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Effects of performance feedback on cardiovascular reactivity and frontal EEG asymmetry

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ABSTRACT

The process of goal-setting may be captured by psychophysiological variables, such as cardiovascular reactivity (representative of effort mobilisation) and frontal EEG asymmetry (motivational disposition). The current study exposed 32 participants to false performance feedback in order to manipulate goal-setting and mental effort investment. Participants performed five consecutive blocks of the n-back task and received false performance feedback. One group received repeated positive feedback (i.e. performance steadily improved over the five blocks) whilst a second group were exposed to repeated negative feedback (i.e. performance deterioration over five blocks). Blood pressure, power in the mid-frequency and high-frequency component of Heart Rate Variability (HRV), heart rate, frontal EEG asymmetry and subjective self-assessment data were collected. Sustained and repeated positive feedback led to increased systolic blood pressure reactivity and a suppression of the 0.1 Hz component of HRV. Increased relative left hemisphere activation was observed at F3/F4 and FC1/FC2 over successive task blocks in the presence of feedback regardless of positive or negative direction. It is argued that upward goal adjustment accounted for the psychophysiological changes observed in the positive feedback condition.

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1. Introduction

The regulation of goals is a regular cycle of psychological activity for most people. When faced with the prospect of failure, we must decide to strengthen our resolve or disengage from the task, effectively abandoning the active goal. When our efforts meet with success, another kind of decision must be made—to relax and rest on our laurels or aspire to even higher levels of achievement. This agentic perspective emphasises the roles of volition and individual agency (Karoly et al., 2005) during the process of goal regulation.

If the investment of mental effort is described as energy mobilisation in the service of cognitive goals (Fairclough and Houston, 2004; Hockey, 1997; Kahneman, 1973; Mulder, 1986; Veltman and Gaillard, 1997), then it is logical that the process of goal regulation is manifested by mental effort investment at a psychophysiological level (Locke and Latham, 1990). Studies of cardiovascular reactivity have characterised effort investment in terms of active coping (Bongard, 1995; Gendolla and Krusken, 2001a; Obrist, 1981), challenge (Blascovich and Tomaka, 1996) and task engagement (Fairclough and Venables, 2006). In terms of physiological pathways, mental effort investment has been associated with beta-adrenergic influences on cardiovascular reactivity (e.g. systolic blood pressure, preejection period) (Richter and Gendolla, 2006, 2009). A related strand of research has quantified mental effort investment as suppression of the mid-frequency component of heart rate variability (HRV) (Capa et al., 2008; Fairclough and Venables, 2006; Mulder, 1986; Mulder et al., 1992).

The relationship between goal-setting and effort investment may be described in terms of self-regulation based on discrepancy reduction and enlargement. When a person wishes to achieve a goal, a negative feedback loop may be activated wherein the individual wishes to reduce any discrepancy between performance and a desired goal standard; alternatively the individual may seek to avoid failure by increasing the discrepancy between themselves and an undesirable state of inadequate performance (Carver and Scheier, 2000). Therefore, the person who desires to 'do well' on a task would compensate for increased task difficulty by investing mental effort in order to achieve the goal. This strategy is both discrepancy-reducing in the sense that increased effort should keep the individual on course to attain the goal; it is also a strategy for discrepancy enlargement as the person invests effort in order to avoid undesirable consequences such as performance failure. However, the capability of the individual to compensate for increased task difficulty is finite and this limitation is clearly articulated in the motivational intensity theory (MIT) (Brehm and Self, 1989; Wright, 2008; Wright and Kirby, 2001). MIT emphasises a compensatory dynamic where effort is increased in response to rising levels of perceived difficulty. However, this relationship is nonmonotonic and includes a 'tipping point' where effort may be abruptly withdrawn due to an appraisal of impossible

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task demand, a perception of insufficient ability or a judgment that the benefits of goal attainment do not justify the required investment of effort (Brehm and Self, 1989; Wright and Kirby, 2001). Finally, changes in goal regulation that are initiated by the individual may influence effort investment directly; in this example the interaction between goal regulation and effort investment reflects a proactive dynamic where goals are adjusted upwards by an individual in order to aspire towards a higher level of performance (Carver and Scheier, 1998; Locke and Latham, 1990), resulting in a higher level of mental effort investment.

