OLIVIER, S. and SCOTT, P.A. 1993. Physiological, perceptual and attitudinal responses to identically matched workloads in field and laboratory testing conditions. *South African journal for research in sport, physical education and recreation*, 16(1), pages 63-72.

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1993

S.A. Journal for Research in Sport, Physical Education and Recreation, 1993, 16(1): 63-72
S.A. Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 1993, 16(1): 63-72
ISSN: 0379-9069

PHYSIOLOGICAL, PERCEPTUAL AND ATTITUDINAL RESPONSES TO IDENTICALLY MATCHED WORKLOADS IN FIELD AND LABORATORY TESTING CONDITIONS

Steve OLIVIER** & Pat A. SCOTT*
**Department of Human Movement Studies, University of Zululand, Kwadlangezwa, Republic of South Africa
*Department of Human Movement Studies, Rhodes University, Grahamstown, Republic of South Africa

ABSTRACT

The vast majority of research investigating individual psychophysiological responses to physical work loads appears to have been conducted in the somewhat artificial ambience of a laboratory setting. The purpose of this research was to investigate what, if any, differences may be found in physiological (HR, VO_2, VE), perceptual (RPE) and attitudinal (Semantic Differential Attitude Scale) responses to identically matched work loads in field and laboratory testing conditions. The VO_2 max was measured on 11 well conditioned marathon runners, who then participated in two 20 minute running conditions, one out in the field and one on a treadmill in the laboratory. Subjects ran at 70% of their VO_2 max, with the gradient of the run, as well as the speed of running matched. Data were collected every 5 minutes. There was no difference in heart rate or oxygen consumption, but minute ventilation was significantly higher during the laboratory work task. Local and overall RPE scores were significantly elevated in the laboratory condition, and the evaluation, activity and overall Semantic Differential Attitude scores were significantly more favourable for the field condition. Despite the very close approximation of the physical work load it was evident that the subjects perceived the laboratory situation to be more demanding, suggesting that cognizance must be taken of the total environment when testing, and perhaps attitudinal and perceptual difference may, in part, be responsible for the elusive 30% of unexplained variance in RPE scores.

Key words: Psychophysical responses; Laboratory and field testing.

INTRODUCTION

The vast majority of research investigating individual psychophysiological responses to physical work loads appears to have been conducted in the somewhat artificial ambience of a laboratory setting. This laboratory-based research has resulted in tangible corroboration of a relationship between various physiological and psychological responses in general, with the subjective ratings of perceived exertion (RPE) being accepted as a reliable index of actual metabolic cost of work.

While RPE is viewed by most as a psycho-biological process representative of a gestalt interpretation of bodily inputs, of both a physiological and psychological nature, several authors (Morgan, 1973; Rejeski & Ribisl, 1980; Williams & Eston, 1989) argue that, in the area of the psychophysiological assessment of physical work demands, there remains an elusive, unaccountable portion of "unexplained variance". Williams and Eston (1989) propose that the source of such variance is likely to stem, in part, from the differences between laboratory test procedures and actual field situations. The focus of the present project was to replicate identical workloads in field and laboratory conditions and to note what, if any, differences occurred in the physiological and psychological (attitudinal and perceptual) responses of subjects.

Carton and Rhodes have conducted extensive research in the application of RPE and in 1985 they reported that working at 62% of maximal oxygen uptake was regarded "perceptually comfortable", and 79% was perceived as "hard". From a physiological perspective McArdle *et al.* (1981) found that the onset of anaerobiosis normally occurs between 55% and 65% of the maximal oxygen uptake in healthy untrained subjects. As the subjects in the present study were well conditioned marathon runners it was decided to conduct the experiment with the subjects working at 70% VO_2 max.

It is natural that while subjects are exercising they are aware of the surrounding environment which in all probability will influence their own perceptual interpretations of the specific, yet total, situational demands. The differentiated weighting of both external and internal factors may well affect the subjects' physical and psychological commitment to the task and subsequent performance. If an individual's perception of the situation is negative he will, in all likelihood, adopt a negative attitude, which in turn may have a detrimental effect on his physical performance.

REVIEW OF LITERATURE

The motor-driven treadmill which simulates overground walking and running, is frequently used in biomechanical and exercise physiology studies of locomotion, as well as for training and rehabilitation purposes. The treadmill offers many advantages to studies in human locomotion, mainly because of the control and convenience it offers. It is relatively easy to vary the intensity of work while the subject performs in close proximity to metabolic and cardiorespiratory recording instruments (Nelson *et al.*, 1972; Wall & Charteris, 1981; Frishberg, 1983). As a result, the treadmill has played an important role in the study of human movement. Although the treadmill is used extensively in research protocols, the literature indicates a wide difference of opinion about the validity of the extrapolation of treadmill information to the overground environment or *vice-versa* (Van Ingen Schenau, 1980). However, Wall and Charteris (1981) state that even though differences between the two conditions may exist, these are probably outweighed by the convenience offered by the treadmill.

