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The influence of performance feedback on goal-setting and mental effort regulation

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Abstract Goal-setting and mental effort investment may be influenced by the perception of success or failure. The aim of the current study was to investigate the dynamics of motivational intensity model using false performance feedback. Forty participants performed a demanding cognitive task over five successive (5 min) blocks. Participants received performance feedback of either progressive success or progressive failure. A number of psychophysiological variables were used to index mental effort investment and emotion, including: HRV components, blood pressure, skin conductance level, EEG, and facial EMG. Subjective estimates of mood, workload and motivation were also collected alongside performance measures. The success group experienced positive affect and a less pronounced decline in subjective motivation in response to a perception of successful achievement. In contrast, feedback of failure led to adverse changes in mood/motivation, but did not lead to the absolute withdrawal of effort, although trends in the psychophysiological data suggest that participants in the failure group were on the verge of abandoning the task. The implications of these findings are discussed within the context of goal-setting and effort regulation models.

Keywords Goal-setting · Effort investment · Performance feedback · Psychophysiology

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Introduction

Goal-setting is fundamental to the relationship between motivation and performance (e.g. the acquisition of skills, task mastery). Mental effort is mobilised by the individual to service those goals deemed intrinsically significant (i.e. serve significant life goals) or linked to extrinsic motives (e.g. monetary incentives) (Hockey 1997; Locke and Latham 1990). The level of energy mobilisation in the service of task goals should represent the relative commitment of the individual to the task. Increased mental effort reflects engagement with task goals whereas effort reduction or conservation may indicate the abandonment or down-regulation of task goals (Hockey 1997; Locke and Latham 1990).

Motivational intensity theory (Wright and Brehm 1989; Wright and Dill 1993; Wright and Dismukes 1995; Wright 1996) proposes that goal commitment (i.e. the willingness to invest effort into the task) is a function of perceived: (1) task difficulty, (2) ability, and (3) likelihood that successful performance on the task will achieve a desired motive (e.g. monetary incentives, prowess, ‘feeling good’). Therefore, if the individual believes they have the necessary ability to achieve success in the service of a tangible motive, then effort is invested into performance. However, if the task is perceived as either too difficult (i.e. demands of the task exceed perceived ability) or not worthwhile (i.e. unlikely to achieve a tangible motive), then effort will be withdrawn.

The relationship between goal-setting and effort investment has been described in a number of hierarchical, cybernetic models of human behaviour (e.g. Hockey 1993, 1997; Locke and Latham 1990; Carver and Scheier 2000). The feature common to these models is the superordinate relationship between goal regulation and effort mobilisation, as well as a negative control loop. If goals are upregulated (i.e. the individual strives for a higher level of achievement), effort is invested as a response to challenge. Similarly, the abandonment or down-regulation of a goal results in reduced effort investment. When performance quality is threatened by dynamic factors, such increased demand (e.g. higher task complexity, multi-tasking) or the presence of stressors (e.g. sleep deprivation) then effort is invested as a compensatory mechanism in order to guarantee adherence to goal standards (Hockey 1993, 1997).

In terms of the dynamic between goal-setting and effort regulation, both the cognitive-energetical framework proposed by Hockey (1997) and motivational intensity theory (Wright and Dill 1993; Wright and Dismukes 1995; Wright 1996) propose that increases in perceived difficulty (from any source) lead to effort investment provided that goal success is perceived to be possible and worthwhile. The differences between both models lie with the level of emphasis and detail with respect to the task context. Research into motivational intensity theory has used indicators of sympathetic nervous system (usually systolic blood pressure) in order to describe the "tipping point" where increased task difficulty forces participants to switch from effortful striving for goal success to disengagement and a significant reduction of mental effort (e.g. Richter and Gendolla 2006, 2007). The model described by Hockey (1997) focuses on sustained and complex task performance; therefore, the investment or conservation of mental effort is realised as a strategic ebb and flow in response to dynamic changes in perceived task difficulty and the possibility of success. In addition, the Hockey model describes how changes in performance and affect may accompany psychophysiological changes at the autonomic level. For instance, effort investment may lead to reduced control over lower priority aspects of performance, or increased levels of tension or anxiety (Hockey 1997). These compensatory costs may also be used as indicators of effort strategy. A link between one such cost, negative affect, and perceived task difficulty was also described by Gendolla (2000) who argued that negative affect inflates the perception of task demand, leading to increased effort investment (Gendolla and Krusken 2001). Therefore, we can see how compensatory costs may influence effort regulation directly by increasing the perception of task demand and the possibility of goal success (Fairclough 2000).

Performance feedback is one moderator of this dynamic process of goal-setting and effort regulation. Performance feedback provides an objective indication of ability, current performance quality, and the longer-term likelihood of task success (Kluger and DeNisi 1996). In this way, performance feedback mediates the regulation of effort investment via a direct influence on the top-down process of goal-setting (Locke 1997). Together, goals and feedback have been found to be more effective in encouraging performance improvement than either goals or feedback alone (Locke and Latham 1990). Dynamic changes in goal-setting, ability-appraisal and effort investment may be assessed by exposing participants to a schedule of "false" feedback on an ascending (progressive improvement) or descending (repeated failure) arc (Bandura and Cervone 1986; Bandura and Journa 1991).

