Effect of anticipation during unknown or unexpected exercise duration on rating of perceived exertion, affect, and physiological function

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ORIGINAL ARTICLE

Objective: To determine the effect of unknown exercise duration and an unexpected increase in exercise duration on rating of perceived exertion (RPE), affect, and running economy during treadmill running.

Methods: Sixteen well trained male and female runners completed three bouts of treadmill running at 75% of their peak treadmill running speed. In the first trial, they were told to run for 20 minutes and were stopped at 20 minutes (20 MIN). In another trial, they were told to run for 10 minutes, but at 10 minutes were told to run for a further 10 minutes (10 MIN). In the final trial, they were not told how long they would be running but were stopped after 20 minutes (unknown, UN). During each of the running bouts, RPE, oxygen consumption (ml/kg/min), heart rate (beats/min), stride frequency (min⁻¹), affect scores (arbitrary units), and attentional focus (percentage associative thought scores) were recorded.

Results: RPE increased significantly between 10 and 11 minutes in the 10 MIN compared with the 20 MIN and UN trials (p<0.05). The affect score decreased significantly between 10 and 11 minutes in the 10 MIN compared with the 20 MIN trial (p<0.05). Running economy, as measured by oxygen consumption, was significantly lower in the UN compared with the 20 MIN trial from 10 to 19 minutes (p<0.05).

Conclusions: The change in RPE between 10 and 11 minutes in the 10 MIN trial suggests that RPE is not purely a measure of physical exertion, as treadmill speed was maintained at a constant pace both before and after the unexpected increase in exercise duration. The associated changes in affect score at similar times in the 10 MIN trial support the hypothesis that RPE has an affective component.

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Abbreviations: PTRS, peak treadmill running speed; RPE, rating of perceived exertion; V\textsubscript{O2}, oxygen consumption
Affect and rating of perceived exertion during exercise

Experimental sessions
Within one week of the familiarisation session and the PTRS test, subjects performed three trials in random order on a motorised treadmill (Quinton Instruments, Seattle, Washington, USA). In all three trials, the treadmill speed for each subject was set at 75% of their PTRS. In one trial, subjects were informed that they would run for 20 minutes and then completed a 20 minute run (20 MIN). In the second trial, subjects were told that they would run for 10 minutes, but, at one minute from completion of the 10 minutes, were asked to run for another 10 minutes, so that the total exercise duration was 20 minutes (10 MIN). Exercise intensity was maintained at a constant level for the entire 20 minutes of the 10 MIN trial. In the third trial, subjects were not told for how long they would be running, but were stopped after 20 minutes had been completed (unknown trial, UN). Thus the total duration and intensity were the same for all three trials (20 minutes at 75% of PTRS), but subjects were informed differently about the expected exercise duration before the start of each trial. The same investigators were present during all trials, and the same level of encouragement was given to the subject in each of the three trials. Subjects performed the three experimental trials at the same time of day, so that effects of circadian rhythm on physiological and psychological function were negated, and at least a day of rest was allowed between each trial.

During each trial, RPE, affect, attentional focus (percentage associative thoughts), \( \dot{V}_{\text{O}_2} \), stride frequency, and heart rate were measured at 3, 5, 8, 9, 10, 11, 14, 17, 19, and 20 minutes. The subjects were made aware of how much time had passed at each of these time points when these measurements were performed. The different length of time between each data point was deliberately chosen, as we expected changes to occur in the first minute after changes in the 10 MIN group at minute 10. Therefore, to assess these predicted changes, data were recorded at 9, 10, and 11 minutes into the trial. As we did not want to have different lengths of time only around the 10 minute time point, length of time between measurements was thus varied throughout the trial in an attempt to make the length of time between measurements appear random. However, the same time points were used for data measurement in all three trials.

RPE
RPE was measured during each trial at the specified times using the Borg category ratio scale. This scale measured the overall feelings of subjective sensation of effort accompanying exercise. The scale and what it measured was carefully explained to all subjects during the familiarisation session and before each experimental trial. It was emphasised that the scale measures physical strain or work, and instructions were given according to suggestions from Pandolf and Noble et al.

