Is the Relationship of RPE to Psychological Factors Intensity-Dependent?

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ABSTRACT

HALL, E. E., P. EKKEKAKIS, and S. J. PETRUZZELLO. Is the Relationship of RPE to Psychological Factors Intensity-Dependent? *Med. Sci. Sports Exerc.*, Vol. 37, No. 8, pp. 1365–1373, 2005. **Purpose:** Although ample evidence shows that ratings of perceived exertion (RPE) are correlated with psychological variables, whether and how these relationships change as a function of exercise intensity remains unclear. The purpose of this study was to examine the correlations of RPE with both dispositional (extraversion, neuroticism, behavioral activation, behavioral inhibition) and situational (self-efficacy) psychological variables across three exercise intensities. Based on the social-psychophysiological model proposed by Rejeski, it was hypothesized that the correlations would be weakened as the intensity increased. **Methods:** Thirty young and healthy volunteers participated in three 15-min treadmill runs, one 20% $\dot{V}O_{2max}$ below, one at, and one 10% $\dot{V}O_{2max}$ above the ventilatory threshold. RPE was assessed at minutes 3, 6, 9, 12, and 15. **Results:** Extraversion, behavioral activation, and self-efficacy showed significant negative correlations with RPE at lower but not higher intensities, whereas neuroticism was unrelated to RPE and behavioral inhibition was positively related across all three levels of intensity. **Conclusions:** The results provide partial support to the hypothesis that the relationship of dispositional and situational psychological factors to RPE changes systematically, becoming weaker at higher exercise intensities. This may have implications for the effectiveness of personality-based adjustments of exercise prescriptions and cognitive techniques for dealing with aversive sensations of exertion. **Key Words:** EXTRAVERSION, NEUROTICISM, BEHAVIORAL ACTIVATION, BEHAVIORAL INHIBITION, SELF-EFFICACY, VENTILATORY THRESHOLD

One of the greatest challenges for research on perceived exertion has been to develop a conceptual model that functionally integrates the two broad clusters of known correlates of exertion ratings, namely the physiological and the psychological. Such integration would be consistent with Borg's (2,3) conceptualization of ratings of perceived exertion (RPE) as a psychophysiological construct. RPE has been shown to relate to several physiological variables, including heart rate, ventilation, respiration rate, oxygen uptake, and blood lactate among others (8,19,25,26). Likewise, RPE has been found to relate to both dispositional and situational psychological factors (17–19). An important issue that remains unresolved is whether and how the relative contributions of these two clusters of correlates vary across the range of exercise intensity.

Several conceptual models have proposed ways to integrate the contributions of both physiological and psychological factors (19,26) but have not considered the moderating role of exercise intensity. An exception is a model proposed by Rejeski (21,22,24). According to this model, "cognitive variables should be expected to influence [perceived exertion] most when the sport/physical task in question is performed at, or has physiological demands of, a submaximal nature" (21; p. 314). Beyond this submaximal level, "there is a point in the physical stress of exercise at which sensory cues, due to their strength, dominate perception. Under such conditions, it is unreasonable to expect mediation by psychological factors" (22; p. 372). It is unreasonable because "powerful metabolic changes may preclude cognitive manipulations from enabling someone to continue an activity" (24; p. 18). The available evidence has provided support for the model. On the one hand, correlations between ratings of perceived exertion and physiological variables seem to get stronger as the intensity of exercise increases (e.g., 4,29). On the other hand, the association of RPE with psychological factors appears to get weaker as the intensity of exercise increases. For instance, the expectation of a longer versus shorter exercise duration was shown to lead to significantly lower RPE up to the 15th minute but not during the final 5 min of a demanding 20-min run at 85% of maximal aerobic

capacity (23). Also, contrary to exercise at 60% and 75% of maximal heart rate, attentional manipulations by means of music and sensory deprivation had no effects on RPE at 85% of maximal heart rate (5). Similarly, the presence of a coactor appeared to be associated with suppressed perceptions of exertion at 25% and 50%, but not at 75% of maximal aerobic capacity (14).

The present study is a test of the model proposed by Rejeski (21,22) that extends the previous research in three important ways. First, we examine the relationship of RPE to self-efficacy, a situational variable of key significance within the social-cognitive theoretical framework (1). Self-efficacy has been found to be negatively related to RPE (15,20,27), but, although it has been proposed that this relationship should vary in magnitude as a function of exercise intensity in a manner consistent with Rejeski's model (15,16), this hypothesis has yet to be tested.