The current study was designed to study the dynamics of the motivational intensity model using false performance feedback, (studies in this area have relied on static and discrete manipulations of perceived ability/demand/achievement). One group of participants will be exposed to feedback of progressive success (i.e. performance improves with each successive block of task performance). It is hypothesised that these participants will experience positive affect (Carver and Scheier 2000) and may increase effort investment in response to a perception of successful achievement and an up-regulation of goals (Hockey 1993, 1997). A second possibility is that feedback of success may inflate the perception of ability or reduce appraisal of task demand, which would result in a reduction of effort investment (Wright and Brehm 1989). A second group will receive repeated feedback of task failure (i.e. performance quality declines with each successive block of task performance). It is predicted that these participants will experience negative effect in combination with reduced ability appraisal and an elevated perception of task demands. These participants may elect to invest effort in order to compensate for perceived failure as an initial response to perceived failure (Hockey 1993, 1997); however, it is hypothesised that the experience of repeated failure will lead to a gradual reduction of effort as task goals are progressively abandoned. Alternatively, this group may withdraw effort as an initial response to feedback of failure without any attempt at a compensatory response.

The study is also designed to extend the range of psychophysiological measures used to index mental effort. The majority of existing research has relied on systolic blood pressure as an indicator of sympathetic activity at the level of the autonomic nervous system (ANS). This study will compliment the measurement of blood pressure with analysis of heart rate variability in both the mid- and high-frequency ranges. The former has been linked with mental effort investment (Fairclough et al. 2005; Fairclough and Venables 2006) whilst the high-frequency range also known as vagal tone is linked to parasympathetic activity in the ANS (Porges 1995). In addition, the skin conductance level (SCL) of participants will be monitored as an additional index of sympathetic activation of the ANS. The study also includes measures of electrocortical activity from the spontaneous measurement of the electroencephalogram

(EEG). There is evidence that alpha activity is inversely related to glucose metabolism in the brain (Larson et al. 1998) and that increased mental effort is associated with suppression of alpha activity, particularly from the frontal areas (Gevins and Smith 2003). In addition to extending the operationalisation of mental effort, the study will also use facial electromyography (fEMG) as a psychophysiological measure of positive and negative affect (Larsen et al. 2003).

Method

Participants

Forty university students participated in the experiment (20 female). The age of participants ranged from 18 to 40 years, (M = 23.3 years, SD = 5.34). Participants were split into two groups of equal numbers of males and females; (1) a success group, who received repeated feedback of improving performance (Mean age = 23.55, SD = 5.45), and (2) a failure feedback group, who were informed of a successive decline in performance (Mean age = 23, SD = 5.35). All volunteers received a financial reward of £15.00 upon completion of the experiment.

Experimental task

The Multi-Attribute Task Battery (MATB: Comstock and Arnegard 1992) was employed as the experimental task for this study. This is a multi-tasking environment used to capture perceptual-motor performance (i.e. Tracking), perceptual vigilance (System Monitoring), and decision-making activities (Resource Management). The demands of a multi-tasking environment made it difficult for participants to subjectively track performance quality, which was important for the performance feedback manipulation. The task had three components: (a) a compensatory Tracking task controlled via a joystick with tracking performance calculated as root-mean-square (RMS) error from a central point, (b) a System Monitoring task that comprised of a set of four gauges with moving pointers, participants were instructed to inspect the gauges and respond to pointer deflections that were *more* than one notch above or below the centre point (the event rate for this task was 1–2 deflections per minute), and (c) a Resource Management task that required participants to maintain a specific level of fuel (i.e. 2,500 units) within two main tanks of a fuel network, which are constantly depleting. Performance on the resource management task was measured by calculating the deviation from the target level of (2,500) units in both main tanks.

Performance feedback manipulation

Participants performed five consecutive blocks of MATB activity, each of which was followed by the presentation of performance feedback represented as total percentage performance accuracy (across all three MATB sub-tasks). Participants were led to believe that performance data was being calculated in real-time following each block of task activity; this illusion was achieved via a macro written in Microsoft Excel. The macro simulated a process of calculation and analysis and produced a chart to display performance accuracy. The charts produced by the macro are illustrated in sequence for both groups in Fig. 1.

The initial Block (A) was to provide a baseline level of performance when no performance feedback was presented. After Block B all participants (in both groups) were presented with performance feedback indicating that performance was currently at 50% accuracy. From that point on performance was presented as either a 10% cumulative *decline* in performance quality (i.e. failure feedback group) or a 10% progressive *increase* of performance accuracy (i.e. success feedback group). (Failure group: declined from 50% (post-Block B) to 46% (post-Block C) to 44% (post-Block D) to 40% (post-Block E). The Success group progressively increased from: 50 to 60% using the same step functions as the Failure group).

Experimental measures

Self-reported variables

Several personality trait measures were collected prior to task performance to ensure equivalence between the independent groups of participants on important inter-individual variables. These included the General Self-Efficacy scale (GSE: Schwarzer and Jerusalem 1995) and a short version of the OCEAN questionnaire (Pervin and John 2001). The GSE is a 10-item questionnaire designed to assess an individual's general perceptions about their capabilities to perform and achieve. The OCEAN questionnaire provides an assessment of the 'Big 5' personality domains described by Costa and McCrae (1992): openness to experience, consciousness, extraversion, agreeableness, and neuroticism.

Three components of self-reported mood (energetical arousal, tense arousal, hedonic tone) were measured before and after each experimental block using the UWIST Mood Adjective Checklist (UMACL: Matthews et al. 1990). Additional subjective measures of state including motivation, and control and confidence were measured using subscales from the Dundee Stress State Questionnaire (DSSQ: Matthews et al. 1999, 2002). In addition, transitory changes in workload were assessed using the NASA Task Load Index (NASA-TLX: Hart and Staveland 1988).