Affect scale
Affect was measured using the affect (feeling) scale, developed and validated by Rejeski and Kenney. The affect scale is a bipolar scale which ranges from +5 to -5 with verbal descriptors: +5 = very good; +3 = good; +1 = slightly good; 0 = neutral; -1 = slightly bad; -3 = bad; -5 = very bad.

Subjects were informed and subsequently reminded that the scale measured the affective or emotional component of exercise, such as whether the sensation of effort during the treadmill running bout felt pleasant or unpleasant, and not the actual level of physical effort or strain.

Associative thought scale
During each trial, subjects were asked to report what percentage of their thoughts were associative thoughts.
Dissociative thoughts were defined as thoughts that distract the subjects from the exercise being performed and directed towards external factors, and were measured as the remainder of the thought score not described as associative thoughts.

**Oxygen consumption**

\( \text{V}_\text{O}_2 \) was measured continuously during all trials using an automated gas analysis system (Oxycon Alpha; Enrich Jaeger, Wuerzburg, Germany), as described previously. 10

**Heart rate**

Heart rate was measured during all trials using a Polar S410 heart rate monitor (Polar Electro Oy, Kempele, Finland), as described previously. 10

**Stride frequency**

The number of times the right foot of the subject landed on the treadmill was counted during the 30 seconds leading up to the specified time points, and this value was doubled to give a measurement of stride frequency (min \(^{-1}\)).

**Statistical analysis**

All data were analyzed using a Statistica (StatSoft Inc, Tulsa, Oklahoma, USA). A repeated measures analysis of variance was conducted to compare data over all three trials (10 MIN, 20 MIN, and UN). Where a significant interaction effect was found, post hoc analyses were conducted using a Tukey HSD post hoc test. Data are presented as mean (SEM). An \( \alpha \) level of \( p<0.05 \) was taken as significant.

**RESULTS**

**Subject characteristics**

The mean (SEM) age of the subjects was 30.4 (4.1) years, mass 68.0 (12.2) kg, height 173 (7) cm, and percentage body fat 20.8 (4.4)%. The \( \text{VO}_2 \text{peak} \) was 56.4 (2.9) ml/kg/min, PTRS 18.1 (1.5) km/h, and mean distance run each week 31.9 (13.3) km.

**RPE**

RPE increased essentially linearly with increasing exercise duration in all three trials (fig 1). However, RPE increased significantly more between 10 and 11 minutes in the 10 MIN trial compared with the 20 MIN trial (\( p<0.05 \)), so that RPE at 11 minutes was significantly higher in the 10 MIN trial than in the 20 MIN trial (\( p<0.05 \)). RPE remained significantly higher in the 10 MIN trial than in the 20 MIN trial until 17 minutes (\( p<0.05 \)). RPE was also higher in the 10 MIN trial than in the UN trial from 11 minutes to 14 minutes (fig 1).

**Affect scale scores**

Affect scale scores decreased significantly (affect became more negative) over the course of the trial in all three conditions (\( p<0.01 \), fig 2). However, the affect score fell more steeply between 10 and 11 minutes during the 10 MIN trial than during the 20 MIN and UN trials. As a result, the affect score during the 10 MIN trial was significantly lower than during the 20 MIN and UN trials at 11 minutes and 14 minutes (fig 2). Affect score was higher throughout the 20 MIN trial than during both the 10 MIN and UN trials.

**Associative thoughts**

The percentage of associative thoughts increased significantly during all three trials (\( p<0.01 \), fig 3). No significant differences were found between trials, although the percentage change tended to be higher in the 10 MIN trial between 10 and 11 minutes compared with the 20 MIN and UN trials.

**Oxygen consumption**

\( \text{VO}_2 \) was significantly lower during the UN trial than during the 20 MIN trial from 10 minutes until 19 minutes (\( p<0.05, \)

![Figure 3](http://bjsm.bmj.com/)

**Figure 3** Associative thoughts percentage during three trials: 20 MIN, subjects told to run for 20 minutes and stopped at 20 minutes; 10 MIN, subjects told to run for 10 minutes, but at 10 minutes told to run for a further 10 minutes; UN, subjects not told for how long they would be running but stopped after 20 minutes. Values are mean (SEM) (n = 16).