Second, we examine whether the relationship of RPE to key theoretically relevant personality variables, namely extraversion, neuroticism, behavioral activation, and behavioral inhibition, also follows the pattern hypothesized by Rejeski's model. The dimension of introversion–extraversion is thought to reflect arousal in the reticulo–cortical circuit. Introverts are theorized to have higher levels of cortical arousal than extraverts. Therefore, extraverts would be likely to seek out sensory stimulation to increase cortical arousal, whereas introverts would tend to avoid sensory stimulation in an effort to decrease cortical arousal (12). Consistent with these theoretical postulates, previous research has found that extraversion is negatively related to RPE (17,18), although whether this relationship varies systematically as a function of exercise intensity is still unknown. The evidence linking neuroticism and RPE is less clear. The stability–neuroticism dimension is associated with arousal in the reticulo–limbic circuit. Individuals high in neuroticism are believed to have high arousability of the reticulo–limbic circuit, making them more likely to respond to emotional stimulation with greater intensity (12). Neuroticism is a variable closely related to trait anxiety and generally entails a predisposition toward negative appraisals of situational demands. As such, it would be expected to show a positive relationship to RPE. However, both positive and negative relationships have been reported in the literature (17,18). Furthermore, in this study, we also examine constructs outside of, but conceptually related to, Eysenck's theory of personality. Specifically, Gray (13) has proposed that the dimensions of behavioral activation and behavioral inhibition (considered rotational variants of Eysenck's dimensions of extraversion and neuroticism) represent manifestations of the approach and avoidance motivational systems, respectively. Based on Gray's conceptualization of these dimensions, individuals high in approach motivation (i.e., with high behavioral activation) should exhibit a tendency to underestimate RPE, whereas those high in avoidance motivation (i.e., with high behavioral inhibition) should exhibit a tendency to overestimate RPE. Gray proposed that BIS and BAS have different underlying biological mechanisms. The mechanisms underlying the BIS are

the septohippocampal system, its monoaminergic afferents from the brain stem, and its projection to the frontal lobe. Although the physiological underpinnings of the BAS are not clearly understood, it is thought to be regulated by catecholaminergic (especially dopaminergic) pathways (7,13).

Third, unlike previous studies in which exercise intensity was operationally defined in terms of percentages of maximal capacity, in the present study we chose to define exercise intensity in relation to the ventilatory threshold as an index of the transition from an intensity that can be maintained through aerobic metabolism to an intensity that requires anaerobic supplementation (i.e., the so-called anaerobic threshold). Recall that Rejeski proposed that the influence of psychological factors on RPE begins to diminish beyond a level of exercise intensity at which "sensory cues, due to their strength, dominate perception" (22; p. 372). We believe that this level of intensity can be specified as the level that corresponds to the ventilatory threshold, as exceeding this threshold is accompanied by an amplification of several peripheral physiological signals that contribute to RPE (i.e., ventilation, respiratory rate, blood lactate, pH). Perhaps as a result of this amplification, exertion ratings corresponding to the ventilatory threshold have been found to be stable (in the 12–14 range) and unaffected by exercise modality, age, sex, or training status (19,25,26).

The hypotheses examined in the present study were that (a) self-efficacy, extraversion, and behavioral activation would be negatively related with RPE, whereas neuroticism and behavioral inhibition would be positively related; and (b) as exercise intensity increases, the magnitude of the correlations between all psychological variables and RPE would decrease.

METHODS

Subjects

Thirty (14 women, 16 men) college-age volunteers participated in the study. The participant characteristics are presented in Table 1. All participants signed IRB-approved informed consent forms and certified that they had undergone a physical examination within the past year that revealed no conditions for which vigorous exercise would be contraindicated. Moreover, the participants were deemed "apparently healthy" after completing the Physical Activity Readiness Questionnaire (30) and a medical history questionnaire, stating that they had no known cardiovascular, metabolic, respiratory, musculoskeletal or mental conditions that might put them at risk during exercise.

TABLE 1. Descriptive statistics (mean $\pm$ SD) for the demographic, anthropometric, and physical fitness characteristics and of the participants.

	Men (N = 16)	Women (N = 14)
Age (yr)	21.50 ± 2.45	21.21 ± 2.04
Height (cm)	182.17 ± 5.00	167.28 ± 9.14
Weight (kg)	78.50 ± 9.20	60.59 ± 6.63
$\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1})	56.59 ± 7.27	47.71 ± 7.61
VT (%$\dot{V}O_{2max}$)	77.37 ± 5.43	77.00 ± 4.61

Measures

Ratings of perceived exertion (RPE). Perceived exertion was assessed with Borg's (2,3) RPE. The RPE is a 15-point single-item scale ranging from 6 to 20, with anchors ranging from "No exertion at all" to "Maximal exertion." A meta-analysis of validity data has shown that the RPE exhibits the following weighted mean validity coefficients with physiological indices of intensity: 0.62 for heart rate, 0.57 for blood lactate, 0.64 for percentage of maximal aerobic capacity, 0.63 for O_2 consumption, 0.61 for ventilation, and 0.72 for respiratory rate (8). The standard instructions were used (given to the participants in written form to study before exercise began).