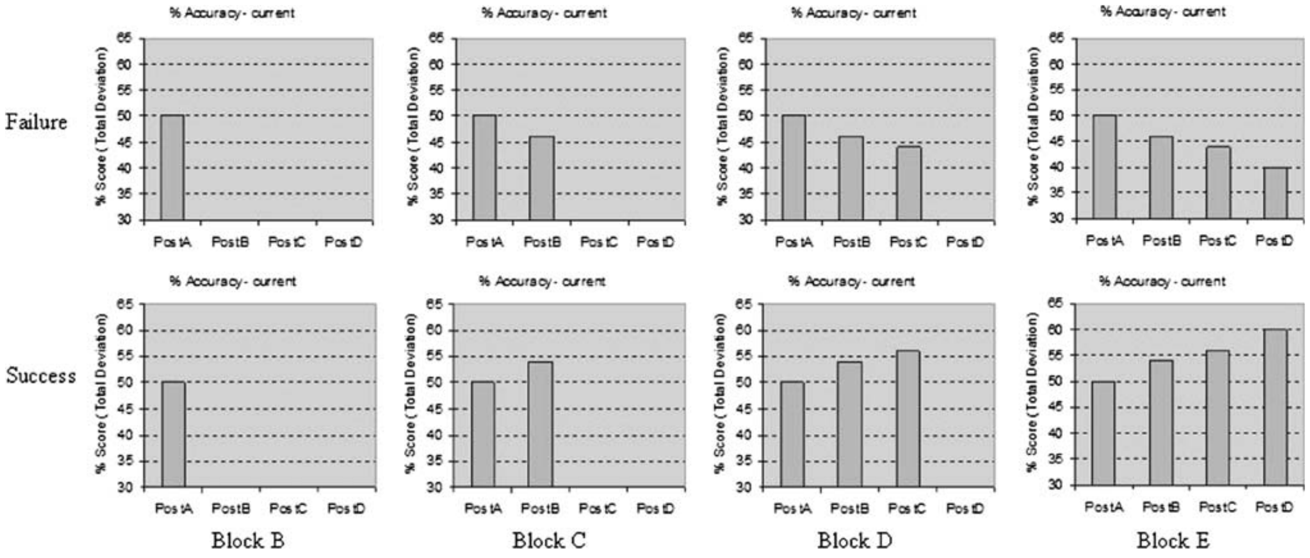

Fig. 1 Illustration of performance feedback as presented to participants following Blocks B, C, D and E for Failure (top row) and Success (bottom row) groups

Psychophysiological measures

To measure heart rate activity, vinyl electrodes were positioned on the 7th intercostal space on the right and left side of the body. A common ground electrode was placed on the hip on the right side of the body. R peaks of the ECG were detected offline, and the inter-beat interval (IBI) between successive R waves was calculated. These data were subjected to Fast Fourier Transform (FFT) to quantify HRV in mid- (0.07–0.14 Hz) and high- (0.15–0.40 Hz) frequency bands. Blood pressure was recorded using a standard pressure cuff placed over the brachial region of the participants left arm, and a Korotkoff sound microphone placed on the artery underneath. Measures for both systolic and diastolic blood pressure were manually obtained at specific points during the experiment, (as described in section "Procedure"). For SCL (a measure of sympathetic nervous system activity), electrodes were attached to the side of the foot in accordance with the sites described by Boucsein (1992). This SCL signal was filtered offline at 1 Hz (low pass) to reduce noise, and values for mean skin conductance were subsequently extracted. EEG activity in the alpha bandwidth was utilised to provide an index of cortical activation. EEG was recorded using silver chloride (Ag/AgCl) coated electrodes and sampled at 500 Hz. Electrocortical activity was measured at the six homologous sites: F3/4, C3/4, and P3/4 (Jasper 1958). A ground site was located midway between Cz and Pz. Each site was referenced to the left mastoid. Electrode impedances were below 10 K ohms at each site. Four BIOPAC EEG100C differential, (high gain), bio-electric potential amplifiers were used to record EEG, (one amplifier module for each EEG site). The high and low bandpass filters were set at 0.1 and 35 Hz, respectively. To assess vertical eye blink activity, Ag/AgCl electrodes were placed above and below the left eye, with a ground electrode positioned in the centre of the forehead. The EOG signals were filtered at 0.05–35 Hz, and amplified by a BIOPAC EOG100C differential, (high gain), corneal-retinal potential amplifier. The EOG record was used to eliminate the influence of eye movement on the EEG data using the approach described by Croft and Barry (2000). Following correction of ocular artifacts, physical artifacts within the EEG record were located and artifact-free epochs were analysed via FFT in steps of 2.65 s with an overlap of 0.5 s. The absolute mean power of the alpha bandwidth (8–13 Hz) was extracted from the EEG record at each of the four sites. fEMG was recorded (1,000 × gain) using Ag/AgCl electrodes placed bilaterally in pairs (in accordance to the locations described by Fridlund and Cacioppo 1986) to attain measures of muscle activity for the zygomaticus major and the corrugator supercilii. These particular muscles are, respectively, associated with the experience of positive and negative emotions. Data values were attained from the mean amplitude of the rectified fEMG signals every 2 s. The sample rate for all channels (ECG, SCL, EEG and EMG) was 500 Hz.

Procedure

Firstly, all participants were prepared for psychophysiological monitoring (e.g. attachment of electrodes, etc.). This procedure was followed by a 5-min familiarisation session on the MATB to ensure that participants understood each of the subtask objectives. Pre-test self-report measures were then attained for state variables (e.g. mood) as well as measures of self-efficacy and personality (OCEAN questionnaire). A 10-min psychophysiological baseline period followed task familiarisation (participants were asked to sit and passively watch the MATB task). Participants then completed a 20-min training session on the MATB, (i.e. a total of 25-min practice as recommended by Prinzel et al. (2003) to produce stable levels of performance).

