Does pupil dilation indicate cognitive dissonance and strength of attitude change?

Replicating the spreading of alternatives effect in a blind-choice task.

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ABSTRACT

The aim of the present research was twofold. First, we aimed to replicate a recent study by Sharot et al. (2010), which found evidence for the spreading of alternatives (SOA) effect. Second, we investigated the hypothesis that cognitive dissonance, which may explain an existing SOA effect, is accompanied by significant changes in pupil diameter. Our results provide neither support for this hypothesis nor do they replicate the SOA effect. We conclude that more research is needed to investigate the SOA effect and call for deploying more suitable experimental paradigms to investigate the link between cognitive dissonance states and pupillary changes.

Keywords

Cognitive dissonance, arousal states, spreading of alternatives, attitude change, preferences, pupillometry

INTRODUCTION

In 1956, a new line of research on attitude change emerged when a classic experiment found that making choices between similarly attractive options can alter subsequent preferences toward those options (Brehm, 1956). The *free-choice paradigm* was the typical experimental procedure used in choice-induced attitude change research. It usually starts with participants rating a set of stimuli according to how much they like them. Participants then choose between stimuli for which they previously indicated identical ratings. Lastly, the first rating task for the stimuli is repeated. Past research typically showed rating differences between the first and the second rating both for chosen and rejected items. Specifically, people increase their preference toward chosen options and decrease their preference toward rejected options, called *spreading of alternatives (SOA).* However, more recent articles (e.g. Chen & Risen, 2010) pointed out a shortcoming of the free-choice paradigm. The problem is that rating differences for initially similarly rated stimuli may only reveal true preference instead of preference change. That is, two stimuli rated identically in the pre-choice task may actually have different underlying true preferences, which the rating task does not capture. Consequently, the observed spreading of alternatives could occur without actual preference change, challenging 50 years of attitude change research.

A recent experiment by Sharot et al. (2010) attempted to clarify whether the SOA effect holds up to experimental procedures free of the shortcoming associated with the *free-choice paradigm.* Therefore, the authors adopted a *blind-choice paradigm*, which started by flashing two stimuli on the left and the right side of the computer screen simultaneously. Participants assumed that the stimuli were two previously rated holiday destinations although the computer presented random strings of symbols that were masked after a very brief time. When the stimuli disappeared, participants chose their preferred option by pressing a button assigned to either the left or right stimulus. However, participants did not know that the subsequently revealed holiday destinations were generated only following their choice. A star appeared above the stimuli that participants believed to have chosen themselves. The blind-choice task was both preceded and followed by a rating task of the presented stimuli, in which participants indicated their preference toward every stimulus. That is, the authors let the participants estimate how happy they would be to vacate at several holiday destinations. The purpose of the blind choice-task was to test whether deceiving participants into believing that they made a choice between previously identically rated options would cause SOA. The result of this study showed that choices indeed influence subsequent preferences. More specifically, the authors found that selected stimuli increased significantly in their subsequent ratings (t (20) = 2.4, p < .03), whereas no significant decrease in ratings appeared for rejected stimuli (p > .9). Sharot et al. (2010) explained the observed SOA in light of both self-perception theory (Bem, 1967) and cognitive dissonance theory (Festinger, 1957; cited in Sharot, Velasquez, & Dolan, 2010). Bem's self-perception theory suggests that people only learn about their preferences in the process of acting them out. That is, people may observe their choices first and shape their preferences accordingly. In contrast, Festinger's theory of cognitive dissonance proposes that people facing decisions between options with identical preferences experience psychological tension, which motivates them to change their attitudes. Thus, people may reduce dissonance by lowering their preference toward the rejected option and increasing their preference toward the chosen option.

Psychological tension due to such inconsistencies seems to be accompanied by physiological arousal. For example, early studies found that participants who wrote counter-attitudinal essays under the condition of having much freedom to choose their topic showed heightened galvanic skin responses and increased attitude change (Croyle & Cooper, 1983). The experience of dissonance has been described as an unpleasant motivational state characterized by heightened electrodermal activity (Harmon-Jones, 2000), vasoconstriction and increased heart rate (Martinie, Milland, & Olive, 2013). It is well documented that a further indicator of sympathetic and emotional arousal are the pupils (e.g. Bradley, Miccoli, Escrig, & Lang, 2008). Specifically, pupil dilation indicates heightened emotional arousal as compared to pupil constriction. Therefore, the question arises whether the pupils can serve as an index for experiencing cognitive dissonance as well. The results of the sparse research on this topic support the notion of pupil dilation as an indirect marker of, among others, cognitive conflict (Hochmann, Glöckner, Fiedler, & Ayal, 2016). However, it remains unclear whether this link also applies to behavior that is incompatible with personal preferences, which approximates our notion of cognitive dissonance.