Many treadmill studies have been conducted on level surfaces, and according to ACSM (1980) prediction formulae, the energy cost for overground running is greater than for running on the treadmill. Furthermore, with the inclusion of a gradient they postulate that at a speed of 3,3 $m.s^{-1}$ and at 7,5% grade, the difference would amount to 10$ml.kg^{-1}.min^{-1}$. Conversely, Van Ingen Schenau (1980) used a theoretical physics approach and concluded that there should be no differences between the metabolic energy requirements of inclined treadmill running and overground hill running. This is supported by Basset *et al.* (1985) who argue that measurements of VO_2 obtained during level and inclined treadmill running are valid when applied to the overground situation. It is generally acknowledged that the concept of an attitude includes the idea of unconscious determinants of behaviour and the dynamic interplay of conflicting motives. As such, attitudes can be seen as predispositions to respond, but are distinguished from other such states of readiness in that they predispose towards an evaluative response (Olivier, 1988). Attitudes are referred to as "tendencies of approach and avoidance" (Osgood *et al.*, 1957) or as Oskamp (1977) postulated, an attitude is a disposition to respond in a favourable or unfavourable manner to a given object or concept. As such, they are amongst the most important determinants of human behaviour.

Although attitudes have been identified as constituting a readiness for response, they are not behaviour *per se*. It therefore follows that they cannot be directly observed but need to be indirectly accessed (Oskamp, 1977). An attitudinal scale which has been established as a valid and reliable assessment tool is the Semantic Differential Attitude Scale (Osgood *et al.*, 1957). This is an instrument which allows for measurement of concept meanings in terms of semantic scales of known factor composition and has been used frequently in situations involving the study of man-in-motion (Maul & Pargman, 1978). In using the scale a subject is not required to make opinion statements but rather responds to bipolar adjectives (selected specifically for the particular situation) in an attempt to communicate his feelings about the task on hand

METHOD

Eleven (N=11) well conditioned male caucasian subjects, all active members of a local running club, volunteered to participate in the study. Subjects were required to participate in five testing sessions, the first three being preparatory and the last two being the main data collecting sessions. At the first session general demographic data were collected and the subjects were habituated on the treadmill (Quinton, Model 643). During the following session (within a week of the first), the subjects underwent a VO_2 max test, comprising a continuous run with progressively increasing work intensities. Once 70% of VO_2 max had been determined for all subjects they were required to return to the laboratory for a speed-matching session in order to determine the overground running speed at the appropriate gradient, thus relativising the intensity at which the subjects would be working.

The last two testing sessions, conducted two weeks later and within a week of each other, included the overground run (national road) and the treadmill run (Sports Science Centre).

Every attempt was made to conduct the laboratory testing under similar environmental conditions to those which occurred in the overground conditions, including the gradient of the 4km road stretch involved in the experiment. The stretch of road used for the outdoor condition involved a 2km distance with a constant gradient of 3,8%, followed by a further 2km with a constant gradient of 7,5%. These field gradients were obtained from road construction charts provided by the Department of Roads, Cape Provincial Administration, and were carefully replicated for the treadmill run in the laboratory. To prescribe an intensity of 70% for the overground run, it was necessary to determine running speed at 70% of VO_2 max for the two uphill gradients of 3,8% and 7,5%. An on-line gas-analysis system developed and validated by Goslin *et al.* (1985) provided ongoing feedback as to the relative VO_2 at which the subject was working.

With the subject running at 3,8% grade, fine adjustments (if necessary) were made to the treadmill speed in order to maintain an exercise intensity of 70% of maximal oxygen uptake. A minimum of ten relative VO_2 values and corresponding speeds were obtained before adjusting treadmill grade to 7,5% and reducing the speed appropriately. Constant adjustments of treadmill speed were avoided if possible in order to enable the VO_2 to stabilise. From the computer printout for the data collection on the treadmill, running speeds for the overground condition were determined in the following way: 1) For both grades, the mean of the 5 closest approximations to 70% of the subject's VO_2 max was determined; 2) The mean of the 5 speeds corresponding to the above VO_2 values was then calculated; 3) This value was then converted to a required running rate in $min.km^{-1}$. This enabled setting each individual's speed, and thus relative intensity, for kilometres 0-2 (3,8% grade) and 2-4 (7,5% grade) in the overground condition.