The exploration of a compensatory dynamic between goals and effort investment has been explored in the psychophysiological literature via cardiovascular reactivity. Both systolic blood pressure and pre-ejection period have been used to operationalise mental effort in response to a range of independent variables, e.g. ability appraisal (Wright and Dill, 1993; Wright and Dismukes, 1995), self-esteem (Gendolla, 1999), mood (Gendolla and Krusken, 2001b), and incentives (Richter and Gendolla, 2006, 2009). The strategic decision to invest or withdraw mental effort has a parallel with the motivational disposition to approach or avoid (see Elliot (2008) for recent collection); in this context, effort withdrawal may correspond with a decline in approach motivation (down-regulation of goal) or an active strategy of avoidance/effort withdrawal (abandonment of goal). Asymmetrical EEG activation in the frontal cortex has been used to capture motivation disposition; greater left activity being representative of enhanced approach motivation whereas avoidance or withdrawal is linked to greater activity from the right frontal area (Davidson, 1995, 2004; Harmon-Jones and Allen, 1998). Evidence to support the motivational model of frontal EEG asymmetry has been generated from several studies where incentives for performance were manipulated. For instance, Sobotka et al. (1992) reported greater left activation at midfrontal sites in response to reward (i.e. opportunity to win money) as opposed to punishment (i.e. opportunity to lose money). This effect was replicated by Miller and Tomarken (2001) and Pizzagalli et al. (2005); the latter used a source localization analysis of EEG data to associate the left dorsolateral prefrontal area with a bias towards reward-related cues. This link between motivational disposition and mental effort is purely intuitive as no previous studies (to our knowledge) linked motivational disposition to mental effort investment, or investigated both frontal EEG asymmetry and cardiovascular reactivity within a goal-setting context.

The purpose of the current study was to explore how the perception of success and failure influenced motivational disposition (frontal EEG asymmetry) and effort investment (cardiovascular reactivity). It was decided to manipulate the perception of success or failure by exposing participants to false feedback of performance quality. Performance feedback exerts a profound effect on goal-setting and mental effort investment (Kluger and DeNisi, 1996). Previous studies have used false performance feedback to investigate the connection between self-efficacy, i.e. expectations of successful task outcome (Bandura, 1997) and cardiovascular reactivity (Wright and Dill, 1993; Wright and Dismukes, 1995). Whilst Wright and colleagues used feedback to alter self-efficacy prior to task exposure, Bandura and Jourden (1991) exposed their participants to bogus performance feedback on repeated occasions within the same task to study the progressive influence of success and failure on performance and self-efficacy. This dynamic adjustment of goals in response to repeated episodes of performance feedback has also been demonstrated by Ilies and Judge (2005) and Donovan and Williams (2003), both of whom reported evidence of upward goal adjustment in response to positive feedback and downward goal revision following negative feedback.

An initial attempt to combine the repeated bogus feedback methodology of Bandura and Jourden (1991) with psychophysiological measures was reported by Venables and Fairclough (2009). This study found some evidence of changes in autonomic activation, i.e. greater activation of both sympathetic and parasympathetic responses in response to negative performance feedback in conjunction with increased negative effect, but it was difficult to interpret findings with a sufficient degree of confidence. This was mostly due to limitations in the experimental design as the study did not include a control (no feedback) condition, hence patterns of psychophysiological reactivity evoked by positive and negative feedback could only be assessed in relation to one another. In addition, the number of sites used for EEG asymmetry analysis was inadequate in terms of coverage and a linked-ears montage was not achieved, which is essential for this type of data collection (Allen et al., 2004).

The aim of the current study is to investigate how repeated exposure to bogus positive and negative performance feedback influences psychophysiological variables related to mental effort investment (blood pressure, heart rate, HRV) and motivational disposition (frontal EEG asymmetry). We hypothesised that initial exposure to negative feedback would increase effort investment (e.g. greater systolic reactivity, greater suppression of 0.1 Hz component of HRV, greater heart rate) and approach motivation (i.e. increased left hemisphere activation at F3/F4) in order to facilitate subsequent recovery. However, consistent and repeated exposure to negative feedback would reduce both effort investment and approach motivation in combination with increased negative affect—as participants feel there is no possibility of reversing the decline of performance. In the case of positive feedback, we anticipated little effect on psychophysiology during initial exposure. However, consistent positive feedback was hypothesised to produce an upward adjustment of task goal with subsequent increase of mental effort investment and approach motivation as well as a decline of negative effect.

2. Method

2.1. Participants

34 participants (17 males and 17 females) were recruited and all received financial remuneration for taking part. All participants were healthy, right-handed and free from permanent medication other than the contraceptive pill. Participants were divided into two groups: (a) a positive feedback group who received false performance feedback indicative of gradual improvement over time, and (b) a negative feedback group who were presented with false feedback of a progressive decline in performance. Data from two participants were omitted from the analysis as both reported serious doubts about the integrity of performance feedback during the debriefing session. Therefore, the positive feedback group contained sixteen participants (age range 18–29, M = 22.8 yrs., S.D. = 3.6) and a negative group of sixteen participants (age range 19–32, M = 23.5 yrs., S.D. = 4.5); both groups contained an equal number of males and females.

2.2. Spatial working memory task

A spatial memory task was created using E-Prime software (Psychology Software Tools Inc.). This task was developed from the 'n-back task' described by Gevins and Smith (2003), specifically the two-back version of the task. During the task, participants were presented with a 3×3 grid on the screen. On each trial, a green square appeared at one of the nine grid locations for 1.75 s. Participants were required to respond to each appearance of the green square by pressing one of two keyboard buttons to indicate that the location of the current square was either in the same location as the square seen two trials previously (a match) or in a different location (a mismatch). The task was divided into five blocks, each of which contained 90 trials and lasted approx. 2.5 min. Matches occurred on approx. 35% of trials.

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