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SELF-REPORT AND CARDIOVASCULAR MEASURES OF AROUSAL: FRACTIONATION DURING RESIDUAL AROUSAL *

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Residual arousal has been conceptualized as a state of physiological activation that is amenable to misattribution-like processes because individuals are unaware of their aroused physiological state (Zillmann, 1978). Although there is considerable evidence showing that people in the state labeled "residual arousal" rate excitatory stimuli in a more polarized fashion (see review by Zillmann, 1983), the available evidence for the notion that residual arousal is imperceptible can alternatively be interpreted as evidence of an inability to discriminate the cause of the residual arousal. To determine the nature of the cognitive representation of residual arousal (and, hence, whether excitation transfer is likely to be a nonconscious rather than conscious misattributional process), cardiac activity and reported arousal were tracked before, during, and following exercise. Results replicated previous research showing that exercise-induced cardiac activity remained significantly elevated when subjects ceased to report feeling aroused due to the exercise. These findings were extended through the joint use of magnitude estimation and psychophysiological procedures to index what level of exercise-induced bodily activation was reportable. Results indicated that residual arousal is unperceived rather than perceived and mistaken as to its cause. Implications of the present research range from theories of arousal and of misattribution to the effects of stress-related variations in cardiac performance on cardiac detection.

1. Introduction

Changes in physiological arousal have been conceptualized within social psychology as being general, diffuse, and misattributable. This global concep-

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port measures of physiological activity is appropriately on the rise. He attributes the popularity of self-report measures of general physiological arousal to: (a) the low cost of the measures; (b) the elimination of need for apparatus, technical sophistication, and physiological expertise; (c) the ease in administering and scoring the self-report measures; and (d) the ability to obtain information about physiological arousal from self-reports which would otherwise be inaccessible.

The latter of these purported advantages is especially important, and provocative. This is because the hypothesized advantage of self-report measures of arousal is not based on the theoretical argument that it is an individual's *belief* that he or she is physiologically aroused that is important, as Valins (1966) and others have contended, but rather it is based on the premise that self-report measures provide a more valid and sensitive index of actual physiological arousal than does a psychophysiological assessment (Mackay, 1980). For instance, Thayer (1967) concluded that self-report measures of arousal (as derived from an adjective checklist) correlated more highly with a "composite" of physiological variables than the individual physiological measures correlated among themselves. Similarly, Clements, Hafer, and Vermillion (1976) found significant correlations between a revised version of Thayer's activation scales and various physiological measures (e.g., heart rate, respiration, skin resistance level), whereas the intercorrelations between the physiological measures were generally small and nonsignificant. After reviewing these and other findings, Mackay (1980) concluded that individuals are able to provide accurate and reliable information about overall bodily activity, and that the phenomenological measurement of arousal is an improvement over actual physiological assessments because self-report measures provide a more accurate reflection of overall bodily activation than do measures of specific physiological systems. [1]

[1] This argument contrasting "single" self-report measures with "multiple" physiological measures of arousal can be somewhat misleading, however. For example, the single self-report measure of arousal used by Thayer (1967) is actually four factor-analytically derived scales based on multiple 4-point ratings of activation-related adjectives. The multiple physiological measures or "composite" measures that he used are in fact not a composite: The distribution of difference scores (treatment minus baseline) for each measure (skin conductance and heart rate) was standardized across subjects, and the larger of the two for each subject served as the composite measure. The robustness of this "largest response model" was again demonstrated by Thayer (1970) when he found that skin conductance and/or heart rate correlated more highly with activation/deactivation self-report measures than with any other physiological measure. Although this is consistent with the principle of symptom specificity and its derivative, individual response stereotypy, it does not provide strong evidence for the argument that single self-report measures are more valid than multiple physiological measures. For example, extraneous factors such as the measurement reliability gained by the use of multiple ratings to achieve a single self-report measure and subjects' beliefs about the physiological effects of the excitatory stimuli could both contribute artifactually to the extant evidence that, "self report is a better indication of general activation than any single commonly used psychophysiological measure" (Thayer, 1970, p. 88).

