

Anxiety fosters relational encoding

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Abstract

This paper presents an experimental study of the influence of state-anxiety on relational encoding. It demonstrates that induced state anxiety enhances encoding of relations. Participants in the anxiety group were faster and more accurate in recognizing identical relations in two successive stimuli than the participants in the non-anxiety group.

Introduction

About 10 years ago, Tohill and Holyoak (2000) made an important point. They suggested that analogy-making could be considered as an important mechanism for managing anxiety-inducing situations. Their arguments were the following: state-anxiety is usually triggered by “novel, poorly understood and problematic” situations, but exactly such situations are the kingdom of analogies, since analogies are considered as the most useful tool for gaining decisions in novel situations (i.e. situations where people do not have ready strategies or rules for appropriate and successful behaviors). Therefore it is crucial to understand how anxiety state modulates the analogy-making performance.

The present study is trying to shed light on the link between anxiety and analogies by arguing that state-anxiety facilitates encoding of relations between superficially distinct structures, which in turn reinforces analogy-making.

Anxiety, Cognitive processes and Analogy-Making

Traditionally it was assumed that anxiety's function is to mobilize the resources of the cognitive system in the search of an adequate reaction toward an anticipated future danger. The seminal work of Eysenck and Calvo (1992) on processing efficiency theory and its follow up extension, i.e. the attentional control theory (Eysenck, Derakshan, Santos & Calvo, 2007) assumes accordingly that anxiety diverts attention toward threatening or threatening-related stimuli. Indeed, behavioral studies showed more efficient visual search for threatening targets than for non-threatening ones (Eastwood, Smilek, & Merikle, 2001; Ohman, Flykt, & Esteves, 2001) and rapid shift of attention toward threatening stimuli (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; Smith, Most, Newsome, & Zald, 2006).

It seems, however, that the picture is not so simple, because at the presence of threatening stimuli people became faster also in visual search for non-threatening

stimuli (Becker, 2009) and overall their contrast sensitivity increases in a contrast-discrimination task (Phelps, Ling, and Carrasco, 2006). Moreover, recent neuroimaging data also favor the hypothesis that state-anxiety facilitates the processing of incoming information in general via two attentional networks: the alerting and orienting network (Pacheco-Unguetti, Acosta, Callejas, Lupianez, 2010). The alerting network maintains the sensitivity level needed for perceiving and processing stimuli. It is associated with the right frontal and parietal brain areas. The orienting network guides the selection of information among perceived stimuli. It is associated with the superior parietal lobe, frontal eye fields, and temporoparietal junction. This was not the case with trait-anxiety that seems to enhance mainly the work of the third attentional network – the executive control network that is responsible for conflict resolution and voluntary action control and is associated with midline frontal areas, anterior cingulate gyrus, and lateral prefrontal cortex. Importantly with respect to the current discussion, the study of Pacheco-Unguetti, Acosta, Callejas, Lupianez (2010) suggests that state-anxiety may make people “more sensitive to bottom-up processing”, i.e. bottom-up processing of both treat-related and treat-unrelated stimuli.

This processing advantage under state-anxiety seems, however, to have a high cost. It was found that anxiety impedes free recall and memory span (Mueller, 1977, MacLeod, & Donnellan, 1993), learning and memory (Eysenck, 1979, 1985), deductive reasoning (Blanchette & Campbell, 2005, Blanchette & Richards, 2004, Blanchette, Richards, Melnyk, Lavda, 2007, Darke, 1988, Oaksford, Morris, Grainger, & Williams, 1996), decision-making (Keinan, G. (1987) and problem solving (Klein & Barnes, 1994). In other words, anxiety tax cognitive resources and handicaps performance on a wide range of cognitive tasks, including the performance on tasks that require analogy-making.

Leon and Revelle (1985) reported lower completion accuracy for geometric analogies when people were high in state-anxiety, measured with *State-Trait Anxiety Inventory* (STIA) (Spielberger, C.D., Gorsuch, R.L., & Lushene, R., 1970). Tohill and Holyoak (2000) also showed that induced state-anxiety made people less likely to use relational-based mappings in a cross-mapping task. Based on these studies, it was assumed that state-anxiety impedes analogy-making by reducing the available working memory resources.

Recently, however, several studies imply the opposite effect of induced state-anxiety. Feldman, Hristova and Kokinov (2010) found high proportion of relational choices in a simple match-to-sample task where both the relational and the attribution mappings were possible. If we consider the match-to-sample task as a simple version of analogy-making task, the straightforward conclusion would be that state-anxiety gives an important priority of processing information that concerns relations. Hence, instead of arguing that anxiety impedes analogy-making it seems reasonable to conclude, based on Feldman's et al (2010) findings that anxiety enhances analogical reasoning.

