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Is the ability to keep your mind sharp under pressure reflected in your heart? Evidence for the neurophysiological bases of decision reinvestment

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ABSTRACT

The aim of this study was twofold: first, to examine the influence of decision reinvestment on decision-making performance using an option-generation task, and second to investigate its neurophysiological basis with heart rate variability. Forty-two male participants performed an option-generation task (i.e., where participants are required to generate their own options rather than being asked to decide from a set of options) under low- and high-pressure conditions. Results showed that the decision-making performance of low and high decision reinvesters was similar in the low-pressure condition, however in the high-pressure condition low reinvesters decided faster than their high reinvester counterparts. Moreover, we found that the pressure-induced reduction in parasympathetic activity was more pronounced in high reinvesters in comparison to low reinvesters. Findings are interpreted in light of the neurovisceral integration model, assuming a positive relationship between cognitive performance and parasympathetic activity. These findings offer a physiological insight into a psychological phenomenon and may also suggest a way to counteract the detrimental effects of decision reinvestment by utilizing interventions that target the parasympathetic activity, such as heart rate variability biofeedback.

1. Introduction

Performance under pressure is vital in a variety of areas. It has the ability to create headlines in the media for those that are able to cope under pressure (e.g. Captain Sullenberger executing an emergency water landing of US Airways Flight 1549 in the Hudson River) equally as much as those who do not (e.g. Rory McIlroy throwing away a four-shot lead in 2011 Masters). In an attempt to understand this phenomenon, research has considered adopting an individual differences perspective. In particular, one such theory explaining performance breakdown under pressure is that of reinvestment. Reinvestment refers to the propensity for engaging in conscious online control of movements, using explicit information when performing under pressure, thus leading to disruption of automatic motor skills (Masters & Maxwell, 2008). Reinvestment is thought to be "a function of individual personality differences, specific contexts and a broad range of contingent events that can be psychological, physiological, environmental or even mechanical" (Masters & Maxwell, 2008, p. 161). Research into the role of reinvestment has been extended from the motor domain to examine decision-making under pressure (Kinrade, Jackson, Ashford, & Bishop, 2010). Decision reinvestment thus refers to thinking too much or less effective, through conscious control strategies and/or ruminative thoughts, by investing high cognitive effort that hinders performance. This study aimed to further the understanding of decision reinvestment, investigating its impact on underlying mechanisms of decision making, as well as its neurophysiological basis.

Decision reinvestment is measured by the decision-specific reinvestment scale (DSRS; Kinrade et al., 2010), which contains two factors: decision reinvestment, assessing the conscious monitoring of processes involved in making a decision, and decision rumination, referring to the negative evaluation of previous poor decisions. Evidence for construct validity has been obtained both in real-life conditions (Jackson, Kinrade, Hicks, & Wills, 2013; Kinrade et al., 2010; Laborde, Dosseville, & Kinrade, 2014) and in the laboratory (Poolton, Siu, & Masters, 2011). Kinrade et al. (2010) found

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that expert basketball, netball, and korfball athletes', from University and National leagues (mean competitive experience of 8.0 years, *SD* = 4.1), DSRS scores were positively correlated to their tendency to choke under pressure during competitions as evaluated by their coaches. Poolton et al. (2011) showed that referees with a higher tendency for decision rumination (i.e., the second factor of the DSRS) were more prone to the home team advantage bias, when asked to make video-based decisions. Jackson et al. (2013) found that netball players who scored higher on the DSRS were more prone to decrements in their passing accuracy during high-pressure games by using match analysis on game performances across a season. Finally, Laborde et al. (2014) found in their first study that intuitive players have lower movement and decision reinvestment scores, and in their second study that low reinvesters scored higher than high reinvesters in terms of stressor perceived controllability, coping effectiveness, and subjective performance. Whilst encouraging, these initial findings need to be further validated, with precise decision-making performance assessment, as well as sounded neurophysiological measurement. For instance, in the study of Kinrade et al. (2010), the tendency to choke under pressure was assessed using self-report measures and not using direct performance variables, similar to Laborde et al. (2014) who used only self-report measures to assess stress and coping appraisals in their second study, whereas Poolton et al. (2011) utilized a task (i.e., referees distinguishing foul and no foul situations) that cannot easily be generalized to other contexts.