(perceived) arousal and heart rate rose sharply due to the exercise, replicating conceptually the results reviewed by Mackay (1980); [2] (c) self-reported arousal due to the bicycle returned, on average, to basal levels in less than 5 min; (d) heart rate and systolic blood pressure remained elevated for over 8 min on average; and (e) all measures of arousal in all subjects returned to basal levels shortly thereafter. Together, these data were interpreted as evidence that residual activation emerges briefly following a strongly excitatory stimulus.

Importantly, subjects in the Cantor et al. (1975) study were told to think of their physiological state prior to exercise as 0% and their level of arousal immediately after the exercise as 100% of their excitatory response to exertion. They were further instructed to report on their arousal level "by stating the *percentage of the arousal originally produced by the exercise that was still present*" (Cantor et al., 1975, p. 71, italics added). The verbal measure used by Cantor et al. (1975) thus required that subjects: (a) be willing and able to detect and report the changes in physiological activity produced by the exercise, (b) correctly recall the level of arousal that existed prior to and immediately following the exercise, and (c) correctly identify what portion of the arousal felt at the point of questioning was caused by their exercise in the lab. These latter two features of the psychological assessments used by Cantor et al. (1975) compromise their evidence for "residual arousal" because, rather than indicating the existence of lingering but unperceived physiological arousal, their results could alternatively be interpreted as indicating that subjects accurately perceived themselves as being physiologically aroused but failed to recall accurately their pre-exercise level of arousal and/or to recognize the true cause of their perceived arousal. Unfortunately, subjects in previous research were never asked simply to rate how aroused they felt when they no longer reported being aroused *due to the exercise*. If the evidence for residual arousal is due to subjects still feeling aroused but forgetting or confusing the cause of their perceived physiological arousal, then subjects' self-reports of their general physiological arousal should be elevated compared to pre-exercise levels even when they no longer reported being aroused due to the exercise. If, on the other hand, there is a fractionation of perceptible and actual physiological arousal, as is implied by the notion of residual arousal, then subjects' reports of felt arousal should be comparable to the levels reported prior to exercising.

In sum, interesting theoretical arguments exist on both sides regarding the efficacy of self-reports as indices of overall physiological arousal. Zillmann's (1978) theory and research can embrace Thayer's (1967, 1970) and Mackay's (1980) assertion that there is a covariation of self-reported and general physiological arousal during and immediately following a strongly excitatory stimulus, but Zillmann goes further in pointing to a possible uncoupling of the

[2] Thayer (1967, 1970) has also consistently found heart rate to be one of the two best physiological predictors of self-report measures of arousal.

Bike Riding" and the 100 value labelled "Immediately After Bike Riding". In addition to standard magnitude estimation instructions, the conceptual distinctions between the two scales were explained. Subjects were told, for instance, that the latter scale referred only to the physiological arousal they felt at that moment in time which resulted from the exercise, whereas the former scale referred to their general feelings of arousal at that point in time, regardless of the source. Other instructions regarding the second scale were modelled after Cantor et. al. (1975), with the exception that values less than zero were *not* permitted (see below).

To clarify the two self-report measures of arousal employed in the present research, consider the magnitude estimation procedure for investigating perceived luminosity. Traditionally, subjects are asked to judge the magnitude of a stimulus (e.g., a light) on multiple occasions across time as the intensity of the stimulus is varied. This scaling procedure is analogous to the self-report assessment missing in prior studies of residual arousal and is termed here the "magnitude estimate of general physiological arousal" measure.

The Cantor et al. (1975) measurement procedure differed from this magnitude estimation approach in two important regards. First, subjects were asked not to rate their perceptions of the stimulus, but rather were asked to rate how much it differed from some earlier point in time. As such, this scaling procedure reflects memory and attributional processes as well as perceptual processes. This is analogous to the second magnitude estimation task outlined above and is termed here the "magnitude estimate of physiological arousal due to the exercise" measure.

The second manner in which the Cantor et al. (1975) scaling procedure differed from traditional magnitude estimation assessments (and the present study) is that subjects in Cantor et al. (1975) were allowed to use *negative* values when rating how much of an earlier increase in stimulus intensity remained. Although a procedure such as this has the advantage of minimizing the response bias against using the endpoints on the scale (e.g., see Borg, 1982), in this context it has the disadvantage of presenting a physically unrealistic circumstance to subjects (i.e., it is impossible for the arousal *remaining* from the exercise to be less than zero). Subjects in the Cantor et al. (1975) study did indeed report values less than zero, but the interpretation of these values, and the means to which they contributed, are ambiguous. Hence, subjects were not allowed to use negative values in the present research.

