent variables, and the trial block as a within-subject factor and emotional stress as a between-subjects factor. Emotional stress influenced the proportion of choices consistent with the take-the-best strategy. In the first half of the experiment, participants' choices under emotional stress were more consistent with take-the-best as compared to the choices of nonstressed participants. In the second half, take-the-best predicted a similar proportion of both stressed and nonstressed participants' choices. Figure 3 illustrates the Block × Emotional Stress interaction, $F(3,102) = 2.89$, $p = .039$.

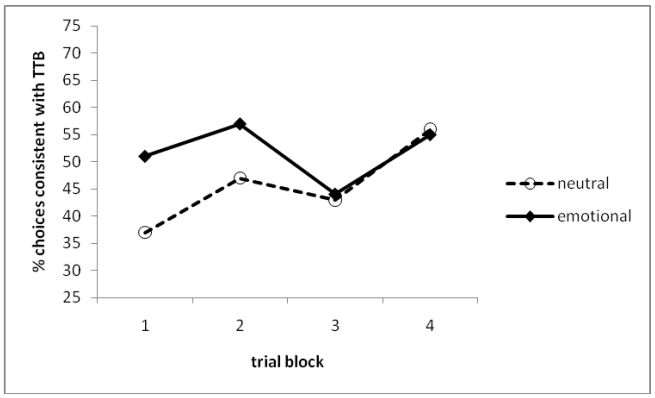

Figure 3: Proportion of choices consistent with take-the-best (TTB) across the four blocks and the two experimental conditions.

In contrast, emotional stress did not influence the proportion of choices predicted by WADD—for this strategy, the only effect was an increase in the proportion of predicted choices across the four blocks (from 49.5% in the first block to 66% in the last block); the main effect of block, $F(3,102) = 10.36$, $p < .001$.

The above effect of emotional stress on the proportion of choices consistent with take-the-best is in line with the results of the information search analysis. Although the process and outcome variables are conceptually different, we observed high consistency of process and outcome measures; that is, we observed correlations between the variables describing the selectivity of search and the proportion of choices predicted by take-the-best (Table 1). Moreover, the pattern of correlations across the two experimental conditions was informative. In the emotional stress condition, the correlation between the proportion of time spent on the worst cue and the proportion of choices consistent with take-the-best was high and negative ($r = -.63$). In the neutral condition, no such correlation was observed. This shows that under emotional stress, the choices consistent with take-the-best are associated with ignoring the least valid cue during information search.

Table 1: Correlations of outcome and process measures.

	Condition	Process measure		
		T/V cor.	Best cue	Worst cue
TTB	Neutral	0.57*	0.85**	-0.26
	Emotional	0.69**	0.85**	-0.63*

TTB = proportion of choices consistent with take-the-best; T/V cor. = correlation between time spent on cues and cue validities; Best cue = proportion of time spent on the most valid cue; Worst cue = proportion of time spent on the least valid cue

*p<.05, **p<.01

Furthermore, we determined the strategy that was best in predicting each participant's choices across the whole task. For example, if WADD predicted 70% of a participant's choices and take-the-best predicted 30% of this participant's choices, then this participant was classified as a WADD user. In case of a tie between WADD and take-the-best, the participant was "partitioned" between WADD and TTB (each strategy received 0.5 points). In the neutral condition, the proportion of participants classified as WADD users was higher than the proportion of take-the-best users (72% vs. 28%, respectively), whereas in the emotional stress condition, the proportions of participants using WADD and take-the-best were equal (Figure 4). This shows that under emotional stress a substantial proportion of participants used the simple lexicographic strategy, so that take-the-best was as good as WADD in predicting participants' choices.

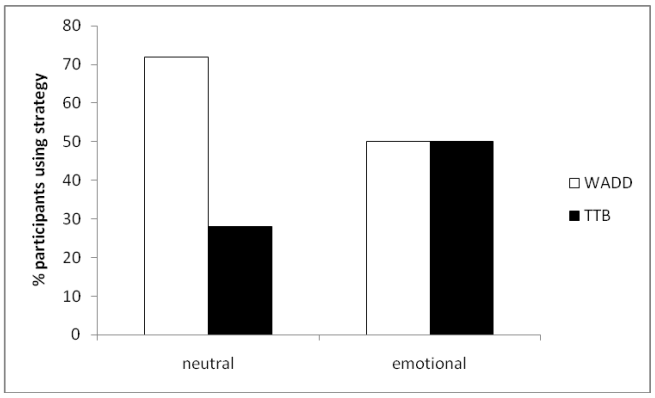

Figure 4: Proportion of participants classified as WADD and take-the-best (TTB) users across the two experimental conditions.

Discussion

The central question of this article was whether the cognitive processes underlying people's inferences are affected by emotional stress. The present study shows that emotional stress does affect information processing and strategy selection in a probabilistic inference task. Under emotional stress, information search is largely organized by cue validities, consistently across the whole task. In contrast, under no stress, information search is initially influenced by cue validities only to a small degree, which increases across the task, presumably due to learning. Furthermore, under emotional stress, the least important information is largely ignored, consistently across the whole task. Under no stress, however, the least important information is initially analyzed to a considerable extent, which decreases across the task. The results of the process analysis were consistent with the results of the outcome analysis. The outcome analysis showed that the simple, noncompensatory strategy take-the-best was selected more frequently under emotional stress than under no stress, at least in the first half of the experiment.

The present results support the hypothesis of the reduction in the range of cue utilization under emotional arousal (Easterbrook, 1959). They are also in line with a similar idea proposed by Ben Zur and Breznitz (1981), namely, the filtration mechanism, according to which decision makers only process a subset of the available information to cope with a stressful, time-pressed situation. One puzzling result is that the difference between stressed and non-stressed individuals diminished across the task due to the change of behavior by the non-stressed individuals. We think that this reflects the interplay between exploration and exploitation of the environment during information search. Participants under emotional stress exploited the environment to make efficient use of the available information, by focusing attention on the important cues and ignoring the unimportant ones. On the other hand, the non-stressed participants initially explored the environment, in order to

learn the contingencies of the task, and then, based on learning, gradually focused attention on the more important cues and ignored the less important ones.

Our results are consistent with other findings on affect and decision making (e.g., Lewinsohn & Mano, 1993; Mano, 1992). Especially, Lewinsohn and Mano (1993) showed that relatively high arousal leads to a selective processing of information by focusing on the more important attributes and ignoring others. Also, Luce et al. (1997) showed that increased negative emotions lead to more focused information processing, particularly at the beginning of the decision process.

We go beyond the previous studies by not only examining participants' information search or their final choices, but by performing a process and an outcome analysis together. Previous studies only indirectly inferred that people select simpler decision strategies under emotional stress (e.g., Mano, 1992). The conclusions we draw from our two analyses are consistent with each other. The results suggest that people under emotional stress select the strategy that is easier to execute, namely, the lexicographic strategy take-the-best, more often than nonstressed people, and the use of this strategy is associated with ignoring less important information. In line with previous research (e.g., Bröder, 2003; Payne et al., 1993; Rieskamp & Hoffrage, 1999, 2008; Rieskamp & Otto, 2006), these results show that people select strategies adaptively depending on the characteristics of the inference situation.

Acknowledgments

This work was supported by research grant no. N N106 219338 from the Polish Ministry of Science and Higher Education to Szymon Wichary and by Swiss Sciex-NMS grant no. 09-083-1 to Szymon Wichary and Jörg Rieskamp.

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