PROBLEM

The purpose of this research was to investigate what, if any, differences may be found in physiological (HR, VO_2, VE), perceptual (RPE) and attitudinal (Semantic Differential Attitude Scale) responses to identically matched workloads in field and laboratory testing conditions.

COLLECTION PROTOCOL

Prior to their participation in the two running sessions, subjects were required to complete a "Semantic Differential Attitude Scale" pertaining (a) to the outdoor run, and (b) to the run on the treadmill. They were also instructed on the use of the RPE scale, and how they would be required to give responses for differentiated central, local and overall ratings relating to how they perceived the physical demands at that particular stage of data collection. Under both conditions the subjects wore a head support for a Hans-Rudolph valve connected to a length of Collins ridged tubing, which in turn was connected to meteorological balloons for gas collection. Heart rate was monitored by means of a cardionics cardiometer. Elasticised conductive strips were attached to the lead from the cardiometer and placed around the subject's chest at the level of the xiphoid process.

Data was collected at each kilometre mark (or equivalent on the treadmill) at the four stages of the run. At a given signal the subject put on a nose clip and inserted the mouthpiece. Expired air was collected for 60 s. Heart rate was recorded halfway through the period of gas collection after 30 s. At the point of completion of the collection of data on physiological parameters, the subjects were required to give three differentiated perceived exertion ratings, providing local, central and overall scores. The whole procedure was repeated at each of the four collection points, after which the meteorological balloons were returned to the laboratory for analysis as soon as possible to obviate diffusion of gas. Fractions of expired oxygen and carbon dioxide were obtained using the analyses of the on-line system (Goslin *et al.*, 1985). The following derived data were then calculated: relative VO_2, VE and respiratory quotient. The subjects' running speed for each 2km section was also determined.

In the laboratory setting the same procedure was followed, with the treadmill speed set to the running speed of the overground run. When the run commenced a stop watch was started and gas collection time was determined by using the elapsed time at each kilometre point of the overground run. Time of collection was thus consistent for both conditions. The treadmill gradient was adjusted from 3,8% to 7,5% after the equivalent of 2km.

Related Student t tests (Ferguson, 1981) were run on all data to assess the possibility of statistical differences between: (1) the results of the two testing sessions and (2) the results of the data collected at both sessions. One-independent variable regression analyses were computed to examine possible correlations between the physiological and perceptual responses during the two conditions.

RESULTS

The mean age of the subjects was 26,6 years (S= 26,8) and they had a mean body fat of 12,5% (S= 2,4). The measured mean VO_2 max for the group was 66,6 $ml.kg^{-1}min^{-1}$, (S= 6,79) with the calculated 70% VO_2 max being 46,62 $ml.kg^{-1}$ min^{-1} (S= 4,75).

There were no significant temperature, barometric pressure, or relative humidity differences between the field and laboratory conditions (Table 1). Likewise, windspeed was measured and found to be minimal, and due to the geological formations surrounding the testing site, highly variable in direction, the effect of this minor breeze was deemed to be negligible.

TABLE 1. **ENVIRONMENTAL CONDITIONS FOR FIELD vs LABORATORY CONDITIONS**

VARIABLE	FIELD	LABORATORY
Temperature (C°)	17,2	16,9
Barometric pressure (mmHg)	717,2	720,2
Relative humidity (%)	75,6	75,2

It was concluded that, with the rigorous control of the speed and gradient of running, together with the similarity of environmental conditions, the work demands of the two conditions were very closely matched, indicating that any differences between physiological and perceptual measures could not be attributed to differences in physical work loads.

The results revealed that there were no differences between the heart rates recorded during the overground run and those recorded during the treadmill run (Table 2). It is unlikely that any perceptual differences were mediated by heart rate. However, it should be noted that correlations between heart rate and RPE were higher in the field than in the laboratory (Table 3), indicating that some perturbation of the relationship may have occurred in the laboratory setting.

TABLE 2. **MEAN PHYSIOLOGICAL AND RPE RESPONSES DURING BOTH FIELD AND LABORATORY CONDITIONS**

VARIABLE	FIELD RESPONSES	LABORATORY RESPONSES
PHYSIOLOGICAL		
HR ($b.min^{-1}$)	157,00	156,00
VO_2 ($ml.kg.min^{-1}$)	47,59	48,45
VE ($1.min^{-1}$)	69,05	75,13*
R	0,91	0,93
RPE		
Local	11,07	11,96*
Central	10,86	11,36
Overall	10,89	11,82*

* Significant (p<0,05)

With work intensity relativised at 70% of VO_2 max, there were no oxygen consumption differences between the overground and treadmill conditions (Table 2). The sensory signals associated with oxygen consumption were unlikely to have been the main driving factor responsible for any perceptual differences between the two work tasks. However, again higher correlations (Table 3) between all RPE recordings and metabolic demands were observed in the overground condition. While the physiological responses of heart rate and oxygen consumption were clearly equated under the two conditions, ventilatory responses were not. Minute ventilation was significantly higher during the laboratory work task than during the field work task. This result was concomitant with significant increases in local and overall RPE, thus reinforcing previously suggested links between VE, perception and cognition (Morgan, 1981; Robertson, 1982; Carton & Rhodes, 1985; Messier *et al.*, 1986). It was also noted that VE/RPE correlations were higher for the field condition than for the laboratory condition.