This raises the important question of how to gauge when subjects perceive that a previously intensified stimulus has returned to its original level of intensity if negative ratings are potentially nonsensical and response biases mitigate against subjects using the endpoints of the scale. The method used in the present study was modelled to the extent possible after magnitude estimation procedures in the psychophysics literature. For instance, subjects can be asked at selected points in time to report the perceived level of some sensation

2.3. Apparatus

An exercise bicycle (Ajay Chapperrel model 2200) was used for the exercise task. Subjects were allowed to adjust the tension setting on the bicycle to whatever setting was comfortable. Pre-experimental blood pressure and heart rate measures were taken initially using an automatic digital sphygmomanometer (Astropulse 88) inflated over the left arm. During the study, heart rate was assessed using a photoelectric sensor placed over the left index finger which was interfaced to a pulse monitor (Pulsetrac model 4800) set to average over 8 beats.

2.4. Procedure

When subjects arrived at the laboratory, they were led to believe that they were participating in a study on exercise-induced arousal and persuasion. The procedures were described, blood pressure and heart rate were measured to ensure subjects were within normal ranges on these measures, and the two magnitude estimation tasks were explained. After ensuring subjects fully understood the meaning and use of these scales, baseline measures were taken (at which point subjects rated their felt arousal due to the exercise as 0, and their overall level of felt arousal at some point greater than 0 and less than 100), subjects performed a brief commercial rating task in keeping with the cover story, and exercised.

Exercise was defined in the present study on an individual basis in terms of its effects on cardiac activity. Once subjects had elevated their heart rate to 185% of their basal level, they maintained their level of activity for an additional 5 min. Subjects who failed to reach the 185% target value after 5 min continued exercising an additional 5 min, for a maximum exercise time of 10 min. Magnitude estimates of arousal were taken and heart rate was recorded once per minute following the completion of the exercise until subjects's magnitude estimates of arousal due to the exercise fell to or below 5% or until 20 min had elapsed. [3]

[3] Seven subjects reached an asymptote on the magnitude estimation of arousal due to the exercise that was less than 10% but greater than 5%. That is, they failed to ever report feeling less than or equal to 5% of the arousal due to the exercise even though their ratings on this scale began to vacillate once they fell below the last major scale-division (the 10% mark) and even though ratings were secured as long as 20 min following exercise. This replicates observations in our pilot study and supports the contention that specifying 5% as a "basal" level on this scale is a stringent cutoff. The analyses reported in the text do not include the data from these subjects, but it should be noted that the results are unchanged when their data are included.

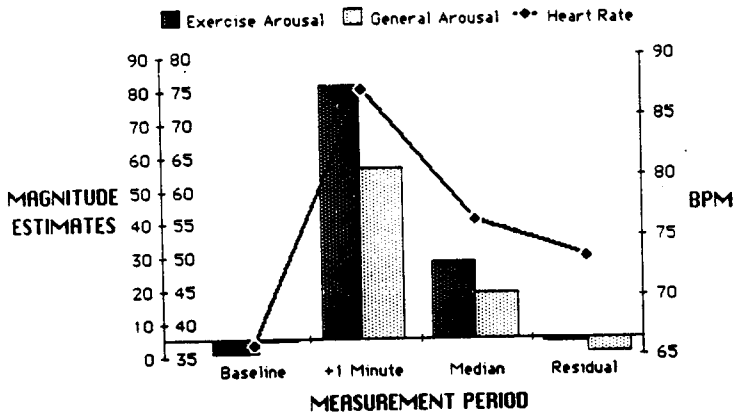

Fig. 1. Mean heart rate and magnitude estimates of general physiological arousal and of physiological arousal due to the exercise. "Baseline" represents measures obtained prior to exercise; "Exercise +1 Minute" represents measures obtained 1 min following the completion of the exercise; "Median Measurement" represents measures obtained midway between the "Exercise +1 Minute" and "Residual Arousal" periods; and "Residual Arousal" represents measures obtained when magnitude estimates of the arousal due to the exercise reached nominal levels (see text).