![Figure 4](http://bjsm.bmj.com/)

**Figure 4** Oxygen consumption (\( \text{VO}_2 \)) during three trials: 20 MIN, subjects told to run for 20 minutes and stopped at 20 minutes; 10 MIN, subjects told to run for 10 minutes, but at 10 minutes told to run for a further 10 minutes; UN, subjects not told for how long they would be running but stopped after 20 minutes. Values are mean (SEM) (n = 16). 

\( \text{†} \)Significant increase over time for all trials (\( p<0.01 \)).
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responses. Interestingly, in their study, hypnotic induced
sense and its relation to heart rate and blood pressure.

**Heart rate**

Heart rates increased significantly over time in all three trials
(p<0.01), but were not different between the trials.

**Stride frequency**

Stride frequency was not different between trials at any time
point, and did not change significantly during any of the
trials.

**Discussion**

The first important finding of this study was that when
subjects were deceived during the 10 MIN trial and were told
near the end of the expected trial duration to run for
10 minutes longer than anticipated, RPE increased significa
cantly at 11 minutes, compared with the 20 MIN trial, before
which subjects had been honestly informed of the correct
duration of the run (fig 1). Exercise intensity (75% of PTRS
for all trials), VO2 (fig 4), heart rate, and stride frequency
were not significantly different from 10 to 11 minutes in any
of the trials. The physiological demands of the running task
did not therefore change at the same stage as changes in RPE
were observed. The increase in RPE consequent to misinfor
mation about the expected exercise duration was therefore
not caused by changes in physiological factors. Therefore we
suggest that the change in RPE at 11 minutes in the 10 MIN
trial, which was significantly higher than in the other trials
until 14 minutes, was the result of affective processes,
responding to the unexpected sudden increase in exercise
duration or the sudden imposition of a mismatch between
the previously anticipated and the new required exercise
duration.

Indeed, affect scale scores, which are a measure of the
emotional perception of the cognitive sensations induced by
the exercise bout, decreased significantly at 11 minutes in the
10 MIN trial, but not in the 20 MIN or UN trial (fig 2). The
increased and significantly higher RPE in the 10 MIN trial
may therefore be attributed to a decrease in positive affect
when anticipations of the exact exercise duration were not
met. This indicates that the perception of exertion is closely
associated with affect. Indeed, Pennebaker\(^{19}\) showed that the
perception of bodily symptoms is influenced not only by
physiological but also by psychological processes. Williamson
et al\(^ {20}\) showed that hypnotic manipulation affected effort
sense and its relation to heart rate and blood pressure
responses. Interestingly, in their study, hypnotic induced
increases in the sense of effort during constant load exercise
were associated with increase in heart rate and blood
pressure, whereas hypnotic induced decreases in the sense
of effort were not associated with changes in either heart rate
or blood pressure. The effect of hypnotic manipulation and
alteration of end point manipulation therefore produced
different results, as increased RPE and affect in our trial were
not associated with increases in heart rate. The reasons for
these differences are not immediately clear, but it would be
interesting to examine the changes in affect associated with
hypnotic manipulation, as these were not measured during
the trial of Williamson et al\(^ {20}\) and may be a cause of the
different findings in the two studies.

Pohl et al\(^ {11}\) have suggested that subjects will display
symptoms to match their expectations in a process termed
symptom belief. That is, expectations have a large influence
on perceived symptoms, which in the present study would
include the RPE during the running task. When expectations
of a task are not met, as occurs in the 10 MIN trial, subjects
may consciously or unconsciously experience negative affect,
including emotions such as anger, frustration, distrust, and
doubt, responses that are reflected in the affect scale scores
in this study (fig 2). St Clair Gibson et al\(^ {21}\) have proposed that
the knowledge of the physiological processes associated with
the fatigue process initially occurs at the subconscious,
cognitive level and that feelings of affective responses are
the conscious representations of these subconscious changes.
The link between the increase in RPE and the decrease in
affect score in the absence of changes in physiological
variables or exercise intensity supports the hypothesis that
fatigue, commonly thought to be a physical process, may
rather be an emotional construct.