Self-efficacy. Self-efficacy (1) is a concept relevant only to specifically delineated tasks, so it is assessed by task-specific rather than domain-general measures. In the present study, self-efficacy was assessed as the participants' belief in their capability to continue exercising for incremental 2-min periods "beyond the point at which exercise starts to become challenging." The scale was constructed according to guidelines provided by Bandura (1). Eight items were used, ranging from "I believe I am able to continue for 2 min" to "I believe I am able to continue for 16 min." For each item, participants were asked to indicate their confidence on a 100-point scale comprised of 10-point increments (from 0%: "Not at all confident" to 100%: "Very confident"). The average of the eight-item scores was calculated and used as the self-efficacy score. Pilot testing of a six-item version of this scale in our laboratory had indicated acceptable internal consistency, with a value of Cronbach's alpha coefficient of 0.92.

Neuroticism and extraversion. Neuroticism and extraversion were measured with the Eysenck Personality Questionnaire (EPQ; 11). This is a 90-item scale that uses a "Yes/No" response format in conjunction with questions inquiring about one's feelings, thoughts, and behavior. The extraversion and neuroticism scales have been shown to have adequate 1-month test-retest reliability (0.89 and 0.86, respectively) when the effects of gender and age are removed (11). The scales have also been shown to have good internal consistency in both men and women, ranging from 0.84 to 0.85 (11).

Behavioral activation and behavioral inhibition. The Behavioral Inhibition System (BIS) and Behavioral Activation System (BAS) scales (7) consist of 20 items that measure the two primary dimensions proposed by Gray (13). Items are scored on a four-point Likert-type scale. The measure includes four multi-item subscales that assess sensitivities to signals of impending reward and punishment. The BIS consists of a single subscale measuring the anticipation of punishment, whereas the BAS consists of three subscales measuring drive, fun seeking, and reward responsiveness. Based on the results of second-order factor analyses showing that all three BAS subscales load on the same factor (7), the scores of the three subscales were summed to produce an overall BAS score. Previous research has shown that the BIS and BAS scales have acceptable psychometric properties (7).

Procedures

The participants visited the laboratory for five sessions, scheduled on different days. During the first session, the participants performed an incremental treadmill exercise test to determine maximal aerobic capacity ($\dot{V}O_{2max}$) and the ventilatory threshold (VT). Before testing, the O_2 and CO_2 analyzers (model OCM-2 Oxygen Uptake System, AEI Technologies, Pittsburgh, PA) were calibrated with gases of known O_2 and CO_2 concentration. The Respiratory Response Data Acquisition System software (ver. 3.51, Physio-Dyne Instrument Corporation, Massapequa, NY) was used to control the components of the metabolic cart and collect the data. Data were recorded for every breath and subsequently averaged over 30-s intervals, with the highest 30-s average designated as $\dot{V}O_{2max}$.

After each participant was given a detailed description of the procedures to be followed, he or she was fitted with a heart rate transmitter (model Smart Edge, Polar Electro Oy, Finland) and a face mask covering the nose and mouth (model 8920/30, Hans Rudolph, Kansas City, MO). A gel sealant (model 7701, Hans Rudolph) was applied to the mask to ensure a leak-proof fit. The mask was equipped with a T-shaped nonrebreathing valve (model 2700, Hans Rudolph), which was, in turn, connected to the metabolic system via plastic tubing (35 mm in diameter). After a 5-min warm-up walk at 4.8 $km \cdot h^{-1}$ and 0% grade, the speed of the treadmill (model Q55xt, Series 90, Quinton, Seattle, WA) was increased to 8 $km \cdot h^{-1}$ (0% grade). Beyond this point, the workload was increased every minute by alternating between increases in speed by 0.8 $km \cdot h^{-1}$ and increases in grade by 1% (starting with an increase in speed). This procedure was continued until each participant reached the point of volitional exhaustion. In all cases, this was verified by at least two of the standard criteria for reaching $\dot{V}O_{2max}$, namely (a) reaching a peak or plateau in oxygen consumption (changes of less than 2 $mL \cdot kg^{-1} \cdot min^{-1}$) followed immediately by a decrease in consumption with increasing workloads, (b) attaining a respiratory exchange ratio equal to or higher than 1.1; and (c) reaching or exceeding age-predicted maximal heart rate (i.e., $220 -$ age). At the end of the first session, the participants were given copies of the EPQ and BIS/BAS, and were asked to complete and return them upon arrival for the next session.

The VT was determined offline using the procedure described by Davis et al. (10). This procedure entails plotting the ventilatory equivalents for oxygen ($\dot{V}_E/\dot{V}O_2$) and carbon dioxide ($\dot{V}_E/\dot{V}CO_2$) across work rates and identifying the point at which there is a systematic increase in $\dot{V}_E/\dot{V}O_2$ without a corresponding increase in $\dot{V}_E/\dot{V}CO_2$. The breakpoint was identified visually and agreed upon by two raters. The method of the ventilatory equivalents has been shown to lead to a determination of the VT that is more accurate compared to alternative graphical methods (6).

Based on the data collected from the graded treadmill test, three exercise intensities were determined in relation to VT: (a) 20% of $\dot{V}O_{2max}$ below VT (<VT), (b) at the VT (@VT), and (c) 10% of $\dot{V}O_{2max}$ above VT (>VT). Based on pilot testing, the >VT intensity was set at 10% above VT to limit the slope of the slow component of O_2 uptake and, thus, ensure that all participants would be able to complete the session despite the expected absence of a physiological steady state at this intensity.