$= 37.34$, $M_{exercise} = 63.23$, $t(34) = -8.72$, $p < 0.001$), as of course did the magnitude estimate of felt arousal due to the exercise ($M_{baseline} = 0.00$, $M_{exercise} = 81.91$). More interestingly, the analysis of the subjects' magnitude estimates of general physiological arousal during the period labelled "residual arousal" by Cantor et al. (1975) revealed subjects' magnitude estimates of general physiological arousal had returned to basal levels ($M_{baseline} = 37.34$, $M_{residual} = 35.03$, $t(34) = 0.80$, n.s.), as by definition had the magnitude estimates of arousal due to the exercise (see fig. 1). This set of outcomes favors Zillmann's contention that residual arousal is not directly reportable and, as such, represents a fractionation of psychophysical and physiological measures of arousal.

Subjects reached the "'residual arousal" period at varying points following the exercise but no subject reached it before 5 min had elasped and all but 7 subjects reached it by 12 min following exercise (see footnote 3). This procedure has the advantage of maximizing the sensitivity of the assessments to individual differences in recovery from exercise, which can be dramatic (see Zillmann, 1983), but has the disadvantage of rendering minute-by-minute averages of subjects' ratings meaningless. Information about the form of the decay functions for each is provided, however, by additionally inspecting measures secured midway between the first (i.e., 1 min following exercise) and the last assessment (i.e., the residual arousal period) for each individual. These data are displayed in fig. 1. As is obvious from inspecting fig. 1, analyses

self-reports in both between-subject comparisons (because significant individual differences exist in the time it takes to recover from an arousing stimulus; see Zillmann, 1983) and within-subject comparisons (because reports are secured at varying points in time following the presentation of excitatory stimuli). Although prior research has confounded assessments of residual arousal with memorial and attributional processes, the present results provide evidence that residual arousal is not directly accessible to verbal reports. These results also raise the possibility that people's perceptions of physiological arousal following a strongly excitatory stimulus *generally* diminish more quickly than does sympathetic arousal. The adaptive significance of interoceptors that are insensitive to stable or slow changes in visceral activity is easy to understand, as this design averts the need for the allocation of limited cognitive resources to the conscious processing of organismic information signalling homeostatic processes. As Claude Bernard (1878) noted, "The constancy of the 'milieu interieur' is the condition of a free and independent existence" (p. 879).

A second potential source of error in self-reports of physiological arousal stems from the fact that self-reports require a translation of an internal representation through the medium of language. As such, self-reports are subject to the idiosyncratic interpretations of the scale (Pennebaker, 1982), the unique disposition and learning history of an individual (Venables, 1984), and the idiosyncratic perspectives that have developed (Ostrom & Upshaw, 1968). Consequently, self-reports of internal states can be highly variable across individuals (Pennebaker, 1982; Venables, 1984), or within an individual when stimuli cause a shift in perspective or interpretation (cf. Petty & Cacioppo, 1981, Chapter 4).

A third potential source of error is the variability in the specific physiological sensations, or set of sensations, that individuals use to gauge their bodily state (e.g., see Gonder-Frederick, Cox, Bobbitt, & Pennebaker, 1986). This variability can also be found across individuals and within individuals across situations, threatening the validity of both between- and within-subject comparisons (e.g., Pennebaker, 1982; Scheier et al., 1983).

Fourth; self-reports can be biased by an individual's beliefs or expectations about the consequences of a stimulus – beliefs that can vary across time, situations and individuals. Zimmerman, Linz, Leventhal, and Penrod (1983), for instance, reported a study in which undergraduates were randomly told either that they had normal blood pressure or that they had high blood pressure. Since subjects were randomly assigned to conditions, it can be assumed that subjects' previous physiological sensations were equivalent across conditions. Zimmerman et al. (1983), however, found that subjects in the high, in contrast to the normal, blood pressure groups reported having experienced a greater variety of symptoms, including arousal, over the preceding three months.

normal levels of physiological arousal. In either case, the physiological activation evoked by an excitatory stimulus in the presence of residual arousal could lead to the perceptions of a greater change in bodily excitement as well as a higher absolute level of perceived bodily excitement. Consequently, the residual physiological activation from an earlier excitatory stimulus can be expected to contribute to the physiological activation evoked by the emotional stimulus and lead to a stronger emotional response to the stimulus than would have been observed otherwise.

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