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Spontaneous eye blink rate (EBR) predicts poor performance in high-stakes situations

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ABSTRACT

Although the existence of 'choking under pressure' is well-supported by research, its biological underpinnings are less clear. In this research, we examined two individual difference variables that may predict whether people are likely to perform poorly in high-incentive conditions: baseline eye blink rate (EBR; reflecting dopamine system functioning) and baseline anterior hemispheric asymmetry (an indicator of goal-directed vs. stimulus driven processing). Participants conducted a switch task under control vs. incentive conditions. People low in EBR were generally capable of improving their performance when incentives were at stake, whereas people high in EBR were not. Hemispheric asymmetry did not predict performance. These findings are consistent with the idea that suboptimal performance in high-stakes conditions may stem from the neuromodulatory effects of dopamine.

1. Introduction

During their lives, people often find themselves in situations where good performance yields immediate monetary or social rewards. Consider, for example, music auditions, sports finals, and college entrance exams. Both inside and outside science, high-stakes situations such as these are often assumed to bring out the best in people. Nevertheless, a growing body of research indicates that high-stakes situations have the potential to cause *choking under pressure*—i.e., worse-than-normal performance when pressure to perform is very high (Beilock and Carr, 2001; Baumeister, 1984). Prior psychological studies indicate that such incentive-triggered performance decrements are due to momentary impairments in working memory and attention regulation (Beilock and Carr, 2001; Beilock et al., 2004; Lewis and Linder, 1997). Yet, at present, much less is known about the biological underpinnings of suboptimal performance in high-stakes situations (Boere et al., 2016; Braver et al., 2014; Chib et al., 2012, 2014; Lee and Grafton, 2015; Mobbs et al., 2009; Silston and Mobbs, 2014). Here, we examine two candidate biological, individual differences that may make people more susceptible to such performance impairments. We consider individual differences in baseline dopamine levels in the midbrain (indicated by spontaneous Eye Blink Rate; EBR) and individual differences in baseline hemispheric asymmetry (measured with electroencephalography; EEG).

1.1. The mesolimbic and mesocortical dopamine pathways

Originating in the ventral tegmental area and the substantia nigra, the brain's ascending dopamine pathways affect a wide range of cognitive functions, such as working memory and cognitive control (Cools and D'Esposito, 2011). In particular, dopamine (DA) may be involved in maintaining a balance between cognitive flexibility and cognitive stability, which is considered important for optimal cognitive control (Cools and D'Esposito, 2011; Dreisbach et al., 2005; Jongkees and Colzato, 2016). It has been suggested that this balance depends on dopaminergic functioning in the striatum and prefrontal cortex (PFC; Cools and D'Esposito, 2011). More specifically, D1 receptor signaling in the PFC is thought to be involved in the facilitation of stable information maintenance, whereas D2 receptor signaling in the striatum is thought to serve as a gating mechanism responsible for letting through goal-relevant information and preventing distraction (Zhang et al., 2015; Cools and D'Esposito, 2011; Braver and Cohen, 1999). Interestingly, DA levels in both the striatum and PFC are thought to follow an inverted U-shape, with too high or low levels of DA impairing cognitive functioning (Arnsten, 2009; Cools and D'Esposito, 2011; Aarts et al., 2014; cf. Yerkes and Dodson, 1908), suggesting that the balance between cognitive flexibility and stability requires moderate levels of DA. Moreover, this idea implies that *choking* on performance tasks that require cognitive control can be induced by raising DA levels beyond their optimum. Given that DA is released when valuable outcomes are at stake (Howe et al., 2013; Schultz, 2007), we will test this idea by incentivizing performance on a task requiring cognitive control.

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Baseline dopamine levels can be estimated indirectly and non-invasively, by measuring spontaneous eye blink rate (EBR; see Jongkees and Colzato, 2016, for a review). DA activity and EBR are positively related (Jongkees and Colzato, 2016; Zhang et al., 2015), in the sense that higher EBR indicates stronger dopamine transmission. EBR can reflect both D1 and D2 receptor activity (Jongkees and Colzato, 2016), although it may be more strongly related to the D2 receptor system (Groman et al., 2014; Jongkees and Colzato, 2016). In particular, baseline eye blink rates measured at rest (i.e., tonic EBR) may specifically relate to D2 receptor functioning (Slagter et al., 2015).

1.2. Hemispheric asymmetry

A hallmark finding from psychological research is that incentive-triggered performance impairments often go hand in hand with the subjective experience of performance anxiety and distracting, task-unrelated thoughts (e.g., Beilock and Gray, 2007; Eysenck et al., 2007). Importantly, such subjective experiences are often suggested to be due to a disbalance between two broad attentional systems (Corbetta and Shulman, 2002; Eysenck et al., 2007): the goal-directed system (including the dorsal posterior parietal and large parts of the frontal cortex; lesions in this circuitry cause deficits in voluntarily directing attention to different locations; Halligan et al., 2003) and the stimulus-driven system (including the inferior frontal cortex and temporoparietal cortex; right lateralized; lesions in this network tend to cause spatial neglect; He et al., 2007). Performance anxiety is associated with a pronounced emphasis of the stimulus-driven system (Eysenck et al., 2007). As the stimulus-driven system is lateralized in the right hemisphere, from where it disrupts the goal-directed system, performance anxiety is thought to result in measurable hemispheric asymmetry (Harmon-Jones et al., 2010)—i.e., greater activity in the right hemisphere's frontal cortex, compared to the left hemisphere's frontal cortex.