Prior to the experiment, participants were informed that: (1) they would be performing six 5-min blocks on the MATB, (in actuality, the participants performed only five 5-min blocks); this false information was an attempt to relieve 'end spurts' sometimes seen during sustained performance (e.g. Baker and Ware 1966; Parasuraman 1984), (2) performance would be scored and participants would receive feedback after each 5-min block. (3) financial remuneration was dependent on performance quality, i.e. they would receive a guaranteed minimum amount of £7.50, which would increase to a maximum value of £15.00 if performance improved over the session. (Performance feedback was bogus; all participants left the laboratory with £15, regardless of performance). Following the performance of all five blocks, and the completion of the post-test subjective measures, participants were debriefed about the nature of the experiment and informed about the feigned scoring. None of the participants expressed any suspicion about the feedback manipulation prior to debriefing and all participants indicated informally that performance feedback was believed to be real and accurate.

Results

Experimental data were analysed using SPSS v. 13.0 (SPSS Inc.). Multivariate Analysis of Variance (MANOVA) procedures were used where several dependent variables were present, and repeated-measures Analysis of Variance (ANOVA) was performed to investigate effects associated with single dependent variables. Outliers were identified from standardised residual scores (i.e. <3). Violations of sphericity were detected using Mauchly's Test and degrees of freedom were subsequently corrected using the Greenhouse-Geisser adjustment. Independent samples *t*-tests were employed post hoc to identify any differences between the feedback groups at all stages of the task.

Between-groups differences

Several personality variables (self-efficacy, extraversion, agreeableness, conscientiousness, neuroticism and openness) were tested for between-group effects as potential covariates. A series of independent *t*-tests were performed on the scores for the five personality factors from the OCEAN questionnaire as well as on the ratings of self-efficacy; the results were not significant, i.e. there was no difference between feedback groups with respect to these personality variables.

Task performance

Performance was quantified via several variables to represent each subtask of the MATB, specifically: (a) RMS error was used to represent tracking error, (b) the deviation from the target value of 2,500 was measured to assess performance on the fuel management task and gauge monitoring performance was measured via both (c) accuracy (%hits/total number of responses) and (d) reaction time. All MATB performance variables were then standardised using a z-baseline procedure, i.e. *zbase = (score − group mean from initial period of performance/ standard deviation of group scores from initial period of performance)*. This approach was adapted from the z-change score reported by Temple et al.(2002), specifically, the initial period of performance (Block A) was used to standardise indices of performance error across the three MATB sub-tasks.

A 2 × 4 × 4 MANOVA (Group × Performance variable × Task block) was carried out on the transformed performance data. Apart from a significant difference between Performance variables [F (3,34) = 17.70, $P = < 0.001$], there were no other significant differences or interactions.

Self-report data

All DSSQ and NASA-TLX components were converted to change scores prior to analysis. That is, raw scores for Task block A (performed before any feedback of performance is given) were subtracted from the raw scores of all subsequent Task blocks, i.e. Task blocks B to E minus Task block A. Mean values for each DSSQ and TLX component of subjective state are shown in Table 1.

Analysis of the subjective workload index (NASA-TLX) revealed a significant interaction between performance feedback Group and Task block [F (3,37) = 5.95, $P = 0.001$], i.e. subjective workload was higher for the failure feedback group. Post hoc *t*-tests illustrated a significant difference between groups for all but the first task block [Task block C: t (37) = 2.03, $P = 0.049$; Task block D: t (37) = 2.25, $P = 0.030$; Task block E: t (37) = 3.20, $P = 0.003$]. When the sub-components of the TLX were analysed separately, effort ratings were higher for the failure group than the success group as indicated by: a significant interaction (Group × Task block, [F (3,36) = 3.14, $P = 0.028$]); a significant between-group difference

Table 1 Z-Change means and standard errors in brackets for the DSSQ and TLX components across four blocks of task activity

	Group	Block B	Block C	Block D	Block E
Energetical arousal	Success	0.45(0.59)	0.25(0.64)	0.15(0.75)	−0.15(0.82)
	Failure	0.80(0.59)	−0.35(0.64)	−1.20(0.75)	−2.60(0.82)
	$P < 0.05$				**
Tense arousal	Success	−0.70(0.74)	−1.95(0.85)	−2.60(0.89)	−3.45(0.88)
	Failure	−0.70(0.74)	0.25(0.85)	−0.10(0.89)	0.40(0.88)
	$P < 0.05$				**
Hedonic tone	Success	0.17(0.78)	1.67(0.56)	1.50(0.78)	1.67(0.63)
	Failure	0.35(0.74)	−1.50(0.53)	−2.05(0.74)	−2.95(0.60)
	$P < 0.05$		**	**	**
Motivation	Success	0.50(0.38)	−0.13(0.39)	0.00(0.48)	−0.23(0.57)
	Failure	0.10(0.38)	−0.30(0.39)	−0.60(0.48)	−1.93(0.57)
	$P < 0.05$				**
Confidence and control	Success	0.35(0.49)	0.65(0.43)	0.70(0.47)	1.60(0.62)
	Failure	0.32(0.50)	−0.37(0.44)	−0.90(0.48)	−2.00(0.64)
	$P < 0.05$			**	**
TLX effort	Success	−1.10(2.11)	−1.55(2.03)	−0.50(2.23)	−3.30(2.07)
	Failure	−0.44(2.23)	5.5(2.14)	6.44(2.36)	5.22(2.18)
	$P < 0.05$		**	**	**
TLX performance	Success	−0.74(3.32)	0.26(3.62)	6.37(2.76)	5.11(3.36)
	Failure	2.42(3.32)	0.32(3.62)	−2.05(2.76)	−2.05(3.36)
	$P < 0.05$			**	
TLX physical demand	Success	0.60(2.51)	1.20(3.12)	6.00(3.44)	−0.35(3.06)
	Failure	4.35(2.51)	6.55(3.12)	9.60(3.44)	10.70(3.06)
	$P < 0.05$				**
TLX temporal demand	Success	1.20(2.06)	−1.40(2.99)	−0.75(2.99)	−0.95(2.92)
	Failure	4.55(2.06)	7.10(2.99)	6.90(2.99)	10.85(2.92)
	$P < 0.05$				**
TLX frustration	Success	1.30(3.29)	2.25(2.72)	1.30(3.23)	−2.30(3.71)
	Failure	1.11(3.38)	7.16(2.79)	5.00(3.31)	9.79(3.80)
	$P < 0.05$				**
Total TLX	Success	1.18(1.50)	0.67(1.61)	0.17(1.64)	−2.27(1.74)
	Failure	1.75(1.54)	4.76(1.66)	5.33(1.69)	5.69(1.78)
	$P < 0.05$		**	**	**