The present study investigated this link by measuring the pupils during the induction and reduction of cognitive dissonance through forcing participants to make decisions that conflict with their attitudes and providing them the opportunity to subsequently change their preferences. We took Sharot et al's (2010) study as a template for this end because their adopted blind-choice paradigm is both free of the shortcomings of the free-choice paradigm and is combinable with pupillometry. Therefore, the present study served two purposes. First, it aimed to replicate the SOA for selected stimuli as observed in the original study. Second, it investigated whether pupillary changes serve as an index of cognitive dissonance as induced during the blind-choice task and possibly reduced in the second rating-task.

METHODS

Material and availability

The present study has been registered on the Open Science Framework prior to data collection and analysis. The preregistration manuscript, stimuli, collected data, and analysis scripts are available from https://osf.io/rtksh/.

Participants, software, and apparatus

25 undergraduate psychology students from the University of Groningen took part in this study. They were compensated in form of SONA credits, which are credits that first-year students ought to collect by participating in research studies. The study was conducted following the approval by the Ethical Committee Psychology of the University of Groningen. All participants provided informed consent prior to the experiment. Pupil size was recorded binocularly with an Eyelink 1000, a video-based eye-tracker with a gaze-sampling frequency of 1000 Hz. The testing took place in a relatively lit room. The experiment was implemented with the experiment builder OpenSesame.

Stimuli and procedure

The experimental procedure followed the original study of Sharot et al. (2010) as closely as possible. However, the experiment started with a 5-point eye-tracker calibration because we tracked participants' pupils throughout the entire experiment. The study started with a pre-choice rating task, of which one trial was 11 s long. In each trial, participants were presented with a holiday destination formulated as a word for 6 s, after which they had 2 s to indicate how happy they were to spend their holidays at that destination. The responses were entered on the keyboard, using the following scale: 1 = unhappy, 2 = a bit unhappy, 3 =neutral, 4 = happy, 5 = very happy, 6 = extremely happy. A fixation cross was presented for 3 s between the total of 80 trials.

An OpenSesame program determined the pairs for the blind-choice task. We replicated this task to include 75% critical trials, in which participants made a blind choice between two identically rated options, and 25% noncritical trials, which included choices between items that were rated differently in the pre-choice task. In the noncritical trials, we determined the revealed blind choice to always be the holiday destination that the participant rated more favourably in the previous rating task. Each stimulus appeared in only one pair.

Participants received several instructions at the start of the study. As in Sharot et al. (2010), we first let participants read the abstract of a research article on subliminal decision making (Pessiglione et al., 2008). The purpose of this was to make participants believe that the present experiment was a follow-up study and to convince them that they can make decisions in line with their attitudes even without conscious processing of their options. After participants read the article abstract, they were instructed that two masked names of holiday destinations that they rated in the first task would be presented side by side for 2 s on each trial. We further informed participants that they will not be able to consciously perceive them because they would appear very briefly and be masked. Participants were not aware that random strings of letters were presented instead of actual holiday destination words. Participants had 2 s to choose between the two masked holiday destinations by pressing the left or right arrow keyboard buttons, respectively. Following their choice, a pair of holiday destinations was presented that either had similar ratings (critical trials) or different ratings (uncritical trials) in the pre-choice task. The destination that the participant chose blindly was indicated by a star above the name. A fixation cross of 3 s appeared before the next blind-choice trial. The experiment typically lasted one hour.

The present study diverted from the original one in several ways because of lacking details in the original research report. First, the replication used a black square that was big enough to cover the letters presented in the blind-choice paradigm as it remained unclear what kind of mask the authors used originally. Second, participants pressed 'z' and 'm' keys in the blind-choice task to indicate their preference for the left or right stimulus, respectively. The original report did not specify which keys participants used in the original experiment. Further, stimuli in the blind-choice paradigm were flashed for 16 ms, as the originally reported presentation time of 2 ms is not possible on regular computer screens. In addition, our replication employed random sequences of normal letters instead of the originally used symbol strings because the latter may prime aggression-related arousal and therefore impact pupil size measures. We also left out the control condition of the original study to include more critical and uncritical trials in the experimental condition. Lastly, we used the Internet website *Travelspin* (https://travelsp.in/) to generate a random set of 80 holiday destinations as our experimental stimuli, which therefore differed from the originally used destinations.

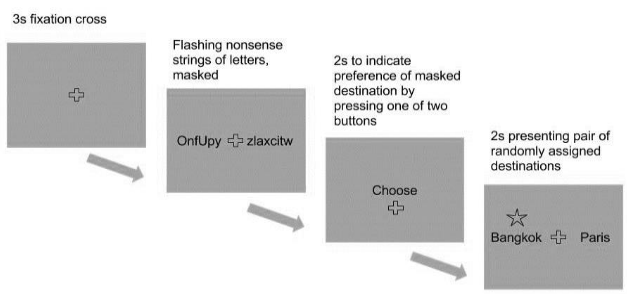

Figure 1: Blind-choice paradigm. The figure shows an example trial during which the participant makes a blind choice between two subsequently revealed holiday destinations.