The second session included a series of brief intensity verification trials. These were deemed necessary in order to avoid having the participants wear face masks for the collection of expired gases during the actual experimental trials. Because these masks slightly increase respiratory effort, they might have influenced the RPE. The specific goal of the trials was twofold. First, we identified treadmill speeds that achieved the desired levels of oxygen uptake while limiting the grade of the treadmill to level or near level (no more than 3%), in order to avoid large grade differences that could introduce a confound (due to differences in biomechanical patterns and muscle group involvement between individuals of different levels of fitness). Second, we verified that the three workloads determined on the basis of the graded treadmill protocol elicited the desired physiological responses when applied to constant work. During the second session, each participant ran on the treadmill for 5 min at each of the three intensities (<VT, @VT, >VT) while his or her ventilatory and heart rate responses were being monitored and adjustments were made if necessary. Between the 5-min runs, the participants were allowed to recover for as long as it was necessary for their heart rate to return to within 10 beats·min^{-1} of the preexercise value.

The third, fourth, and fifth sessions were the main experimental sessions. Identical procedures were followed in all three sessions with the exception of the intensity that was used in each. The order of exercise intensities was randomized using a computer algorithm. The participants were told that they might have to run at a "relatively low," a "moderate," or a "relatively high" intensity. However, to maintain the preexercise conditions constant across all three sessions, they were not told in advance the intensity that was selected for each session. Instead, they were told that the three sessions could include any combination of the three intensities, including the possibility that all three sessions would be performed at the same intensity.

The self-efficacy questionnaire was completed at the beginning of each session, before instrumentation. After being fitted with the heart rate transmitter, the participants warmed up by walking on the treadmill for 5 min at 4.8 km·h^{-1} and 0% grade. When the 5-min warm-up period was completed, the intensity was changed to the level that had been selected for the day. This intensity (speed and grade) was maintained constant for 15 min. The RPE was assessed during the last 15 s of minutes 3, 6, 9, 12, and 15 (last) by presenting the participants with a poster-size version of the scale and asking them to indicate their response either verbally or by pointing to the appropriate number. After a 5-min cool-

down walk and 20-min recovery period, the participants were released. At the completion of the 5-session series, the participants received a monetary compensation ($50) and were debriefed about the purposes of the study.

RESULTS

Manipulation checks. A 3 (intensity conditions) × 6 (time points: end of warm-up, minutes 3, 6, 9, 2, 15) repeated-measures ANOVA on the heart rate data showed a significant main effect of intensity condition [$F_{(2,54)} = 101.06$, $P < 0.001$], a significant main effect of time [$F_{(1.90, 51.25)} = 1797.65$, $P < 0.001$], and a significant intensity condition by time interaction, $F_{(3.35, 90.32)} = 38.62$, $P < 0.001$. The average heart rates (± SD) at the end of the runs (minute 15) were 162.14 ± 13.47, 172.77 ± 11.15, and 182.83 ± 10.67 beats·min^{-1} for the <VT, @VT, and >VT intensity conditions, respectively. All the pairwise comparisons between conditions at that time point (Bonferroni-corrected t-tests) were significant (for all, $P < 0.001$). Likewise, a 3 (intensity conditions) × 6 (time points: end of warm-up, minutes 3, 6, 9, 12, 15) repeated-measures ANOVA on the RPE data showed a significant main effect of intensity condition [$F_{(2,58)} = 70.99$, $P < 0.001$], a significant main effect of time [$F_{(2.08, 60.19)} = 225.64$, $P < 0.001$], and a significant intensity condition by time interaction, $F_{(5.23, 151.53)} = 28.32$, $P < 0.001$. The means and standard deviations for RPE are shown in Table 2. Although no conditions differed at the end of the warm-up, all the pairwise comparisons between conditions at the conclusion of each run were significant (for all, $P < 0.001$).

Psychometric analyses. The means, ranges, standard deviations, and Cronbach's alpha coefficients of internal consistency for self-efficacy and each of the personality variables are shown in Table 3. The alpha coefficients were within the acceptable range, with the exception of BAS, which was marginal at 0.64. Extraversion and neuroticism scores were similar to published norms (11). The means for BIS and BAS were also similar to those reported previously (7). The correlations between the psychological variables are shown in Table 4.

Hypotheses 1 and 2. The correlations of RPE with the personality variables and self-efficacy at each of the three exercise intensity conditions are shown in Table 5. The correlation coefficients for each variable were fairly consistent across the five time points within each intensity condition. This is important because the stability of correlational statistics can be of concern with small sample sizes (e.g., less than 100). With a sample size of 30, the critical

TABLE 2. Descriptive statistics (mean ± SD) for RPE in the three exercise intensity conditions.