'**' refers to a significant difference between groups ($P < 0.05$) as revealed by the independent *t*-tests at each stage of the task

[F (1,36) = 5.16, $P = 0.029$]; and subsequent *t*-tests for blocks C, D and E [Task block C: t (36) = 2.35, $P = 0.026$; Task block D: t (36) = 2.14, $P = 0.039$; Task block E: t (36) = 2.83, $P = 0.008$]. The analysis of TLX physical demand only revealed a main effect for Task block [F (3,38) = 3.21, $P = 0.026$]; physical demand showed a general increase for both groups up until the last block wherein ratings of physical demand decreased for the success group (as revealed by the *t*-test at block E [t (38) = 2.55, $P = 0.015$]). There were also significant interactions between performance feedback Group and Task block for the following components: perceived performance [F (3,36) = 4.01, $P = 0.016$]; frustration [F (3,37) = 2.91, $P = 0.038$]; and temporal demand [F (3,38) = 3.75, $P = 0.013$], temporal demand also demonstrated a significant between-groups difference [F (1,38) = 4.76, $P = 0.035$]. To summarise, increased subjective workload was reported by the failure feedback group who reported higher levels of effort, temporal demands and frustration; unsurprisingly, this group also rated their own performance as poorer than the success feedback group (see Table 1).

The analysis of the motivation scale demonstrated a significant main effect for Task block [F (3,38) = 8.51, $P = < 0.001$], in addition to a marginal interaction between performance feedback Group and Task block [F

(3,38) = 3.03, $P = 0.058$]. Motivation exhibited a general decline over time for both groups, but this decline was pronounced for the failure group during the last block of performance. This effect is supported by a post hoc *t*-test analysis which indicates a difference between groups for the last block of the task [Task block E: $t\ (38) = -2.09$, $P = 0.043$] (see Table 1).

The analyses of Control and Confidence revealed a respective increase and decrease for the success and failure feedback group over each successive task block (see Table 1). This was demonstrated by a significant interaction between performance feedback Group and Task block [$F\ (3,37) = 9.74$, $P = < 0.001$], as well as a significant between-group difference [$F\ (1,37) = 6.96$, $P = 0.012$]. Subsequent *t*-tests yielded a significant difference between groups for the last two task blocks [Task block D: $t\ (37) = -2.38$, $P = 0.023$; Task block E: $t\ (37) = -4.05$, $P = < 0.001$] for Confidence and Control. With respect to mood, Energetic Arousal (EA) (i.e. alert-tired) displayed a significant main effect for Task block [$F\ (3,38) = 7.26$, $P = 0.001$] and was observed to decline across successive blocks (see Table 1). However, there was also a significant interaction between performance feedback Group and Task block [$F\ (3,38) = 3.60$, $P = 0.024$], whereby energetic arousal remained relatively stable for the success feedback group but declined for the failure group; further analyses of EA using *t*-tests confirm a significant difference between groups for the last block of the task [Task block E: $t\ (38) = -2.12$, $P = 0.041$]. The analysis of Hedonic Tone (HT) (i.e. happy-sad) revealed a significant interaction between performance feedback Group and Task block [$F\ (3,36) = 10.01$, $P = < 0.001$], i.e. HT showed a respective increase and decrease from the first period of the task for the success and failure feedback groups. HT also continued to decline for the failure feedback groups as demonstrated by a significant between group difference [$F\ (1,36) = 13.23$, $P = 0.001$] (see Table 1). Subsequent *t*-tests illustrated a significant difference between groups for all but the first task block [Task block C: $t\ (36) = -4.11$, $P = < 0.001$; Task block D: $t\ (36) = -3.32$, $P = 0.002$; Task block E: $t\ (36) = -5.34$, $P = < 0.001$]. Finally, the analyses revealed a decrease in Tense Arousal (TA) (i.e. tense-relaxed) for the success feedback group unlike the failure feedback group, for whom TA remained higher and stable in comparison. This was demonstrated by a significant interaction between performance feedback Group and Task block [$F\ (3,38) = 5.30$, $P = 0.002$], as well as a significant between group difference (i.e. failure vs. success feedback) [$F\ (1,38) = 4.35$, $P = 0.044$]. Subsequent *t*-tests revealed a significant increase of TA for the failure feedback group at task block E [Task block E: $t\ (38) = 3.10$, $P = 0.004$].

Psychophysiological variables

All psychophysiological data were converted to change scores in the manner described above, (i.e. Task blocks B to E minus Task block A).

Cardiovascular data

A univariate analysis of IBI revealed a near significant interaction between performance feedback Group and Task block [$F\ (3,35) = 2.82$, $P = 0.058$]. This interaction reflected a pattern wherein heart rate remained stable for both feedback groups up until the last task block E, when heart rate decreased (i.e. IBI is increased) for the failure feedback group only ($M = 0.018$), in comparison with the success feedback group ($M = 0.006$).