Progresses toward the understanding of decision making have been realized during the last decade using the option-generation paradigm, developed by Johnson and Raab (2003). Responding to the recommendation of evaluating complex decision environment, that for example go beyond card sorting (Fawcett et al., 2014), and contrary to many paradigms that present participants with a set of available options, the option-generation paradigm mirrors real-life contexts in allowing participants to generate options according to the course of action (Johnson & Raab, 2003). This enables exploration of various parameters of the decision, such as decision time (i.e., the time taken to generate the initial option), the generation time of all options, the number of generated options, dynamic inconsistency (i.e., the number of trials in which the first and the best choice are not identical), the quality of the first option, and the mean quality of options. Regarding performance criteria, in some option generation tasks, a higher number of generated options was not found to be detrimental to performance (Ward, Suss, Eccles, Williams, & Harris, 2011). However it seems that when under temporal pressure, fewer generated options result in better choices, at least for experts, supporting the foundations of the Take-the-First heuristic (Johnson & Raab, 2003). The Take-the-first heuristic assumes that the first option generated by an individual is often the best, arguing for a less-is-more effect and has received recent support (Hepler & Feltz, 2012; Laborde & Raab, 2013). For example, Raab and Laborde (2011) showed that the faster decisions made by intuitive players were found to be better than the slower decisions made by deliberative players. In line with the premises of decision reinvestment, intuitive athletes might have a lower tendency to reinvest, which was evidenced by Laborde et al. (2014), given their lower tendency to consciously control their thoughts. The option-generation paradigm offers an appropriate medium in which to examine the mechanisms of decision reinvestment as it evaluates the monitoring and cognitive effort through the time spent to make the decision, the number of options generated, and the consistency between the first option generated and the final choice. Using such paradigm would ensure having precise decision-making performance measures, going beyond previous decision reinvestment research that was only linked to subjective performance satisfaction (Laborde et al., 2014) or global match performance (Jackson et al., 2013), and a more complex decision task than the one used in Poolton et al. (2011).

Due to the implication of the prefrontal cortex in decision-making (Rolls & Grabenhorst, 2008), it is very likely that decision reinvestment is linked to the activity of this network. According to the neurovisceral integration model (Thayer, Hansen, Saus-Rose, & Johnsen, 2009), an appropriate, cost-effective, and accessible variable to index the activity of the prefrontal cortex is heart rate variability, which represents the time variation between peaks of the QRS complexes. Heart rate variability allows identification of the branch of the autonomic nervous system that is mediating heart rate (i.e., sympathetic and parasympathetic, Malik, 1996). The neurovisceral integration model assumes that there is a core set of neural structures that provide an organism with the ability to adaptively regulate cognition, among other aspects (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). The heart and the brain are connected bidirectionally, with efferent messages from the brain affecting the heart and afferent messages from the heart affecting the brain. HRV would serve as an index of the degree to which the core integration system guided by the medial prefrontal cortex is integrated with the brainstem nuclei that directly regulate the heart, mainly through the vagus activity. According to the neurovisceral integration model, higher cognitive effectiveness is linked to greater activity of the parasympathetic system (Thayer et al., 2009). This relationship originates from the common structures and networks at stake for cardiac control regulation and for cognitive regulation. The effectiveness of the prefrontal cortex is underlined by the optimal activation of neural networks that may have been acquired during separate moments in time. Optimal functioning of the prefrontal cortex ensures that the flow of activity along neural pathways will establish adequate mappings between input, internal states, and outputs needed to perform a given task (Miller & Cohen, 2001), therefore enabling flexible responses to changing environments (Thayer et al., 2009). Such flexibility is ensured by the central executive, whose role is to control and to coordinate different inhibitory, attentional and memory functions into higher-order cognitive functions (Thayer et al., 2009).

In addition to its links with cognition, the activity of the parasympathetic system is also usually used as an emotion marker (Kreibig, 2010), and was found to decrease when individuals face pressure (Watkins, Grossman, Krishnan, & Sherwood, 1998). At the interplay between cognition and emotion, rumination, which is reflected in the second factor of decision reinvestment, has been found to be associated with a decrease of the parasympathetic activity, which is here characterized as an autonomic dysregulation (Ottaviani, Shapiro, Davydov, Goldstein, & Mills, 2009). With regard to decision reinvestment per se, the neurophysiological correlates have so far yet to be examined, as existing studies focused mainly on self-report indicators of stress, coping and performance (e.g., Kinrade et al., 2010; Laborde et al., 2014). In contrast to these previous studies the present study was performed in a controlled laboratory environment with direct performance measures and therefore allows for a more detailed examination of the relationship between decision reinvestment and decision-making performance under pressure. This investigation aims to provide a better understanding of the underlying mechanisms of decision reinvestment and may inform the development of applied interventions by investigating decision-making performance in an ecologically valid and well-established paradigm and by recording the activity of the autonomous nervous system simultaneously.

One important aspect of this experiment is the induction of pressure. Pressure is a context-trigger for reinvestment, because it usually provokes either self-focus or distraction (Masters & Maxwell, 2008). Baumeister (1984, p. 610) defines pressure as "any factor or combination of factors that increases the importance of performing well on a particular occasion". Pressure is