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RESULTS

Exclusion criteria

We excluded participants from the data analysis if one or more of the following cases occurred: the participant frequently looked away from the fixation dot in the blind-choice task, the participant blinked excessively, technical issues prevented high-quality recording, or the participant decided to cancel the experiment or not to show up. We also excluded blind-choice trials in which participants did not respond within 2s, after which a frowning face indicated a timeout. After the data collection, we decided to exclude participants who did not give responses in more than 50 percent of blind-choice trials. Further, we decided to exclude participants who pressed one of the keys ('m' or 'z') to choose a destination in more than 90 percent of the blind-choice trials. We excluded seven participants according to these criteria, leaving 18 participants in the final analysis.

Behavioural results

We employed a random-effects analysis to examine the differences in choice ratings between the two rating tasks for every trial. We considered the new preference rating for a holiday destination the dependent variable whereas the original rating and blind choice as the independent variables. To test for the SOA effect, we used the following model in the R-package lme4style:

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new_preference ~ old_preference * selected + (1+old_preference * selected | subject_nr)
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We predicted to replicate the SOA effect resulting from choosing and rejecting stimuli in critical trials. That is, we expected increased ratings for chosen items and decreased ratings for rejected items in the second rating task as compared to the first rating task. Moreover, we expected a high test-retest reliability for items as rated in both tasks. The LME analysis included the pre-choice ratings and blind choices as fixed effects, participant number as a random effect, and post-choice ratings as the dependent variable. We found a t-value of 14.512 for the fixed effect of the pre-choice rating, which implies that the first ratings were strong predictors of the second ratings. The fixed effect of whether a destination was chosen or rejected had a t-value of -0.420. Although we did not specify a significance criterion for the behavioural analysis in advance, we deemed this result as evidence against the hypothesis that blind choices affected post-choice ratings. Our results are contrary to previous reports showing evidence for the SOA effect.

Pupil size analysis

Next, we investigated whether the pupils dilate most strongly in critical blind-choice trials because we expect revealed blind choices with more similar ratings to evoke more dissonance as compared to less similar ratings. We conducted the following linear mixed effects (LME) model for each pupil-size sample (n):

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pupil[n] ~ rating_diff + (1+rating_diff | subject_nr)
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Here, rating_diff was the difference between the initial preferences for two simultaneously presented items in a blind-choice trial. We considered an effect reliable when $t > 2$ for at least 200 consecutive samples. We predicted that there is an effect of rating_diff, such that the pupil is largest when rating_diff is small. The analysis focused on the time interval of 1500 during which participants' blind choices were revealed on the computer screen. We averaged the pupil sizes measurements into 15 bins of 100 ms each.

Our results showed that none of the 15 bins reached the significance threshold of $t > 2$. The largest significance value (t = 0,868) corresponded to the recordings of 200-300 ms before the end of each trial. We did not find evidence for an association between pupil size and rating differences of stimuli in the blind-choice trials.

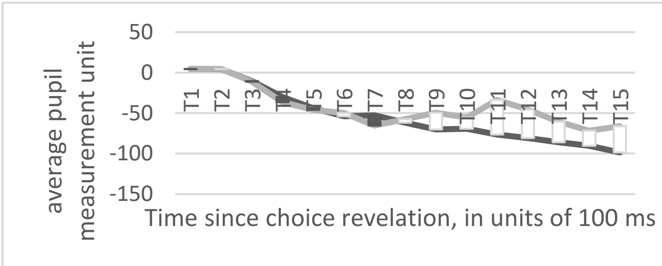

Figure 2: Average pupil size data depicting the final 1500 ms of blind choice trials across 18 participants

Correlation-trace analysis

This analysis focused on our hypothesis that pupil size during critical blind-choice trials correlates with spreading of alternatives (SOA) strength for selected and rejected stimuli. We predicted that the larger the pupil dilation, the greater the dissonance and therefore more attitude change in the second rating task is necessary to reduce it. We estimated the SOA for individual trials and pupil size samples by using the following two linear mixed effects (LME) models:

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preference_change_selected ~ pupil[n]+ (1 | subject_nr)

preference_change_rejected ~ pupil[n]+ (1 | subject_nr)
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Here, preference_change was the difference in pre- and post-preference for a given item. As above, we considered an effect reliable when $t > 2$ for at least 200 consecutive samples.