The IBI from the ECG was subsequently subjected to FFT analysis utilising the dedicated software module available in AcqKnowledge 3.9 (BIOPAC Systems). This yielded total power values for both the mid-frequency 0.07–0.14 Hz bandwidth (the 0.1 Hz component, also referred to as sinus arrhythmia) and the high-frequency 0.15–0.40 Hz bandwidth (vagal tone). Both variables were subjected to a Natural Log transformation prior to analysis via 2 × 2 × 4 MANOVA (Group × HRV variable × Task block). This analysis revealed a near between group difference [$F\ (1,34) = 3.16$, $P = 0.084$], whereby power for both variables is higher for the failure feedback group). Subsequent *t*-tests illustrated a significant difference in vagal tone between groups for the third (penultimate) task block [$t\ (34) = -2.063$, $P = 0.047$]. The findings for vagal tone are illustrated in Fig. 2.

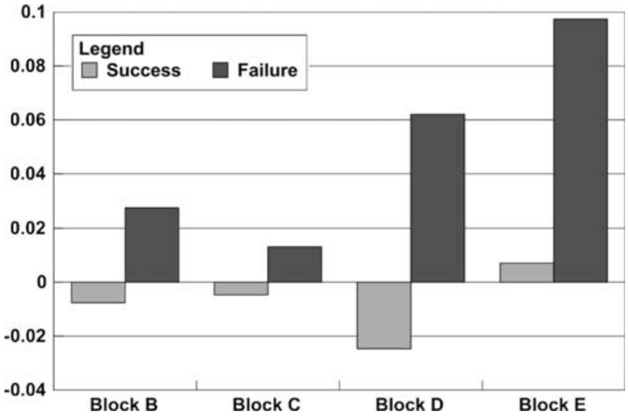

Fig. 2 Mean values for vagal tone (expressed as a change from baseline) for both performance feedback groups across four blocks of task activity

Blood pressure data

Surprisingly, the 2 × 4 × 2 MANOVA (Group × HRV variable × Task block) procedure performed on the two blood pressure variables—diastolic and systolic blood pressure—revealed no significant differences.

SCL data

The data for SCL revealed a significant main effect for Task block [$F\ (3{,}35) = 3.82$, $P = 0.031$], although there was also a near significant between-group difference [$F\ (1{,}35) = 3.67$, $P = 0.064$]. That is, skin conductance decreased for both groups with each successive task block, however, the overall level of SCL remained higher (and more stable) for the failure feedback group. This trend is illustrated in Fig. 3. This interaction was confirmed by a post-hoc *t*-test analyses that revealed a near significant difference between groups for the last task block [$t\ (35) = -1.96$, $P = 0.058$].

EEG alpha data

Alpha activity (8–13 Hz) from the EEG was calculated for each block of MATB activity using the FFT and correction for eye movement artifacts described in section "Procedure". These data were subsequently baselined using Block A to correct for between-group differences prior to the presentation of performance feedback, i.e. alpha power during Blocks B–E were subtracted from alpha power during Block A. Alpha power was calculated in terms of three regions (Frontal, Central, Parietal) and left/right hemispheres. These data were subjected to a 2 × 3 × 2 × 4 ANOVA (Group × EEG region × EEG hemisphere × Task block). Data from five participants were identified as outliers and were omitted from this analysis. The ANOVA revealed two interaction effects: Task block × Group [$F(3{,}31) = 3.09$, $P = 0.05$] and EEG hemisphere × Task block × Group [$F(3{,}31) = 4.23$, $P < 0.05$].

Post-hoc testing on the Task block × Group interaction revealed that alpha levels were significantly lower for the failure feedback group during Block C ($M = -0.013$) and Block E ($M = -0.017$) compared to the success feedback group ($M = 0.014$ and 0.026, respectively) ($P < 0.05$). Post-hoc testing on three-way interaction between EEG hemisphere × Task block × Group revealed that alpha activity was significantly reduced for the failure feedback group compared to the success feedback group, but only during Block E and specifically for EEG sites in the left hemisphere (F3, C3, P3). This effect is illustrated in Fig. 4.

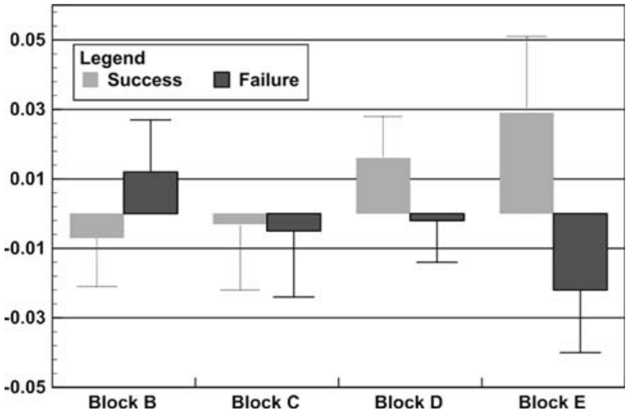

Fig. 4 Mean values for EEG alpha activity for all three sites on the left side of the hemisphere (F3, C3, P3), (expressed as a change from baseline) for both performance feedback groups across four blocks of task activity