The authors speculated that the inconsistency between their results with respect to the role of anxiety on analogy-making and the results reported by Tohill and Holyoak (2000) can be explained either by a thorough analysis of the two tasks for analogy-making used in these studies or by difference of the obtained levels of induced state-anxiety.

The state-anxiety was induced by different procedures in both studies. Feldman et al (2010) used the "public speech" procedure which was used successfully to induce state anxiety in a number of other studies (Graeffl, Parente, Del-Ben, Guimarães, 2003; Pertaub, Slater & Barker, 2002; Feldman & Kokinov, 2009). Participants in the anxiety group were left to believe that they will be asked to make a presentation in favour of a specific claim within 5 minutes. They also thought that their presentation will be video-recorded and their communication skills will be evaluated based in their performance. Tohill and Holyoak (2000) used the backward counting task (Sgoutas-Emch et al., 1994; White & Yee, 1997). Participants in the anxious group were asked to count aloud backwards from 1000 in decrement of 13 for 45 seconds. Hence, anxiety induced by these two procedures may differ in intensity and consequently may influence performance on the same task differently with respect to the classical Yerkes-Dodson law (1908), i.e. higher anxiety may impede analogies but lower one may facilitate it.

An alternative explanation would be that the analogy-making task (the cross-mapping task vs. the match-to-sample task) differed in a number of specific ways between the two studies. The close inspection showed that not only the complexity of both task but also the procedures of presenting these tasks made possible anxiety to influence different subprocesses of analogy-making (i.e. encoding, forming hypotheses of possible correspondences, and competition between them¹). Tohill and Holyoak (2000) gave 15 seconds to the participants for observing the target

¹ Most of the models of analogy-making like ARCS (Holyoak & Thagard, 1989), AMBR (Kokinov, 1994, Kokinov & Petrov, 2001), CopyCat and TableTop (Hofstadter, 1995), LISA (Hummel & Holyoak, 1997) agree for these 3 subprocesses of analogy-making: perceiving (encoding) the relations, forming hypotheses of possible correspondences, and competition between them (constraint satisfaction). SME (Gentner, 1983, Falkenhainer, Forbus, Gentner, 1989) assumes alternative but analogous subprocesses.

pictures and then asked them to point the corresponding object of a hinted one. Hence, participants were able to encode all the necessary relations and possibly to build hypothesis for correspondence prior to the pointing and then start the constraint satisfaction and answer. Participants in the Feldman et al (2010) study received the base and the two possible targets at once and were asked to answer as fast and as accurate as possible. The average RT in this experiment was 4 seconds. Thus Feldman and colleges (Feldman et al., 2010) have argued that the anxiety state most probably has influenced the relational encoding in their experiment rather than the final competition between the hypothesis for correspondence in the Tohill and Holyoak's study (2000). Feldman et al. discussed this possibility with respect to the Pacheco-Unguetti, Acosta, Callejas, Lupianez (2010) findings for change in the alerting and orienting attention network under state anxiety. They argued that anxiety in their study may have influenced the relational encoding by changing these two attention networks, while it probably influenced only the executive control network in the Tohill and Holyoak study (2000), since there participants were given enough time to encode all relations.

The present research aims to test the suggested possibility for enhanced relational encoding under state anxiety.

Experiment

The match-to-sample task used in Feldman et al (2010) was replaced in order to focus on the relational encoding only: participants first saw the base stimulus and were allowed to encode all possible relations, subsequently just one of the targets was presented (i.e. either the attribution or the relational match) and participants were asked to indicate whether it contains the same relations as the ones in the base. Anxiety was induced by the backward counting procedure used by Tohill and Holyoak (2000) and was measured by the STAI (Spielberger, C.D., Gorsuch, R.L., & Lushene, R., 1970). In this manner we hoped to investigate the hypothesis of speeded relational encoding under state-anxiety, while controlling for anxiety intensity. If participants with high state-anxiety, induced by the backward counting procedure, would be faster in recognizing the base relations within the target, we would conclude that anxiety might enhance the encoding stage of analogy-making.

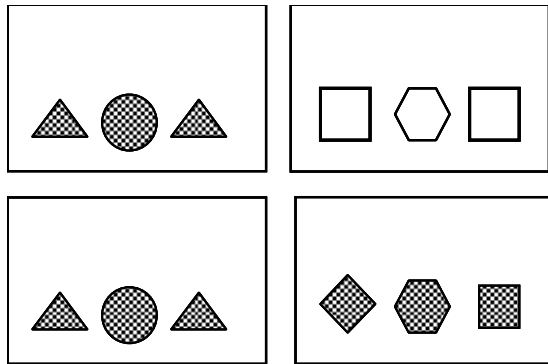
Design

The independent variable was state anxiety and it was varied between subjects. The dependent variables were: the number of correct relational identifications and the response time.