	< VT	@VT	> VT
End of warm-up	6.67 ± 1.03	6.70 ± 0.92	6.77 ± 1.17
Minute 3	9.13 ± 1.80	10.77 ± 1.77	11.73 ± 2.03
Minute 6	9.93 ± 2.07	11.83 ± 1.68	12.93 ± 1.95
Minute 9	10.53 ± 2.29	12.37 ± 1.79	13.77 ± 1.99
Minute 12	10.80 ± 2.40	12.90 ± 1.90	14.63 ± 1.88
Minute 15	11.17 ± 2.17	13.53 ± 2.18	15.47 ± 2.15

TABLE 3. Descriptive statistics (mean ± SD), the possible and observed score ranges, and values of Cronbach's alpha coefficients of internal consistency for the personality variables and self-efficacy.

	Mean	Range (Observed)	Range (Possible)	SD	Alpha
Extraversion	15.15	7–20	1–21	4.22	0.82
Neuroticism	9.38	4–17	1–23	3.64	0.83
BIS	20.72	10–28	7–28	3.51	0.82
BAS	39.32	26–51	13–52	5.15	0.64
Self-efficacy (<VT)	68.21	9–100	0–100	22.01	0.96
Self-efficacy (@VT)	66.58	9–98	0–100	21.56	0.95
Self-efficacy (>VT)	64.67	10–94	0–100	23.27	0.96

difference for two correlation coefficients to differ to a statistically significant degree is 0.317. Except for one case (BIS in the >VT condition, where the correlation with RPE was 0.07 at minute 3 but was raised to 0.45, 0.46, and 0.45 at minutes 9, 12, and 15, respectively), the correlations of self-efficacy and the personality variables with RPE across the five time points within each of the three intensity conditions were not significantly different from each other. Therefore, the average correlations can be meaningfully used to summarize and interpret the results. The average correlations shown in Table 5 were derived by converting the correlation coefficients to Fisher's z, averaging the z, and finally back-transforming the z to r, as recommended by Silver and Dunlap (28), to address the problem of the average r underestimating the population correlation.

Extraversion was significantly correlated with RPE, in a consistently negative direction, during the <VT (r_{avg} = −0.44) and @VT (r_{avg} = −0.38) conditions, but at none of the time points during the >VT condition. On the other hand, neuroticism was not correlated with RPE at any time point during any of the intensity conditions. BAS was significantly correlated with RPE, in a consistently negative direction, during the <VT (r_{avg} = −0.32) but at none of the time points during the @VT and >VT conditions. On the other hand, BIS was correlated with RPE, in a consistently positive direction during all three intensity conditions, <VT (r_{avg} = 0.65), @VT (r_{avg} = 0.41), and >VT (r_{avg} = 0.35), although, as noted, the results were somewhat inconsistent during the >VT condition, with the correlation at minute 3 being significantly lower than those at minutes 9, 12, and 15. Finally, similar to Extraversion, self-efficacy was correlated with RPE, in a consistently negative direction, during the <VT (r_{avg} = −0.52) and @VT (r_{avg} = −0.49) conditions, but at none of the time points during the >VT condition.

DISCUSSION

Although the literature on perceived exertion contains ample evidence that RPE is associated with a multitude of physiological and psychological variables, how these influences interact and codetermine RPE is less clear and presents a considerable conceptual challenge. The present study was based on the fundamental assumption that the relationships of physiological and psychological variables with RPE are not stable but rather change systematically as a function of exercise intensity. This notion is based on previous efforts to integrate physiological and psychological factors into a conceptual model for RPE (19,26) and, in particular, the model proposed by Rejeski (21,22). Our hypotheses were that dispositional (extraversion, neuroticism, behavioral activation, behavioral inhibition) and situational (self-efficacy) variables would be correlated with RPE but also that these relationships would become weaker at higher levels of exercise intensity.

According to Eysenck's (12) theory of personality, extraverts prefer and seek out higher levels of sensory stimulation, presumably including exercise-associated bodily stimulation. Therefore, higher extraversion scores should be associated with lower RPE. The present results largely agree with previous findings (17). The correlations between extraversion and RPE were consistently negative across all three intensities examined. Additionally, however, the results supported Rejeski's (21,22) model, showing that the extraversion-RPE correlation was significant at lower (<VT, @VT) but not at higher (>VT) intensities. This is not consistent with the only other known investigation that has examined the extraversion-RPE relationship across different intensities. In a study involving nine men exercising on a cycle ergometer at five levels of resistance (300, 600, 900, 1200, and 1500 kpm) for 1 min each, Morgan (17) found that the relationship between extraversion and RPE was significant at the three higher intensities, namely 900 kpm (r = −0.62), 1200 kpm (r = −0.69), and 1500 kpm (r = −0.71) and not at the two lower, namely 300 and 600 kpm. Despite the apparent inconsistency, however, the methodological differences between the two studies are too many to consider the findings to be in direct contrast. Morgan's preliminary study involved a small sample (9 vs 30), a different exercise mode (cycle ergometry vs treadmill running), exercise bouts lasting for only 1 min (as opposed to 15) and conducted consecutively during the same session, absolute levels of intensity (as opposed to intensities deter-

TABLE 4. Pearson product–moment correlation coefficients between personality variables and self-efficacy.