For the pupil size analysis, we used 15 bins of 100 ms each in this analysis. The LME analyses revealed that only the pupil recordings between 200 – 300 ms reached the significance threshold (t = 2.767) to predict SOA for selected items. Similarly, only one significant model (t = -2.231) predicted SOA for rejected items, which consisted of the recordings between 700 – 800 ms of the last 1500 ms in critical blind-choice trials. However, most slopes of the 15 bins pointed into the expected direction (see figure 3). Although not significantly, pupil dilation seemed associated with positive SOA for selected items and negative SOA for rejected items.

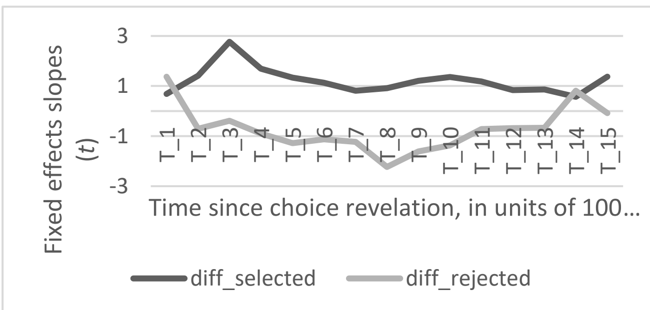

Figure 3: Fixed effects slopes for each pupil size bin. The depicted slopes indicate whether pupil size predicted SOA both for selected and rejected items in critical trials.

DISCUSSION

Here we report that we cannot replicate the findings of 50 years of research on the spreading of alternatives (SOA) effect, which holds that actions also influence cognitions instead of merely following from them. Moreover, we did not find evidence for an association between pupil dilation and the induction or reduction of cognitive dissonance. Our experiment involved three hypotheses, which consisted of replicating the SOA and linking the assumed cognitive dissonance to SOA strength and pupil dilation.

The behavioural analysis aimed to replicate SOA. Sharot et al. (2010) observed a significant increase in post-choice ratings for selected stimuli (t (20) = 2.4, $p < .03$), whereas they found no significant decrease in ratings for rejected stimuli (p > .9). The present study does not provide evidence for SOA in either direction. However, the preferences across the two ratings tasks remained relatively stable, which implies that participants were largely consistent in their responses. Therefore, our results add to the uncertainty surrounding the SOA effect as raised by the methodological flaws of the free-choice paradigm.

Both pupil size analyses did not provide evidence for a link between the induction and the reduction of cognitive dissonance and pupillary changes. Nonetheless, plotting the fixed effects slopes indicated an expected but nonsignificant association between pupil dilation and more positive ratings for selected stimuli as well as with more negative ratings for rejected stimuli in the second rating task. Two scenarios could explain why our observations did not fall in line with the hypotheses. First, our methods may have failed to detect a true association between the heightened state of arousal during cognitive dissonance and pupil dilation. The other option is that there truly is no association, pointing to a theoretical inconsistency arising from of previous research showing that heightened arousal is associated with attitude-behaviour inconsistency as well as with pupil dilation.

The present study includes several limitations. First, we believe that the blind-choice paradigm is not an ideal way to evoke cognitive dissonance. This is because numerous participants stated after the experiment that their commitments toward their blind choice was minimal. Similarly, participants typically did not believe in their agency of making choices themselves, despite the experiment's cover story suggesting otherwise. Further, a temporary revelation of only 1500 ms for selected and rejected stimuli in the blind-choice task may not be sufficient time to understand the inconsistency between one's blind choices and preferences. An additional point to consider is that we excluded all blind-choice trials in which participants did not respond within 2 s. from analysis. Although we similarly kept this timeout limit for replication purposes, it is possible that these trials indicated particularly strong dissonance that would require more time to choose. Lastly, we point out that the experiment's theoretical framework focusing on cognitive dissonance theory is assumptive. Sharot et al. (2010) explained their findings both in light of cognitive dissonance theory (Festinger, 1957; cited in Sharot, Velasquez, & Dolan, 2010) and self-perception theory (Bem, 1967). Hence, other consistency theories may explain the originally observed SOA as well.

Although a close replication of Sharot et al. (2010), our study failed to lead to similar findings and thus marks the controversy surrounding this effect since a decade. Nonetheless, we cannot yet make a firm conclusion about the reality of the SOA effect as it requires more research. Future studies should examine the SOAeffect by employing more robust methods, including the blind-choice paradigm, the rate-rate choose paradigm of implicit choice paradigm (Chen & Risen, 2010). Research investigating the physiological and pupillary effects of cognitive dissonance should incorporate more appropriate and suitable ways to evoke dissonance that are independent of the paradigms used to investigate SOA. Moreover, both directions of research should aim at larger participant numbers to increase confidence in the stability and generalizability of results.

ROLE OF THE STUDENT

Alexander was an undergraduate student working under the supervision of Dr Sebastiaan Mathôt when the research in this report was performed. The student was involved in all steps of the research project. Dr Mathôt helped both with programming the experimental task and data analysis.

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