Stimuli

The 22 stimuli used by Feldman et al (2010) were divided in such a way that each base (B) was coupled with each target stimulus (i.e., T1 or T2, respectively). In this manner we obtained 44 stimulus pairs comprised of one base and of one target stimulus. Hence, half of the pairs were relationally similar and the other half – attributionally similar. Example of one of the original stimuli used in the match-to-sample task

by Feldman et al (2010) and the resulting stimulus pairs, used in this experiment are presented in Figure 1. As you see each base stimulus was presented with either the relational (i.e., the first pair in Figure1) or the attributional (i.e., the second pair in Figure1) match. The order of presentation of the relational and attributional stimuli was randomized within subject and across participants.



The first stimulus pair contains identical relations (i.e. similar transformation of geometric figures with the same color), while the second one - contains identical attributes (i.e. texture) but not identical transformation

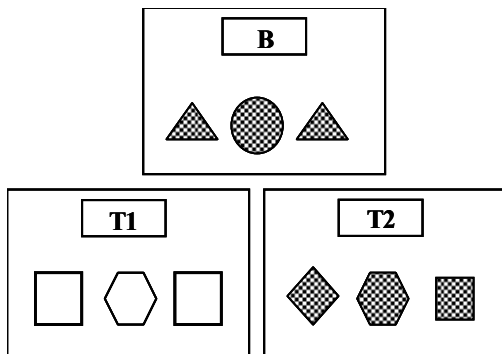


Figure 1. One of the original stimuli used for the match-to-sample task in Feldman et al, (2010) and the resulting stimulus pairs for this experiment.

Procedure

Anxiety manipulation

The experiment was run individually. Participants were randomly assigned to one of the two conditions in the experiment. Those who were assigned to the experimental condition performed the serial subtraction task first, which successfully induce anxiety in a number of experiments (Tohill and Holyoak , 2000; Sgoutas-Emch et al., 1994; White & Yee, 1997). Participants were asked to count aloud

backward from 1000, 970 or 950² in increments of 13 for 45 seconds. One experimenter corrected any mistakes, while a second experimenter urges participants to count backward faster because the predetermined time passes out. After 45 seconds, experimenter informs participants that the same counting backward task would be repeated at the end of the experiment.

In non-anxious group participants started the main experiment without any additional tasks.

The procedure for the remaining part of the experiment was identical for both groups.

Relation encoding task

Participants' task was to indicate by pressing the respective button, whether the second stimulus share the same relations as the first one within a given trial. The left button on the BBOX was for "yes" answer, the right – for "no" answer.

The timing of events in the experiment is illustrated on Figure2. First, black fixation cross on light gray background appeared on the screen for 2000ms. Then the base stimulus was presented for 5000ms, followed automatically by a mask. The screen was left blank for 1000ms. , then the target stimulus was presented until participants have not pressed the respective button on the BBOX. The time window for answering was fixed to 5000msec³. If participant did not answer, however, the mask appeared and the next trial began.

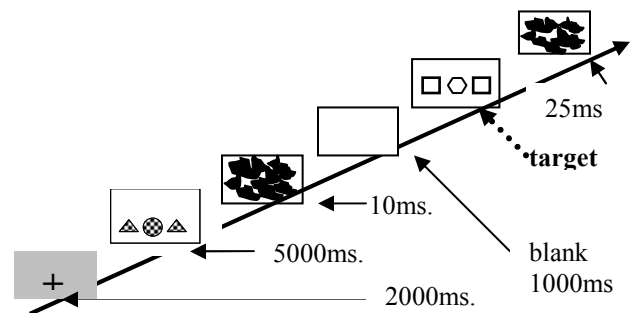


Figure2. Stimulus displays and the timing of events

Manipulation check

At the end of the experiment participants were asked to fill in the Bulgarian adapted version of Spielberger's, *State-Trait Anxiety Inventory* (STIA) (Щетински, Паспаланов, 1989) and were fully debriefed.

² The beginning was randomly assigned to each participant in the anxious group.

³ It seems that the time window was long enough for all participants and trials, since we didn't obtain missing values.

Participants

39 students (24 female and 15 male) from New Bulgarian University took part in the experiment in order to satisfy a course requirement⁴. The mean age was 23 years within the range between 19 and 33 years.

Results and Discussion

Manipulation check

The mean *STAI state-anxiety* scores were higher for the anxious (41.32) than for the non-anxious group (36.85) and the difference between the two groups was estimated as marginally significant: $F(1,38)=3.932$, $p=0.05$, while the mean *STAI trait-anxiety* scores did not differ significantly ($F(1,38)=0.002$, $p=0.962$) between anxious (40.63) and non-anxious (40.50) group. This is what we were aiming at.