	Extraversion	Neuroticism	BIS	BAS	Self-Efficacy (<VT)	Self-Efficacy (<VT)	Self-Efficacy (<VT)
Extraversion							
Neuroticism	−0.46*						
BIS	−0.45*	0.45*					
BAS	0.37	−0.10	−0.14				
Self-efficacy (<VT)	0.53**	−0.32	−0.58**	0.27			
Self-efficacy (@VT)	0.54**	−0.36	−0.54**	0.28	0.88**		
Self-efficacy (>VT)	0.43*	−0.15	−0.34	0.20	0.86**	0.77**	

*P < 0.05; **P < 0.01.

TABLE 5. Pearson product–moment correlation coefficients of RPE with personality variables and self-efficacy across the three exercise intensities.

	Minute 3	Minute 6	Minute 9	Minute 12	Minute 15	Average
<VT						
Extraversion	−0.35*	−0.46**	−0.39*	−0.46**	−0.51**	−0.44**
Neuroticism	0.02	0.13	0.14	0.23	0.29	0.16
BAS	−0.39*	−0.36*	−0.32*	−0.28	−0.22	−0.32*
BIS	0.49**	0.59**	0.64**	0.69**	0.79**	0.65**
Self-efficacy	−0.53**	−0.52**	−0.50**	−0.52**	−0.55**	−0.52**
@VT						
Extraversion	−0.32*	−0.39*	−0.44**	−0.34*	−0.40*	−0.38*
Neuroticism	0.11	0.12	0.07	0.07	0.21	0.12
BAS	−0.2	−0.12	−0.11	0.01	0.00	−0.08
BIS	0.26	0.35*	0.41*	0.45*	0.54**	0.41*
Self-efficacy	−0.40*	−0.57**	−0.52**	−0.49**	−0.48**	−0.49**
>VT						
Extraversion	0.09	−0.09	−0.07	−0.13	−0.28	−0.1
Neuroticism	−0.29	−0.18	−0.05	0.00	0.19	−0.07
BAS	−0.01	0.09	0.13	0.15	0.11	0.09
BIS	0.07	0.28	0.45**	0.46**	0.45**	0.35*
Self-efficacy	−0.07	−0.08	−0.12	−0.17	−0.25	−0.14

*$P < 0.05$; **$P < 0.01$; single-tail tests of significance were used due to the directional nature of the study hypotheses. For reference, for a sample size of 30, the cut-offs are 0.3061 (0.05, one-tail test), 0.4226 (0.01, one-tail test), 0.3610 (0.05, two-tail test), and 0.4629 (0.05, two-tail test).

mined in relation to the VT, thus taking into account individual differences in the transition from aerobic to anaerobic metabolism during exercise), and, importantly, the ratings on the RPE scale were given "immediately following each exercise bout" (as opposed to while the participants were still exercising and, thus, being continuously exposed to exercise-induced bodily cues). In our experience, especially the last observation might be particularly important, as responding to RPE while still active as opposed to retrospectively might critically change the nature of the response, relying much more on direct perception in the former case and on cognitive appraisal in the latter.

It should also be noted that, discussing the earlier finding in a more recent paper, Morgan (18) expressed the opinion that finding stronger negative correlations between extraversion and RPE at higher rather than lower intensities is to be expected. We should emphasize, however, that this view, which seems to contradict the predictions of Rejeski's (21,22) model, was based on statistical rather than conceptual considerations (i.e., does not constitute a critique or refutation of the conceptual premise of Rejeski's model). Specifically, Morgan (18) noted that "since the sensation of effort grows in a positively accelerated manner, one would not expect cognitive or personality factors to have a great deal of influence at lower power outputs," and this is due to the fact that "there is little variability in psychophysical judgments at low power outputs but there is considerable interindividual variability at higher power outputs" (p. 1073). In other words, stronger correlations at higher intensities should be expected because larger variance means less restriction in range and a higher probability of covariance with extraversion, assuming that a relationship is present. Although this is a reasonable statistical proposition, such a pattern was not observed within the range of exercise intensities employed in the present study. The size of the standard deviations grew as each exercise bout progressed (from the 3rd to the 15th minute), but there was no consistent difference in the size of the standard deviations at the

same time points across bouts performed at different intensities. For example, at the 15th (final) minute, the standard deviations in RPE were 2.17, 2.18, and 2.15 for <VT, @VT, and >VT, respectively. Importantly, however, there was no restriction in range either, so the absence of significant correlations at the >VT conditions cannot be attributed to the potential attenuating effect of range reduction and diminished score variance.