1.3. The present research

To test our ideas, we used an incentivized task switch paradigm (adapted from Colzato et al., 2010). In this task, on each trial, people are exposed to a stimulus (in this case, a digit and a letter) on which they have to perform either of two tasks (in this case, odd/even vs. vowel/consonant judgments). In research that used this paradigm, a well-replicated finding is that people perform worse on *switch trials* (trials in which people perform a different task than on the previous trial) vs. *repeat trials* (trials in which people perform the same task as on the previous trial; Monsell, 2003).

Importantly, performance on the switch task is thought to rely on PFC functioning (Sohn et al., 2000; Gnadt and Andersen, 1988; Corbetta and Shulman, 2002). Also, previous research indicated that performance on the switch task is related to the catechol-*O*-methyltransferase (COMT) gene ($Val^{158}Met$ polymorphism), a gene that is involved in generating an enzyme that in turn affects the supply of dopamine (Colzato et al., 2010). Interestingly, having the $Val^{158}Met$ polymorphism also seems to be related to right hemisphere frontal asymmetry (Wacker et al., 2013). So, several previous findings suggest that the switch task may well respond to dopamine-related and hemispheric-asymmetry-related processes.

A novel aspect of our version of this task is that we will incentivize participants' performance in an all-or-nothing fashion. Specifically, one group of participants learns that they will lose[1] sum of money if they fail to meet a pre-specified performance criterion (see Chib et al., 2012). A control group of participants learns that they may lose money, but that this loss does not depend on their performance. So, crucially, all participants will be exposed to information regarding a potential loss and their performance; however, the potential loss is only contingent on people's performance in the experimental condition. We examine how this incentive manipulation affects performance (in general, but also on switch trials specifically) and we examine how this effect relates to EBR and hemispheric asymmetry (at baseline and during task performance).

We hypothesize that participants are more prone to performance decrements when their monetary payoff depends on performance, relative to when their payoff is not contingent on performance. Furthermore, we expect that people with high EBR are more susceptible to incentive-triggered performance impairments, compared to people with low EBR. Finally, we hypothesize that people who are inclined toward having greater activity in the right frontal cortex (i.e., at baseline) should be more prone to incentive-triggered drops in performance.

In the online Supplementary information, we present a pilot study in which we test our incentivized switch task. In the main text, we present a study that uses the same task, adding measures of EBR and hemispheric asymmetry.

2. Material and methods

2.1. Participants, design, and overview

Thirty-eight undergraduate students participated in the study (mean age = 21.5, 19 females). A priori exclusion criteria included (1) caffeine use twelve hours prior to the experiment, (2) left-handedness, (3) current substance abuse, (4) neurological conditions, and (5) mental disorders. Data from one participant was excluded due to performance below chance level on the task. Physiological data from another participant was excluded because of equipment failure. Participants were randomly assigned to the loss vs. the control condition. Participants earned €10 in exchange for their participation (see below). All participants gave written informed consent. The study was approved by the local ethics committee (Faculty of Social Sciences, Utrecht University). For a discussion of the limitations of using samples from western, educated, industrialized, rich and democrat communities, we refer the reader to Henrich et al. (2010).

2.2. Procedure

After preparing the participants for EEG data collection, participants first underwent two periods of resting state measurements. That is, participants were asked to relax with their eyes open (5 min; while we measured hemispheric asymmetry and EBR) and their eyes closed (2 min, while we measured hemispheric asymmetry). Then, the incentivized switch task was started.

Participants first familiarized themselves with the task. Specifically, they completed 2 instruction runs (34 trials; see below for a description of the trials), which included performance feedback after every trial, and 4 practice runs (68 trials), which included no feedback. Then, they learned that the experiment was about to start. Also, to make sure participants performed the task to the best of their ability, it was mentioned that they would "probably be able to perform better than they did during the practice block". Specifically, they were asked to improve their performance with 20%. Next, they performed 4 experimental runs (68 trials). Subsequently, they received the *incentive manipulation*. Specifically, they were told that they had reached their optimal performance level and they were asked to "retain their performance, or improve their performance even further" in the second block. In the loss condition, participants were told that whether they would lose their reward (€10) depended on their performance. In the control condition, participants instead learned that a lottery (after the experiment) would determine whether they would lose their payment. So, like in the

[1] Our incentive manipulation was designed to strongly increase the importance of success for participants—i.e., more strongly than typical within-subjects incentive manipulations in experimental psychology. After all, prior work (Ariely et al., 2009) suggests that stronger (vs. weaker) incentives are more likely to impair (vs. improve) performance. To strengthen our manipulation, we used an all-or-none reward schedule (i.e., participants receive nothing if they fail) and loss framing.