It turned out that the obtained difference (4.47) between the state-anxiety score for anxious and non-anxious group was lower than the one reported by Tohill and Holyoak (2000) with the same procedure (i.e. 10.3 (experiment1) and 9.2 (experiment2)). The measured state-anxiety for our control group turned to be higher. Possibly, the main reason for this discrepancy between our and Tohill and Holyoak study (2000) is due to the fact that participants in our non-anxious condition did not count forward (beginning at 1 for 45 sec at a pace that felt relaxed for them) and hence did not receive the chance to relax at the begging of the experiment. However, even though our control participants entered the study more anxious than participants in the analogous group of Tohill and Holyoak (2000) we still obtained a shift in the *STAI state-anxiety* score. That is why, we interpreted these results as supporting the successfulness of our anxiety manipulation and assumed that any possible differences, if we find such at all, between relational encoding of anxious and non-anxious group can be dedicated to the induced anxiety.

The impact of anxiety on encoding of relation

The main goal of this research was to investigate the possibility for faster encoding of relations under anxiety. We hypothesized that participants in Feldman et al (2010) study actually made higher percentage of relational mapping because they were able to encode faster the important relations between and within stimuli. We expected that anxious participants will be more accurate in determining whether the two subsequent stimuli share the same relation.

Participants in the anxiety group accurately recognized 87% of the relational matches, while participants in the non-anxiety group – only 79%. This difference between the accuracy level of relation encoding turned to be significant: $F(1,38) = 7.432$, $p=0.010$. Participants with higher state-anxiety demonstrated higher abilities to detect and recognize similar relations (Figure3).

The effect of anxiety on the proportion of identified relations was obtained at the background of faster RT in anxious group, i.e. anxious participants were faster at recognizing accurately the identical relations embedded in two subsequent stimuli. The RT of relational matches for

anxious group was 1620.9ms., while for non-anxious group was 1944.3ms. This difference was statistically significant: $F(1,38) = 9.902$, $p=0.03$ (Figure4). Thus, anxious participants were not only able to accurately identify the perceived relations but also to find them faster.

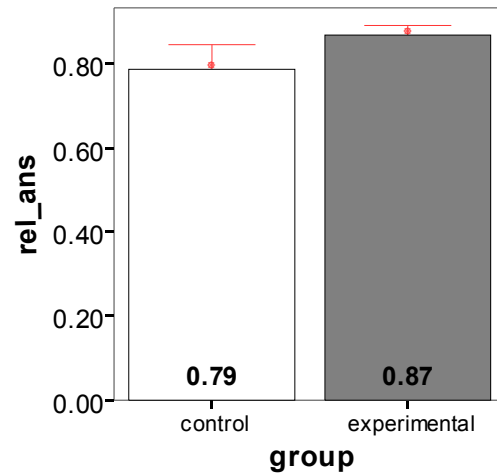


Figure 3. Mean proportion of relational matches found in anxious (gray bar) and in non-anxious (white bar) group. Error bars represent the 95% confidence interval for the mean.

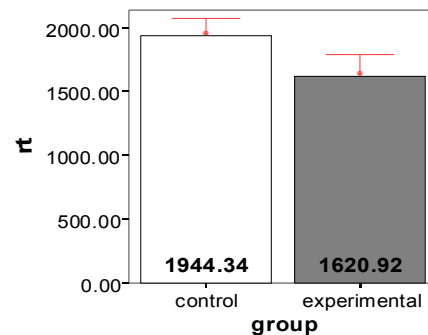


Figure 4. Mean RT for indicating the relational matches between two subsequent stimuli for anxious (gray bar) and non-anxious (white bar) group. Error bars represent the 95% Confidence intervals for the mean.

Conclusion

This experiment demonstrates that people in an anxiety state are more sensitive to relations regardless of their irrelevance to the source of anxiety. This finding, combined with the data of Feldman et al (2010) allows us to argue that

⁴ Initially the experiment was run on 40 students but one of them was excluded from further analyses because E-prime failed to record his data.

state-anxiety leads to a specific profile of information processing. It seems that anxiety facilitates the encoding of relations and thus finding possible analogies between superficially distinct and relationally similar structures.

This doesn't mean however, that people under anxiety become better analogical reasoners. Possibly, state anxiety facilitates only encoding of relations and hypothesis formation between superficially distinct entities, but hinders the subsequent competition between those hypotheses as we have already argued (Feldman et al, 2010). Indeed, the careful comparison between Feldman et al (2010) and Tohill and Holyoak (2000) studies suggests that performance on complex tasks that either contain more relations or require much more difficult competition (i.e. competition between several meaningful hypotheses for correspondences) may be deteriorated by anxious situations.

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