With respect to the Eysenckian dimension of neuroticism, we noted in the introduction that previously published results were conflicting. Morgan (17) reported the findings of a preliminary investigation, involving nine men who exercised on a cycle ergometer for 5 min at 50 rpm and 600 kpm. As in the aforementioned study on extraversion, the RPE ratings were obtained immediately after the exercise bout and not while the participants were still cycling. Morgan reported a significant negative correlation ($r = −0.69$), indicating that higher levels of neuroticism were associated with lower RPE. As discussed later by Morgan (18), this finding was somewhat perplexing and "not congruent with some theoretical expectations" (p. 1074). This is because, theoretically, persons with higher levels of neuroticism are expected to exhibit a tendency for exaggerated appraisals of challenging and potentially threatening stimuli, which also manifests itself as high trait anxiety. Furthermore, Morgan (18) noted that his "subsequent research, in which perceived exertion ratings were obtained during exercise, has *consistently* demonstrated that perception of effort is significant correlated in a *positive manner* with variables such as anxiety, depression, and *neuroticism*" (p. 1074; emphasis added). However, no further details of this research were provided. Nevertheless, in accordance with theory and this report of previous positive correlations, we also hypothesized that neuroticism and RPE would be correlated in a positive direction. However, in our study, the neuroticism–RPE relationship was consistently low and not statistically significant. Importantly, this absence of a reliable relationship cannot be attributed to a reduction in the range of neuroticism scores, as neither the range nor the standard deviation was lower than the corresponding values for extraversion. Therefore, particularly given the consistent absence of a relationship across multiple sessions and time points, we tend to believe that this was a substantive finding, delimited, of course, by the characteristics of the sample, the exercise stimuli, and the experimental procedures involved in the present study (e.g., absence of any elements of competition or social evaluation).

The literature contains no previous reports on the relationship of RPE with behavioral activation and inhibition, as conceptualized by Gray (13) and assessed by the BIS/BAS (7). According to Gray, the behavioral activation (or "behavioral approach") system underlies approach motivation (the movement toward one's goals) and is associated with sensitivity to reward, the pursuit of reward, and positive affect. On the other hand, the behavioral inhibition system underlies avoidance motivation (the inhibition of movement toward one's goals) and is associated with sensitivity to punishment and negative affect. Based on this conceptual-

ization, in the present study, we hypothesized that the BAS, a measure of behavioral activation, would be correlated with RPE in a negative direction, whereas the BIS, a measure of behavioral inhibition, would be correlated with RPE in a positive direction. Only the latter of these hypotheses was supported. In fact, the BIS showed some of the strongest correlations with RPE (as high as 0.79, 0.54, and 0.46 in the <VT, @VT, and >VT conditions, respectively). Conversely, the BAS-RPE correlations were lower and only reached significance inconsistently during the <VT condition. Thus, support from these findings for Rejeski's hypothesis is mixed. Although, BAS, as predicted, did correlate with RPE at lower (<VT) and not higher (@VT, >VT) levels of intensity, BIS, contrary to predictions, was correlated with RPE across all three intensity conditions. As this is the first study to examine BIS/BAS relationships with RPE, the reliability of these findings will have to await replication in future studies before any meaningful attempts at interpretation can be made.

Self-efficacy (1) produced consistently negative correlations with RPE at <VT and @VT and a consistent absence of significant correlations at >VT, thus lending clear support for our hypotheses. Both the direction (negative) and magnitude of the correlations between self-efficacy and RPE found in the present study (on average, $r = -0.52$ in <VT and $r = -0.49$ in @VT) are consistent with those previously reported in the literature. McAuley and Courneya (15) examined 88 men and women who participated in a graded cycle ergometer protocol and performed until they reached 70% of their age-predicted maximum heart rate. After controlling for fitness, body fat, age, gender, and affect, preexercise self-efficacy accounted for 3.1% ($P < 0.05$) of the variance in RPE at the conclusion of the protocol, whereas the bivariate correlation between self-efficacy and RPE was -0.22 ($P < 0.05$). Rudolph and McAuley (27) studied 50 young men who ran on a treadmill at 60% $\dot{V}O_{2max}$ for 30 min. After controlling for $\dot{V}O_{2max}$, preexercise self-efficacy accounted for 14% ($P < 0.001$) of RPE obtained at the 29th minute, whereas the bivariate efficacy–RPE correlation was -0.67 ($P < 0.001$). Finally, Pender et al. (20) studied 103 adolescent girls who participated in a 20-min bout of cycle ergometry at 60% $\dot{V}O_{2peak}$. RPE ratings were collected every 4 min and then averaged. After controlling for $\dot{V}O_{2peak}$ and body fat, preexercise self-efficacy accounted for 14% of the variance in average RPE, whereas the bivariate efficacy–RPE correlation was -0.41 ($P < 0.001$). Where the present study extends previous research is in examining how the relationship changes as a function of exercise intensity. Although previous studies only examined the relationship at a single level of intensity, generally considered "moderate" (i.e., 60–70% of max), we examined multiple levels including slightly lower and somewhat higher intensities. Commenting on this issue, McAuley and Courneya (15) had noted that the relationship between self-efficacy and RPE should be most strong at levels of exercise intensity that present an appreciable challenge (but without being overwhelming), such as 70% of max, and later McAuley et al. (16) added that, at even higher

intensities that generate inherently aversive bodily cues, the relationship should be expected to weaken, because "at high intensities, physiological cues ... override cognitive processing" (p. 352). These propositions, which derive from Rejeski's (21,22) model but had not been fully tested previously, were clearly supported by the present findings—the efficacy–RPE relationship was consistently negative and statistically significant throughout the exercise bouts below and at the VT, but the relationship was consistently nonsignificant above the VT.