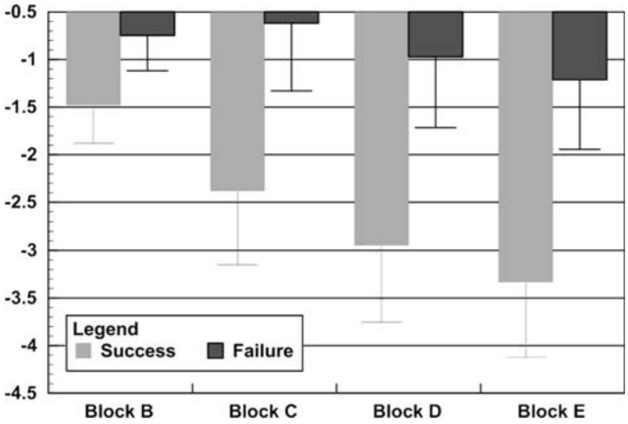

Fig. 3 Mean values for skin conductance level (expressed as a change from baseline) for both performance feedback groups across four blocks of task activity

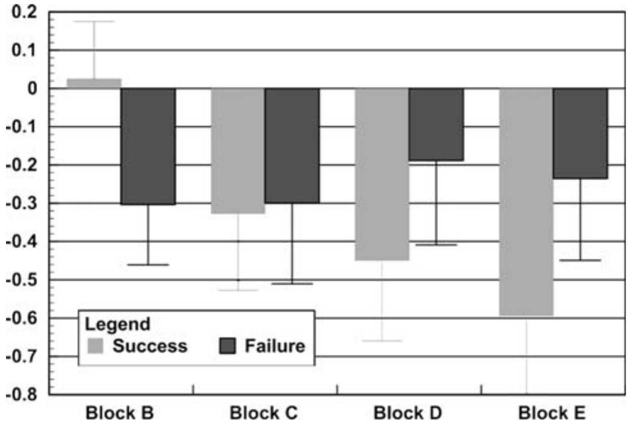

Fig. 5 Mean values for Corrugator muscle activity (expressed as a change from baseline) for both performance feedback groups across four blocks of task activity

fEMG data

The data for facial EMG i.e. muscular activity recorded from the corrugator supercilii and the zygomaticus major, were not correlated and each variable was analysed separately via a 2 × 5 (Group × Task block) ANOVA. The analysis of the corrugator data revealed a significant interaction between performance feedback Group and Task block [F (3,36) = 4.73, $P = 0.016$]. Corrugator activity shows a somewhat linear decline for the success feedback group, in contrast to the failure feedback group for whom corrugator activity is much more stable as illustrated in Fig. 5. No significant differences were found for zygomatic activity.

Discussion

The current study manipulated the perception of ability and task demand by providing performance feedback of increasing success or progressive failure. Feedback was believed to be an accurate reflection of performance by participants. Therefore, participants who received feedback of failure rated subjective task workload as higher and their own performance to be of lower quality compared to the success feedback group (Table 1)—hence, we can have confidence that the feedback manipulation altered the perception of task demand and performance quality, as well as influencing the perception of task success in the long-term.

The study employed several psychophysiological markers of effort mobilisation to discriminate between both feedback groups. Markers of sympathetic activation, e.g. systolic blood pressure (SBP) and SCL provided contradictory patterns; no significant effect was observed for SBP whilst SCL remained higher for the failure feedback group (i.e. SCL was less resistant to habituation following repeated feedback of failure; Fig. 3).

The combination of vagal tone and SCL provide some evidence of an autonomic mode (e.g. Berntson et al. 1991, 1993) where both branches of the ANS are coactivated (i.e. these autonomic variables describe different modes of autonomic control). For instance, the failure group showed a gradual decline in parasympathetic inhibition from Block B to Block E (vagal tone: Fig. 2) in combination with declining sympathetic activation (SCL: Fig. 3), i.e. an uncoupled pattern of autonomic regulation. However, the EEG data provided some confirmation of higher mental effort investment for those participants in the failure feedback group. A suppression of alpha activity was apparent for failure participants, particularly in left hemispheric sites during the latter stages of the task, which was indicative of greater electrocortical activation (Fig. 5). This pattern of EEG activity indicated increased effort mobilisation for the failure group. Alternatively, the left-hemispheric activation could indicate an approach orientation (see Coan and Allen 2004).

It is important for future research to address the issue of coherence between markers of mental effort in the service of cognitive goals. The 0.1 Hz component of HRV didn't make significance as expected (although the data indicated a rise of power in the 0.1 Hz bandwidth for the negative feedback group—indicative of effort conservation—during the latter period of performance, it failed to significantly distinguish between the positive and negative feedback groups). Furthermore, there were no significant changes in systolic blood pressure for either of the feedback groups, which was unexpected. A fall in systolic blood pressure has been observed by Wright and Dill (1993) when a person disengages from a cognitive task. It is likely that the timing of the blood pressure measurements may have impaired the data collected (i.e. played down the impact of the failure feedback manipulation); e.g. recordings perhaps need to be taken during the task or on receipt of feedback, rather than pre- or post-task performance. (Unfortunately, the BP monitoring equipment was not automatic; a measure of BP mid-session would have been too much of an intrusion to performance). A further possibility for the null findings might be due to the fact that blood pressure was measured directly by the experimenter, perhaps resulting in "white coat hypertension" (evaluation apprehension), thereby elevating blood pressure for participants in both feedback groups.

Analysis of the subjective data demonstrated the expected changes in affect associated with success and failure feedback; specifically, reports of task success or failure resulted in respective positive and negative changes in affect (Kluger et al. 1994; Podsakoff and Farh 1989) (i.e. see HT data in Table 1). This is supported by activity over the corrugator supercilii (which 'knits the brow': Fridlund and Cacioppo 1986) and is associated with the experience of negative affect. The analysis of corrugator muscle activity revealed a linear decline for the success feedback group (Fig. 5), whereas corrugator activity remained relatively stable for the failure feedback group. This suggests that success feedback reduced the level of negative affect associated with complex, cognitive performance. Provided that participants believe success is possible, the observed negative affect for the failure group may have played a role in mobilising effort investment in an attempt to compensate for perceived failure (e.g. Hockey 1997).