A further finding was that associative thoughts percentage
shows a significant increase over time for all trials (fig 3).
Progressive increases in the percentage of associative
thoughts suggest that the subjects have a narrower attention
focus. That is, as the trial progresses, subjects engage in
thoughts more related to the task of running. Although no
significant differences in associative thoughts were found
between trials, there was a tendency for the percentage
associative thoughts to decrease from 11 to 14 minutes in the
10 MIN trial, immediately after a sharp increase from 10 to
11 minutes. This pattern of change may indicate that subjects
attempted to reset their focus in order to complete the trial, or
as an attempt to improve the reduced affect caused by the
instruction to continue for a further 10 minutes (fig 2). These
changes in associative thoughts occurred at the same time as
an increase in RPE (fig 1) and a decrease in feeling score
(fig 2), as discussed previously.

The next important finding was that VO2 during the UN
trial was lower than in the 20 MIN trial throughout, with
significant differences from 10 minutes until 19 minutes
(fig 4). At the same exercise intensity, a lower VO2 suggests
improved running economy,\(^ {22}\) and the lower VO2 in the UN
trial supports the hypothesis that when a task of unknown
duration is performed, subjects will be more economical
in their use of physiological resources, in order to maintain a
reserve in anticipation of a longer exercise bout and greater
physiological demand. The mechanism for this improvement
is not clear, and the data do not allow us to conclude which
factors may be responsible for the measured improvement in
running economy. Running economy has previously been
related to heart rate and biomechanical variables.\(^ {24–26}\) Neither
heart rate nor stride frequency showed any significant
differences between the three trials, suggesting that more
subtle changes, such as changes in muscle recruitment\(^ {14}\)
which were not measured in the present study, may underlie
this finding.

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**What is already known on this topic**

Previous work has suggested that perceived exertion during
exercise is causally linked to changes in running speed and
physiological variables such as heart rate, ventilation rate,
and blood lactate concentrations.

**What this study adds**

This study shows that perceived exertion during exercise may
rather be a psychological construct, which is scaled using
knowledge of the exercise duration, and altered by changes
in affect and cognitive focus of the athlete.
In a study to measure the effect of psychological state on running economy, Williams et al. found that less negative affect was associated with lower \( \text{VO}_2 \) for a given workload. We did not observe such an association, as affect was least affected in the 20 MIN trial (fig 2) but this trial did not produce the lowest \( \text{VO}_2 \) (fig 4). However, that study used the profile of mood states scale to determine mood state of the subjects during the week before a run, whereas we used the feeling scale. Mood has been defined as a more stable measure of emotion, whereas affect is a more immediate change in emotion, and the use of two different scales to assess two different constructs may account for this finding.

An interesting observation was that the \( \text{VO}_2 \) during the 10 MIN trial decreased after 17 minutes, and was significantly lower in the 10 MIN trial than in the 20 MIN trial at 19 and 20 minutes (fig 4). This may indicate that subjects become more economical as the end of the second 10 minute period of the 10 MIN trial approached, because of their experience a few minutes earlier of having been deceived. If they anticipated a second deception and the possibility that they would be told to continue exercise for another 10 minutes, they might have chosen to become more economical. It is noteworthy that the 10 MIN trial essentially becomes a trial of uncertain duration after the first 10 minutes, as subjects will no longer trust the experimenter. Thus the decrease in \( \text{VO}_2 \) at the end of the 10 MIN trial agrees with the suggestion that subjects adopt a more economical running strategy when the duration of exercise is unknown.

In conclusion, in this study we found that unknown exercise duration and an unexpected increase in exercise duration influenced RPE, affect, and \( \text{VO}_2 \). RPE appeared to be influenced by affect, and was not merely the result of a direct interpretation of the physiological changes occurring in different metabolic systems, as RPE increased significantly after an unexpected increase in running duration in the absence of changes in exercise intensity, \( \text{VO}_2 \), or heart rate in this trial. Further research is required to determine what specific emotions correlate with perception of effort and running economy during exercise.

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REFERENCES
3 Cofarelli E. Peripheral contributions to the perception of effort. Med Sci Sports Exerc 1982;14:382–9
18 Morgan WP, Pollock ML. Psychological characterization of the elite distance runner. Ann NY Acad Sci 1997;301:382–403
19 Pennebaker JW. The psychology of physical symptoms. New York: Springer Verlag, 1982

COMMENTARY
This paper has come up with some fundamental questions that exercise scientists have ignored for far too long. The implications of these data will be far reaching in pushing the scientific boundaries further.

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