Overall, support for Rejeski's (21,22) model was obtained from the correlations of RPE with extraversion, self-efficacy, and, to a lesser extent, behavioral activation. On the other hand, contrary to expectations, neuroticism did not correlate with RPE at any level of intensity, whereas behavioral inhibition correlated with RPE consistently across all three levels of intensity, thus showing no signs that this particular relationship is influenced by exercise intensity, contrary to the prediction of the model.

This work has both theoretical and practical implications. From a theoretical perspective, the present findings complement data concerning physiological determinants of RPE. Noble and Robertson (19) commented on the fact that, following the lactate inflection point, there is a "sudden onset of signals reflecting respiratory-metabolic exertion" (p. 118). Several peripheral physiological indices, including $\dot{V}_E/\dot{V}CO_2$, $\dot{V}_E$, and $\dot{V}O_2$, develop strong correlations with RPE but only at high levels of intensity, presumably exceeding the lactate inflection point and ventilatory threshold. What we found in the present study is that this level of intensity is also where the role of personality and cognitive influences begins to subside. Collectively, these findings are in agreement with Rejeski's (21,22) model and are consistent with the notion that the genesis of perceptions of exertion shifts systematically between two modes as the intensity of exercise increases. One mode reflects the influence of peripheral physiological cues along with a substantial role of personality traits and cognitive factors, whereas the other mode, which gradually emerges beyond the aerobic-anaerobic transition, reflects the dominant influence of accentuated physiological cues. This conceptualization is also consistent with accumulating evidence on the neuroanatomy and neurophysiology of interoception, the sense of the physiological condition of the body (9). This sensory modality appears to have a unique multilayered and hierarchically organized structure that could allow it to switch between cortically mediated and noncortically mediated modes of operation, depending on which mode better serves its adaptational purpose. A noncortically mediated mode of operation may be advantageous when a physiological steady state can no longer be maintained, metabolic limits are nearly reached, homeostasis is compromised, and the intervention of cognitive mechanisms or personality factors could introduce critical distortions of the magnitude of the impending threat.

The findings also have some potentially important implications from a practical standpoint. Specifically, in an effort to help novice exercisers cope with the aversive sensations

associated with exercise during the critical early stages of participation after a long period of sedentariness, fitness professionals often adjust one's level of exercise intensity to fit the exerciser's perceived preference or recommend the use of cognitive techniques. In addition to statements aimed at boosting self-efficacy (e.g., verbal persuasion and encouragement, use of models and vicarious experiences), these may include instructions for using attentional dissociation (i.e., turning one's attention away from the body by listening to music or concentrating on elements in the external environment) or cognitive reframing (i.e., thinking of the aversive experiences as positive signs that one's body is getting stronger). The present findings, within the limitations of a correlational design, suggest that these methods may be less effective at higher intensities of exercise. This is important because higher intensities, such as those exceeding the lactate inflection point or ventilatory threshold, may be unavoidable in the cases of individuals who are severely deconditioned, obese, elderly, or suffering from exercise-limiting medical conditions such as COPD or heart failure.

In interpreting the results of the present study, researchers and practitioners should take into account its inherent limitations. As we mentioned in the previous paragraph, this was a correlational study and, as such, it does not suffice to substantiate causation (i.e., that personality and cognitive factors cause changes in RPE). Furthermore, the findings stemmed from a single exercise modality (treadmill running) and exercise bouts with specific dose characteristics (intensity and duration). Whether similar results will emerge from different types and doses of exercise remains to be seen. On this subject, the issue of exercise intensity is of particular importance. Although the three levels of exercise intensity we examined differed in relation to the VT, a difference that we deem critical, the range they covered was still quite narrow (i.e., approximately 20 beats·min^{-1} or just 10% of age-predicted maximal heart rate at the conclusion of the runs) in relation to the entire functional range of exercise capacity. Moreover, the results cannot be assumed to generalize to other populations without additional research. It is possible that the young age, physically fit status, and volunteer nature of our participants might have influenced the results. It is worth noting, however, that, if the model we tested is correct (21,22), then among older or less active and fit participants, the decline in the contribution of psychological factors to RPE at high exercise intensities should be even more pronounced than shown here.

Future studies in this line of research, besides replicating the present findings and extending them to different modes of exercise and demographic groups, should attempt to confirm them using an experimental approach where cognitive interventions designed to alter RPE are applied across different levels of exercise intensity. Furthermore, to fully test the relative contribution of peripheral physiological and psychological factors, studies should examine the role of both classes of determinants within the same study (e.g., manipulating self-efficacy and respiratory/metabolic function).

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