Motivational intensity theory (e.g. Wright and Brehm 1989) would predict a decline of effort for the failure group once it became apparent that success was unlikely. We found little evidence of this pattern: our data revealed no influence of success/failure feedback on performance quality, and there was a marginal increase in sympathetic activation (i.e. SCL was less resistant to habituation following repeated feedback of failure; Fig. 3) for the failure participants. This is in conjunction with alpha suppression in left hemispheric sites, which was indicative of greater electrocortical activation. These results were consistent with Hockey's cognitive-energetical model (1997) in most respects, i.e. participants in the failure group attempted to compensate for perceived failure (i.e. lower performance quality, reduced confidence in ability, reduced likelihood of success in the future) by investing higher levels of mental effort in order to minimise the discrepancy between performance and goals. It should be noted that little evidence was found of effort mobilisation or the up-regulation of goals in response to feedback of success although interpretation of the data suggests that participants in this group experienced higher positive affect and sustained motivation in a subjective sense, but the psychophysiological data suggests that they actually invested lower levels of mental effort.

However, there is some convergence between Hockey's framework and motivational intensity theory; the strategy of compensatory effort investment cannot continue indefinitely and will eventually lead to effort reduction as perceived difficulty surpasses the maximum capability of the participant (as predicted by motivational intensity theory). Whilst our data demonstrated that participants had not yet "given up", the findings for autonomic activity suggest that feedback of failure was veering participants towards a downward goal adjustment, (e.g. the cardiovascular data (HR, vagal tone) suggests that energy mobilisation at the autonomic level declined for the failure feedback group during the latter phase of the task. In addition, there is some evidence from the subjective scales (Table 1) that the failure group may have been on the point of abandoning the task after Block E. Participants in both groups experienced a general decline in motivation, which is likely to be a consequence of time-on-task, however, the reduction in motivation was much greater for the failure feedback group during the last task block. Therefore, there is an open question about whether motivational intensity theory would have been supported if task had continued beyond Block E. Those who received repeated failure performance feedback also exhibited a reduction in energetic arousal, and confidence and control, which further supports this assumption.

The current study aimed to extend the range of variables that can be used to operationalise effort investment. This led to conflicting results and was arguably only moderately successful. For instance, the manipulations had no influence with respect to activity at the zygomaticus major (which 'pulls the lip corner up and back': Fridlund and Cacioppo 1986, and is traditionally associated with the experience of positive affect). However, it has been suggested that activity over the zygomaticus muscle is less reliable than the corrugator muscle; (which exhibits a stronger linear effect of valence), i.e. it is less generalisable across different modes of (affective stimuli) presentation, it has also shown responsitivity to aversive stimuli, and may serve no real purpose in a non-social context such as a laboratory (see Larsen et al. 2003).

The range of psychophysiological variables used in the current investigation may have been improved by including additional measures such as cortisol. Cortisol is a neuroendocrine measure known to be implicated in situations that induce effort and distress (Frankenhaeuser 1978), and as such might provide an alternative context in which to interpret the degree of disengagement from the task and withdrawal of effort, (i.e. abandonment of goals due to ineffective coping). In addition, it would have been interesting to extend the recording of all psychophysiological measures; obtaining psychophysiological data not only during task performance, but also at the point when performance feedback was presented to the participant. Another weakness of the current study is that it was difficult to reliably assess the impact of performance feedback per se, relative to feedback of success or failure. In retrospect, the inclusion of a control group where no feedback was provided, as well as a feedback group for whom performance neither improved nor deteriorated (as used in the original study by Bandura and Jourden 1991) would have improved the sensitivity of the design.

The levels of performance feedback in the present investigation were selected via pilot testing with the main criterion being the credibility of feedback, hence increments and decrements of performance fell in a short 10% range. It would be interesting to extend this methodology to consider greater magnitude of performance change in order to increase the impact of feedback on motivation and emotion. However, this would require careful planning as to not arouse the suspicions of participants. Within the post-experiment debrief during the current study, none of the participants reported any conscious disbelief or skepticism as far as the feedback presented to them was concerned. Nevertheless, Ilies and Judge (2005) presented the argument that different mechanisms may exist for responses to real versus manipulated feedback, and these may have differential effects on subsequent goals (Ilgen et al. 1979; Podsakoff and Farh 1989, cited in Ilies and Judge 2005).

In conclusion, the current study was designed to study the dynamics of the motivational intensity model using false performance feedback of progressive success or failure. As predicted, the success group experienced positive affect in response to a perception of successful achievement. In contrast,—as hypothesised—the failure participants experienced negative effect in combination with reduced ability appraisal and an elevated perception of task demands. However, the willingness to invest effort into the task was not greatly affected by the failure feedback and participants in the failure group chose to invest effort in order to compensate for perceived failure (Hockey 1993, 1997). The experience of repeated failure led to adverse changes in mood/motivation, but did not lead to the absolute withdrawal of effort, although trends in the psychophysiological data suggest that participants in the failure group were on the verge of disengaging from the task.

This research highlights the importance of using a multidimensional approach—i.e. assessments of subjective state and (continuous, covert) measures of psychophysiology (e.g. sympathetic/parasympathetic ANS and CNS), in addition to objective measures of performance quality—to assess dynamic changes in motivational state (e.g. commitment to goals) and mental effort investment. Furthermore, the investigation of *dynamic* motivational intensity (compared to static/discrete manipulations) suggests, unsurprisingly, that a more complex perspective is required to fully understand and describe the mechanisms underlying goal-setting and effort regulation.

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