TABLE 3. **CORRELATION CO-EFFICIENT BETWEEN PHYSIOLOGICAL PARAMETERS AND RPE RESPONSES IN BOTH CONDITIONS**

VARIABLES	FIELD 'r'	LABORATORY 'r'
Local RPE/HR	0,65	0,49
VO_2	0,83	0,61
VE	0,70	0,62
Central RPE/HR	0,50	0,14
VO_2	0,55	0,23
VE	0,45	0,32
Overall RPE/HR	0,59	0,29
VO_2	0,74	0,49
VE	0,66	0,54

Morgan *et al.* (1976) demonstrated that "thinking" that a work task is more difficult than it actually is can result in elevated ratings of perceived exertion and the authors associated the alterations in subjective reactions with alterations in ventilatory responses. Thus cognitive factors linked with ventilatory changes appear to influence RPE. In other words, if the subjects' cognitive appraisal of the exercise situation led them to believe that a work task was more difficult, both RPE and VE could be elevated. In the present study, in reply to the question (asked retrospectively of all subjects) "which of the two exercise tasks was the more stressful?", all eleven subjects reported that they thought the laboratory condition was the more stressful.

In order to obtain some tangible measure of psychological influence on RPE ratings, attitudes, as measured by the Semantic Differential Attitude Scale, were assessed prior to participation in both the field and laboratory runs. Table 4 illustrates that there were significant differences in attitude towards the two conditions, with the *evaluation, activity* and *overall* scores being significantly more favourable for the field condition.

TABLE 4. **SEMANTIC DIFFERENTIAL ATTITUDE RESPONSES UNDER FIELD AND LABORATORY TESTING CONDITIONS**

VARIABLE	FIELD	LABORATORY
Factor E (Evaluation)	26,53	16,73*
Factor P (Potency)	16,64	13,91
Factor A (Activity)	18,27	16,81*
Overall scores	61,46	46,82*

* Significant ($p< 0,05$)

Finally the results of the differentiated ratings of perceived exertion revealed that local and overall RPE scores were significantly elevated for the laboratory condition as compared to the field condition (Table 2). As there were no task-characteristic or performance differences between the two conditions, it is evident that some other factor(s) must have occasioned the observed increases.

CONCLUSIONS

In developing the protocol for data collection under the two conditions of field and laboratory uphill running, every effort was made to match the physical demands on the subjects. The data recorded for working heart rate and oxygen consumption indicate that these physiological responses were identical at both testing sessions, although the minute ventilation was elevated during the treadmill run. Despite this close approximation of the physical work load it is evident that the subjects perceived the laboratory situation more demanding, in that their RPE responses were higher under laboratory condition with local and overall ratings being significantly so ($p< 0,05$).

If working conditions were identical (other than the actual site of the experiment) and given that the physiological responses were similar, why then were the perceptions of exertion higher in the laboratory? A possible reason put forward in the present paper is the subject's attitude to the task on hand. Borg (1970) proposed that RPE was a gestalt response taking cognizance of both physiological and psychological input. Despite considerable research on the topic, the mechanism(s) by which individuals perceive the intensity of exertion during exercise remains unknown (Purvis & Cureton, 1981) and it appears that multiple physiological indices only account for about 70% of the variance in RPE (Rejeski & Ribisl, 1980). Maybe the elusive 30% of unexplained variance (Morgan, 1973; Rejeski & Ribisl, 1980) is accounted for in part by the attitude of the individual towards the overall ambience of the working condition. In the present study the attitudes of the subjects were significantly more favourable towards running in the natural outdoor environment rather than the less familiar confines of the laboratory, thus offering support for Morgan's suggestion of the influence of psychometric factors (Morgan, 1973).

While there may have been no metabolic or biomechanical differences between the two conditions, the laboratory environment perceived as being more stressful, may have resulted in unfavourable attitudes towards that condition. It is possible that these attitudinal differences were, at least in part, due to the perceptual and cognitive interpretations of the particular characteristics inherent in the two environments, and, assuming a link between attitudes and RPE, this is suggested as a possible explanation for the perceptual differences between the two conditions.

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